
MT PEQUAWKET

THE GEOLOGY

OF

NEW HAMPSHIRE.

A REPORT COMPRISING THE RESULTS OF EXPLORATIONS ORDERED BY THE LEGISLATURE.

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PART II. STRATIGRAPHICAL GEOLOGY.

CONCORD:
EDWARD A. JENKS, STATE PRINTER.
1877.

PREFACE.

Nearly two years and a half have been occupied in the compilation and printing of this volume. Material additions to our knowledge of the rocks, consisting of two summers' field-work, have often corrected, improved, and added to the statements already printed. This has been the most marked in the White Mountain district. Mr. Huntington has performed an excellent work, in his chapter upon the Coös and western Merrimack districts, particularly in distinguishing the coarse granite belt and the fine-grained division of the Bethlehem gneiss, the first being of practical consequence in determining the best places to work mica quarries. We have constantly endeavored to state all facts in the briefest possible language; and, in consequence of the immense number of observations recorded, the last four chapters have been much abbreviated. In spite of all our efforts, the subjects of Surface Geology, Economics, Mineralogy, and Lithology are crowded out into a third volume, nearly a hundred pages of which are already printed. Mr. Warren Upham has undertaken the description of the Modified Drift; and Mr. Geo. W. Hawes will discuss Mineralogy and Lithology. Both these treatises will be of rare value. We have undertaken the collection of several sets of specimens illustrating our Lithology, each consisting of two hundred and fifty varieties. These may be found at the college museum, at the state house, and at the normal school. Other sets are on hand for exchange or sale.

The study of the topography of the state has not ceased with the publication of Part I. Our labors have been unexpectedly successful, so that we shall present upon the geological map contour lines for every hundred feet throughout the state. These lines will not interfere with the coloring representing the distribution of the formations, but will the rather aid in understanding their relations to mountains, plains, and valleys. We have also constructed a model of the state, about fifteen feet in length, on the scale of one mile to the inch horizontally, and one thousand feet to the inch vertically. Copies of this model are to be found at Concord and Hanover. It is our belief that this topographical model is one of the most important practical results of the survey. Special attention is called to the unique method of arranging rocks, in relation to geography and structural geology, described in Chapter IX.

Arrangements have been made for the publication of our geological map, upon the scale of two and a half inches to the mile, in the best style, by Julius Bien, of New York. The engraving is completed, and it only remains to execute the coloring. We had hoped the sheets might be ready for distribution with this volume. Most of the descriptions refer to the map, so that they cannot be thoroughly understood without it.

C. H. HITCHCOCK.

HANOVER, May 12, 1877.

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PART II.

STRATIGRAPHICAL GEOLOGY.

CHAPTER I.

THE RELATIONS OF THE GEOLOGY OF NEW HAMPSHIRE TO THAT OF THE ADJACENT TERRITORY.

BEFORE discussing the particulars of the geology of New Hampshire, it will be desirable to recall the general features of the geological structure of the continent, in order to properly understand our place upon it. Next, we shall turn our attention to the physical characteristics of that particular section of which we find ourselves an important component; and then examine more minutely the various groups of strata peculiar to our district. It will be to the latter topic that we shall devote the most attention.

Continental Subdivisions.

North America is rudely triangular in shape, with its most prominent mountain ranges adjacent to the eastern and western borders, the latter being the broadest, highest, and opposite the larger ocean. The rocks, so far as needful for our present purpose, may be classified as the crystalline, two sets of sedimentary sandstones, limestones, and shales, and, lastly, the loosely-coherent superficial formations occupying various basins and water margins underlaid by the more compact ledges. These four groups correspond in order with the Eozoic, Paleozoic, Mesozoic, and Cenozoic systems of geological authors, the first being the oldest, or that first reclaimed from the universal ocean.

In order to illustrate the relative positions of these four classes of rocks, and the consequent method in which the continent has been gradually built up, I have prepared a small geological map, which will exhibit these mutual relations far better than words. The projection is the ordinary one, exhibiting the surface as nearly as possible like nature, and not distorting the northern regions so fearfully as Mercator's. The formations for the United States are copied in outline from the geological map by W. P. Blake and myself, published in the supplementary atlas pertaining to the ninth census, Gen. F. A. Walker, superintendent. The delineation of the northern portion is taken mainly from a map by Robert Bell, in Walling's topographical atlas of the dominion of Canada, and from notes respecting Alaska, kindly furnished me some years since for another purpose by W. H. Dall. As the scale is so small, the absence of many considerable outcrops, especially in the Rocky Mountain region, is a matter of necessity.

An inspection of our map will show a natural division into the following grand districts, the most important being stated first, without regard to age: 1. The immense Rocky Mountain crystalline area, extending from Alaska into Mexico. This is the foundation for innumerable minor basins, which cannot be represented. 2. An equally extensive crystalline area, embracing the north-eastern section of the continent, chiefly in the territories of Canada, Labrador, and Greenland. This portion is rather quadrangular in shape, with a central depression for the Hudson's Bay Paleozoic area. 3. The interior Paleozoic basin, nearly divided along the middle so as to separate between the arctic and eastern United States regions. 4. A somewhat similar Mesozoic region lying to the west of the preceding, and broadest southerly. 5. The elevated fresh-water Tertiaries of the upper Missouri, and the marginal Cenozoic groups on the Atlantic, Gulf of Mexico, and the northern waters off Alaska. 6. The Atlantic belt of Eozoic formations. 7. Various local basins, as the Paleozoic of Acadia and of the Colorado river; the Mesozoic of Vancouver's island, California coast range, of Utah and New Mexico, and of Alabama and Mississippi; Cenozoic of Rocky Mountains, Greenland, etc. It is the sixth of these districts that we shall call particular attention to very soon.

I cannot resist calling attention to a very few points suggested by this map: *First.* At the close of the Eozoic period the grand features of the North American continent were distinctly outlined, including the Atlantic and Rocky Mountain areas. The work of later geological periods seems to have been the filling up the bays and sounds between the

Fig. 1.
GEOLOGICAL MAP OF NORTH AMERICA.

great islands, elevating the consolidated mass into a continental area, and probably submerging other equally important islands beneath the Atlantic and Pacific oceans.

Second. Although the Rocky Mountain Eozoic area existed very early, it seems to have oscillated considerably during the Paleozoic and Mesozoic periods, sometimes elevated and often submerged, while the Eozoic districts of the east remained elevated above the sea from the very first. This is shown partly by the gradual extension westwards of the submarine deposits. East of the Mississippi river there is scarcely anything in the interior basin later than the coal measures. Then comes the development of enormous Triassic and Cretaceous deposits between the long Paleozoic strip from Texas to the Arctic zone and the Rocky Mountains, while along the latter region we fail to find the former groups to any very marked extent, as would be expected were the western outcrops steadfastly elevated at the same period with the eastern. If we may say that the North America of Triassic times extended from Greenland and the Atlantic ocean to Texas, we may also say that, by the close of the Mesozoic, she had annexed to herself, by means of a specially constructed causeway, the whole of the Rocky Mountain series of islands. Possibly the genius of the continent is now looking forward to a similar absorption of the West India islands, through the filling up of the straits of Florida and the intra-insular spaces.

Third. There were two promontories extending south-easterly from the early continent,—one the well-known Adirondack area, and the other the metalliferous district near Lake Superior. The latter sent off a prominent spur also towards the Laramie Mountains of Wyoming, projecting eastwardly from the Rocky range. In fact, it is not unlikely that a bridge connected these projections of land through the Black Hills during middle Paleozoic times.

Fourth. The immense areas and the enormous thicknesses attained by the Eozoic formations, especially in comparison with the later groups, suggest that the earlier rocks have yet revealed to us very little of their history. The later formations occur in comparatively thin incrustations, easily studied and identified through fossils. The earlier groups are much more difficult of identification, are best developed in the thinly settled or absolutely wild districts, and hence have not yet assumed that importance in stratigraphical columns which they are destined to receive in the future. We trust, therefore, that geologists will not be too hasty in deciding against the attempts of this volume to set forth the reality of several new subdivisions in the Eozoic column of the Atlantic system.

The Atlantic Area.

In the chapter upon Topography, vol. i, p. 170, mention is made of two sections of the mountains along the Atlantic, the first culminating in western North Carolina, the second in New Hampshire. By referring to Fig. 1, I think it will appear that the Atlantic system should be extended to include the Eozoic area of Newfoundland, though separated by the Gulf St. Lawrence. The lowest line between the northern and southern sections reaches tide-water along Hudson river; and as the disappearance of the Cenozoic margin at Cape Cod suggests a more extensive depression of the land northerly, it is not strange that the remotest section of the Atlantic area should be depressed more than the others. There is a correspondence in the arrangement of the Newfoundland formations with those of the adjacent provinces of New Brunswick and Nova Scotia. The Paleozoic rocks of the north-west side of Newfoundland correspond with those of Gaspé; the central gneissic area is continuous from New Brunswick; and, not to mention all, the outer Eozoic area of the outer Newfoundland island is the continuation of the Nova Scotia Atlantic strata. Hence I believe a new classification is possible,—that of the northern or Newfoundland, the middle or New Hampshire, and the southern or North Carolina sections of the Atlantic range. The middle and southern will correspond with the northern and southern sections of the Appalachian system, so ably set forth by Prof. Arnold Guyot, in his memoir published in the *American Journal of Science and Arts*, II, vol. xxxi, p. 157. The Appalachian system relates more properly to the Paleozoic elevations to the west of the Atlantic chain, the name having been improperly extended in application through false theories of the age of the New England rocks.

In the southern section Laurentian areas are abundant. They are less so in the middle district; but I will now introduce a map and sections, which will characterize the formations with considerable minuteness.

The Map.

Herewith is annexed [Plate 1] a small geological map of New England, with portions of the adjacent states and provinces. The territory includes what might be termed the "Champlain island," or that portion of the continent east of the Hudson valley which existed as an isolated district for a long time after the Glacial period, the then submerged Hudson, Champlain, and St. Lawrence valleys, and the remoter portions of Nova Scotia, Cape Breton, and Newfoundland. It corresponds exactly with the middle and northern section of the Atlantic belt, as defined above. The lines were carefully drawn upon the scale of twenty-four miles to the inch, and then reduced to about one hundred miles to the inch by photography. The area has been sufficiently extended to include all the Canadian representations of the Labrador system. Outside of New England, the geological boundaries have been copied from Logan's map of 1869, as amended by Dawson's sketch of Nova Scotia and Prince Edwards island, Prof. L. W. Bailey's and G. F. Matthews's report upon New Brunswick, and Alexander Murray's recent map of Newfoundland. The authorities for New England are my own maps and observations in the four northern states, my father's map of Massachusetts of 1844, Percival's Connecticut, Jackson's Rhode Island, and a few isolated facts presented by various authors. It is the first published attempt to subdivide the crystalline and metamorphic formations of all this region.

Looking at the map in the most general way, a fourfold division naturally suggests itself. First, the more ancient gneisses and granites, embracing the Laurentian, Atlantic, and Labrador systems. Second, the immense areas of hydro-micaceous and micaceous schists, which are here termed Huronian. Third, an equally great expanse of clay slates and all the known fossiliferous groups of the Paleozoic. Fourth, the comparatively restricted patches of slightly inclined areas of Mesozoic and Cenozoic age. All these divisions possess characteristics peculiar to New England, those of the first two being the ones most important to us in the discussion of the geology of New Hampshire.

The first division is divided into four parts,—first and oldest, the *Laurentian;* second, the *Porphyritic gneiss* and various undetermined granites; third, the *Atlantic;* and fourth, the *Labradorian.* The second division cannot yet be well subdivided upon the map. The third consists more largely of clay slates than anything else in the East, with all the well determined Paleozoic formations of New York and Canada. These slates are grouped under the general term of Silurian and Cambrian of the Atlantic area, in distinction from the same formation in the St. Lawrence and Champlain valleys. These might be further divided, did the scale of the map allow minuter representation. The outcrops of the Devonian and Carboniferous are also distinguished from the preceding. The fourth portion is easily divided into Triassic, Cretaceous, and the capes and islands off southern New England, composed of Tertiary and Alluvium.


PLATE I.
GULF OF ST. LAWRENCE
BAY OF CHALEUR
BAY OF FUNDY
GULF OF MAINE
GEORGES BANK
WESTERN BANK
Sable Id
ST PIERRE BANK
GRAND BANK
GEOLOGICAL MAP
Illustrating the
Relation of the New Hampshire Formations
to those of the adjacent territory
EXPLANATION.
Alluvium and Tertiary.
Cretaceous
Triassic
Carboniferous
Devonian.
Silurian and Cambrian of the St. Lawrence Valley
Silurian and Cambrian of the Atlantic area
Huronian
Labradorian, including Syenite.
Atlantic.
Porphyritic and undetermined Granites
Laurentian.
Submarine banks of less than 300 feet depth are indicated by dots.

Laurentian. Beginning at the south-west corner, we observe three areas marked as of this age. The greater one comprises the highlands of New York and New Jersey. Nearly all writers have agreed in this reference, save that Prof. H. D. Rogers at one time regarded the crystalline limestones of New Jersey as metamorphosed Lower Silurian. Prof. W. W. Mather separated from this "Primary" area various metamorphic limestones and schists, thought to be of Silurian age, which are mostly placed with the Atlantic system upon our map. Hall and Logan, in 1864, found this so-called primary area in eastern New York to be the same with what they had elsewhere called Laurentian.* Prof. Dana comes to a similar conclusion.†

The two smaller areas to the north-east, partly in Connecticut and Massachusetts, are Formations K 2 and K 3 of Percival, and are accepted as Laurentian by Profs. Hall and Dana. The correctness of the bounds of the latter area in Massachusetts may be open to question.

The large areas of Laurentian, in the Adirondacks and north of the St. Lawrence river in Canada, are the exposures originally called by this appellation by Sir W. E. Logan.

In New Brunswick this formation has been outlined in accordance with the views of Bailey and Matthews.

In Nova Scotia, the metamorphic rocks accompanying the magnetic iron ores of the Cobequid mountains and an extensive area running the whole length of the peninsula, are referred to this period by Hugh Fletcher, of the geological survey of Canada, in the topographical atlas of the Dominion of Canada (1875), published with the approval of Mr. Selwyn, the director of the survey. In accordance with the views of T. Sterry Hunt, the latter area is placed in the Atlantic group.

The more central portions of Newfoundland, embracing more than half its territory, may be referred to the Laurentian.

Porphyritic gneiss and undetermined granites. The importance of this group in New Hampshire has been set forth to some extent in the first volume. Upon the authority of the text of the Massachusetts report, I have added an area between Worcester and the Connecticut valley. There is probably another in Warwick. I cannot satisfy myself from Percival's report that this formation occurs in Connecticut. The one

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* *Amer. Jour. Sci.*, II, vol. xxxix, p. 96. † *Id.* III, vol. iii, p. 255.

thus named by him near Bridgeport is lithologically unlike the New Hampshire rock, resembling, however, a portion of our Bethlehem group. In Maine, there is a small area midway between Rangeley lake and the Kennebec river in the west, and along the Penobscot river at the granite quarries. An unusually broad band of it lies between Bangor and Ellsworth, represented in one of the long sections in this chapter. The other areas are mainly of the undetermined granites. The largest is connected with the porphyritic granite just mentioned, and it reaches from the islands of Penobscot bay, or possibly St. George, to the Bay of Chaleur on the Gulf St. Lawrence, a distance of 290 miles, and a width of from two to twenty-two miles. That near New Bedford, Mass., is along the same general line of outcrop. It is everywhere flanked by the Huronian. In the neighborhood are the similar areas of eastern Hancock and western Washington counties, Me., and the one extending from Addison, Me., nearly to the St. John's river. A portion of this latter area is called Laurentian by Bailey and Matthews in the New Brunswick report, and they are all referred to this horizon in the topographical atlas of Canada. Another important granitic area is that of Mt. Katahdin. Much of it is surely not porphyritic, and is not unlike certain Labrador granites. As all these granites are quite ancient, they are associated together in the representation of their geographical positions, though not necessarily identical in age.

Atlantic System. This system commences at New York city, and extends north-easterly through Connecticut, thence more northerly through Massachusetts and Vermont, along the Green Mountain range into Canada. Probably the Montalban and Lake groups are both represented, especially in western Connecticut. The Green Mountain range has some relation with the Montalban. The eastern Connecticut range branches first to New Bedford, second to near Newburyport, third to Manchester, N. H., and fourthly along the western part of New Hampshire continuously to the White Mountains, and thence as far as the Androscoggin lakes in Maine. From these lakes the presence of this rock is general west of the Androscoggin river, west of the Kennebec and Penobscot rivers, also below Augusta and Bucksport. Small areas exist at the head waters of Dead river in Franklin county, in New Brunswick, and Nova Scotia. The areas of this system in Newfoundland are not yet known with precision; but it is likely that future investigations will add to their present representation upon the map, at the expense of the Laurentian.

Labrador System. All the known Labrador areas in eastern America appear on this map. Five of them lie north of the River St. Lawrence. One of the largest is situated a few miles north-west of Montreal, much of it evidently concealed by the Lower Silurian groups. Next is a small area bordering the St. Lawrence, on the Montmorency river, above the falls. Its northern extremity is not over fifteen miles from the Murray Bay area. A fourth is on the Saguenay river, below and east of Lake St. John. The fifth is on the Moisie river, well towards Labrador. Still another mass of labradorites has been recently reported in the south-west part of Newfoundland. The Adirondack area is given as carefully as possible from Emmons's descriptions of his hypersthene rock. All these terranes are accepted as types of the Labrador system outside of New England.

After the discovery of the physical structure of the granites and labradorites of Pemigewasset, it occurred to me that several granitic districts in Vermont might perhaps be included with it, and they are so delineated on the map. They are in the northern part of Essex county, about Willoughby lake, Craftsbury, and the high lands east of Montpelier. It may be that Megantic mountain, Canada, belongs to the same system. There are good reasons for believing that granitic rocks of perhaps Silurian age have penetrated the earlier Labrador outflows in Vermont. Besides the Pemigewasset and Starr King mountain areas, I have marked in the same way the eruptive rocks of Red hill in Sandwich, Ossipee mountains east of Winnipiseogee lake, and Gunstock. In Maine, the granite of Biddeford closely resembles the Conway division of New Hampshire, while that of Kennebunk is related to it. The Sanford area carries felsite; while the York division is like the sienite of Exeter, Dover, N. H., Gloucester, and Quincy in Massachusetts.

Huronian. The rocks referred to the Huronian cover immense areas. A very important one, and the most characteristic of all, is that referred to the Quebec group by Sir W. E. Logan. Beginning at Granville, Mass., it passes into Vermont and Canada east of the Green Mountains, connecting not far from the province line with the wider belt starting at

Ripton, Vt. The two united continue to the end of the peninsula of Gaspé, passing the city of Quebec, and adjoining the St. Lawrence beyond this point. An interesting spur from this area extends from Memphremagog lake to Weedon, P. Q. The next area is the one occurring along Connecticut river, commencing at Rockingham, Vt., expanding to the Ammonoosuc gold field, winding along the Upper Ammonoosuc in Stark, Milan, Dummer, Whitefield, and Dixville, to connect with a broader expanse in Pittsburg, the corner of Maine, and so on along the Quebec and Maine boundary to the head waters of the St. John's river, thence near the Maine line almost to the St. Francis river, separating the most northern angle of Maine from Quebec and New Brunswick. There is a small attendant of this terrane near Moosehead lake, Me., while the felsite of Mt. Kineo is doubtfully referred here, also.

The next area in size extends from the Bay of Chaleur past the Kennebec river in Maine, enveloping the long granite ridge of nearly 300 miles' length, mentioned above. Smaller outcrops exist along Dead river, north-easterly from the Katahdin granite, at the mouth of the Penobscot river, three or four in New Brunswick; and the Portland rocks, possibly including the Merrimack group in Massachusetts, some feldspathic rocks about Boston, and possibly those associated with serpentine and dolomite at Newport, R. I., belong here. The small area west of New Haven, Conn., is evidently a part of the Connecticut River range, the intermediate portions being largely covered by the New Red Sandstone.

In Newfoundland the Huronian system occupies chiefly the south-eastern promontories. The reference of these rocks to the Huronian is the more satisfactory, since it is at the instance of Alexander Murray, Provincial geologist, who was one of the first to describe this system in its typical locality upon Lake Huron. It may be that portions of the strata thus referred by him, called the "Intermediate series," will prove to be higher in the scale, more especially since they yield an *Arenicolites* and *Aspidella*.

Several areas of andalusite and mica schists in New Hampshire are left unrepresented upon the map, though indicated by lettering. At the moment of writing, it is not clear to which of the great subdivisions these rocks should be referred. Mts. Monadnock and Kearsarge are composed of this formation.

Cambrian and Silurian. It is in the Cambrian and Silurian formations that the New England rocks show very distinctive peculiarities, and I have therefore distinguished between them upon the map. In the St. Lawrence, Champlain, and Hudson valley we have the following series:

In the St. Lawrence valley the bottom member is the Lower Potsdam group. Skirting the west base of the Hoosac and Green Mountains, this is a quartzite 1100 feet thick. Near its termination in northern Vermont there succeeds a mixture of red sandstone and mottled sandy dolomites, about 300 feet thick. In New York and northern Vermont two areas of clay slate occur, with a thickness of at least 3000 feet. In Quebec the older slate, with interstratified thin limestones, belongs to this series, the quartzite and sandstone not appearing. There are limestones of this age at Belle Isle, Anse Au Loup, and Bonne bay. This group is characterized by the presence of *Olenellus.*

The Upper Potsdam is almost uniformly a sandstone, with fossils indicating its existence as an ancient sea-beach. Its surface is covered by ripple marks and crustacean tracks. The thickness along the Champlain valley is about 250 feet; north of the Adirondacks it rises to 300 and 700 feet. About 75 miles below Quebec a large area of related rocks has been described by Richardson, having a thickness of 2000 feet. At the remotest localities named above, the thickness of both the Potsdam periods rises to 1174 and 2020 feet. At Canada bay the mass is 5600 feet thick, according to Murray.

The calciferous sandrock is about 300 feet thick in the Champlain and St. Lawrence valleys. It crops out occasionally on either shore, and is developed in Newfoundland. It is overlaid by over 1000 feet of limestones containing a peculiar set of fossils, referred by Logan and Billings to the Upper Calciferous, a formation entirely absent on the main land.

Next comes an immense thickness of slaty and calcareous rocks, intercalated in the geological column quite recently, and known as the Quebec group. Much remains to be learned respecting its limits, but it may embrace most of the limestones, marbles, and talcoid schists of western Massachusetts and Vermont, amounting to 4000 feet or more. They somewhat exceed this thickness adjacent to the province line, in Highgate, Vt., and Phillipsburgh, P. Q. Logan describes similar rocks near Quebec, with related fossils. He has associated with them, upon theoretical grounds, the whole of the Huronian series from southern Massachusetts to Gaspé, dividing it into the Levis, Lauzon, and Sillery formations. He supposes the latter assemblage has been metamorphosed so as to lose its original mineralogical character. The two sets of beds may often be distinguished by the presence or absence of fossils, the Huronian being usually destitute of any decided evidences of life. The Quebec rocks are associated with the preceding group, also, in northern Newfoundland, attaining a thickness of 6600 feet.

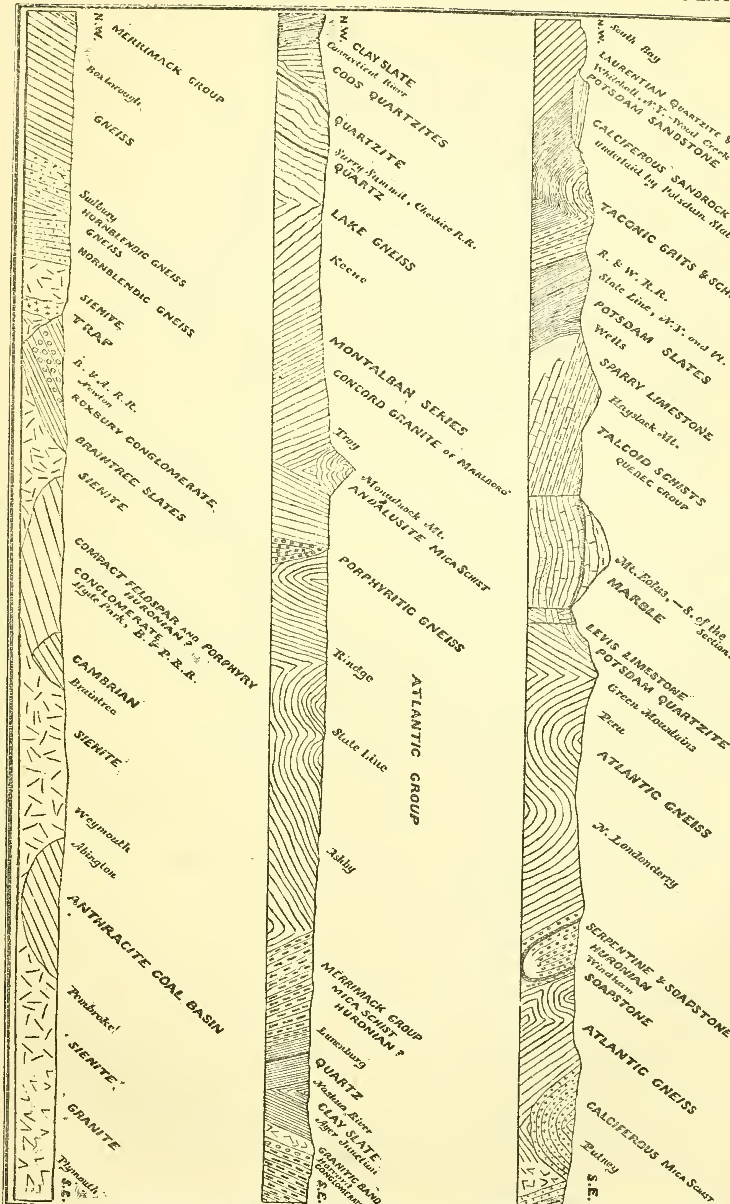
Next in order are the Chazy, La Motte or Black River, and Birdseye limestones, not usually much over 150 feet thick, and, so far as known, confined to the Champlain and Upper St. Lawrence valleys.

The Trenton limestone is one of the most characteristic of the Lower Silurian formations. In Quebec and New York the maximum thickness is 600 feet. It may be represented by the lower limestones of Anticosti island; at least, more than 1200 feet thickness is referred to the Trenton and Lorraine series combined.

The Utica slate is rather a local deposit, estimated at 300 feet along the Champlain and St. Lawrence valleys. It passes into the Lorraine shales, or Hudson River group, which everywhere accompanies the Utica formation. Logan says it must be 2000 feet thick in Canada. These shales in New York are the equivalents of limestones in Ohio, etc., just as seems to be the case in Quebec and Anticosti.

Two interesting conclusions may be derived from this summary of the Cambrian and Silurian of the St. Lawrence valley: first, the thickness uniformly increases in passing north-easterly; secondly, slaty, sandy, and siliceous rocks occasionally change into limestones. Both these features are explicable upon the theory of the deepening of the ancient ocean north-easterly, the slates increasing in deeper water, and the sea-beaches corresponding to calcareous accumulations out at sea.

The Upper Silurian groups are sparingly represented in the St. Lawrence valley. There is nothing of this age west of Montreal, in the area of the map. St. Helen's island, in the river opposite Montreal, belongs to the Lower Helderberg. Farther east are considerable masses of red shale, occupying at least three outliers, which are referred by Logan to the Medina period. Near the end of the Gaspé peninsula are 2000 feet of limestones, apparently a great development of the Lower Helderberg.



SECTION FROM WHITEHALL, N.Y., TO PLYMOUTH, MASS.

No. 1.

The upper members of Anticosti island, amounting to more than 1000 feet, appear to range through the whole of the Upper Silurian. The principal development of the Upper Silurian is therefore in the neighborhood of the St. Lawrence gulf, in the same district with deep sea deposits of the preceding system. They may connect with the north-eastern extension of the more eastern ranges of the same age.

Let us now note the character of the Cambrian and Silurian formations of the eastern or Atlantic. We find, first, a series of slates rather older than the Lower Potsdam, characterized by the presence of *Paradoxides*. At Braintree, Mass., are clay slates of this age several hundred feet thick, associated with great thicknesses of grits and conglomerates, shown upon Section 1 of this chapter. Related rocks are abundant along the New Hampshire and Maine coasts. Near St. John, N. B., they have been studied carefully, and consist of slates and grits certainly 2000 feet in thickness, with the fossils *Conocoryphe*, *Agnostus*, *Ellipsocephalus*, *Microdiscus*, and *Paradoxides*. In south-east Newfoundland the last of these genera has also been found; also, 6000 feet of the Lower Potsdam or *Olenellus* formation. In Nova Scotia the auriferous rocks are latterly referred to the Potsdam series, or the Lingula flags of Great Britain. Their thickness is very great, probably exceeding that of the Potsdam rocks below Quebec, in the St. Lawrence valley.

The next series that seems to belong to the Lower Silurian is the clay slate of central Maine. Portions of this near Waterville abound in *Nereites* and related impressions of rather uncertain affinities. Section 3 of this chapter crosses them, and they must be several thousand feet thick. There are numerous smaller areas of similar slates, without fossils, in other parts of the New England area. A measurement of one of them, in Lyman, gives a thickness, certainly, of 1500 feet.

In the west part of New Brunswick, passing into Maine, is the *Mascarene series* of Bailey and Matthew, which evidently belongs to some part of the Silurian system. A carefully measured section gives nearly 2000 feet, arranged in five divisions. The rocks are feldspathic shales, felsites, flags, sandstones, and conglomerates, much resembling the Huronian. The fossils are *Lingula*, *Modiolopsis*, and *Loxonema*. Similar rocks make their appearance in limited patches off the coast of Hancock and Washington counties, in Maine. A detailed section of them at Machiasport is published in the Maine reports. The resemblances to Huronian schists may show the origin of the materials, and, necessarily, the later age of the fossiliferous beds.

One of the most characteristic formations of the East is the Gaspé slate group, including the calciferous mica schist of Vermont, and the Coös group of New Hampshire. Commencing at the Gulf St. Lawrence, there is a broad band of slates, slaty grits, with calcareous, ferruginous, and sandy varieties, often carrying Lower Helderberg, and perhaps Niagara fossils. They are several thousand feet thick. Little is yet known of them, save their general distribution. They extend south-westerly through Quebec, New Brunswick, and Maine, entering Vermont and New Hampshire with a somewhat altered facies. Logan describes them on all the north-west-south-east streams tributary to the St. Lawrence. The area of its distribution is mostly in a forest. In northern Maine I have crossed it along the St. John's river, as high as the mouth of the Alleguash. The divisional planes are commonly nearly vertical, consisting in so many places of cleavage that one is tempted to believe the strata lines are mostly obliterated. No formation occupies a larger area upon our map than this.

In Quebec, as we approach the United States boundary, two types of rock prevail in the Gaspé series,—one, a well defined clay slate, abundantly quarried for tiles, traversed by cleavage planes, and a siliceous limestone. The slates contract near the line. A narrow area passes from Memphremagog lake, through Montpelier, to a point beyond the centre of Vermont. Another enters New Hampshire in Pittsburg, crops out at intervals along the Connecticut valley, being quite prominent between Bellows Falls and Greenfield, Mass. The limestone seems to undergo a species of metamorphism, as it passes from north to south. For fifty miles of its course in Quebec it is clearly a limestone. As it passes into Vermont, micaceous and hornblendic layers show themselves, and increase southerly, so that midway in Vermont the schists and calcareous layers are equal in amount. It is here, also, that the area contracts very much. In southern Vermont and in Massachusetts the mica schists predominate, and the limestones are scarce. The formation terminates near the north line of Connecticut, but appears in a limited area, west of the Huronian and clay-slate outcrops, near New Haven, Conn.

A formation, closely allied to this calcareo-micaceous Gaspé series, has been termed the Coös group, in New Hampshire. It consists of mica schists abounding in staurolite, hornblende rocks, and quartzite. Its area lies along the east border of Connecticut river, and it may be 5000 or 6000 feet thick. In the subsequent portions of this volume, the relations of this group will be fully discussed. It may not be confined to the Connecticut valley, as there are rocks of similar character in western Maine and western New Brunswick.

At Port Daniel, on the St. Lawrence gulf, and at Squam lake, in northern Maine, are limestones and shales, abundantly fossiliferous, over 1000 feet thick, referable to the Niagara group, or, possibly, a little higher.

The developments of the Lower Helderberg series in the east are very great, far exceeding anything of the same age in other parts of the country. In the Connecticut valley these rocks occur in several places, sufficient to indicate the former submergence of this area beneath the ocean. These outcrops will be fully treated of in succeeding chapters. I need now only to say that the Connecticut valley Helderberg series consists of several thousand feet thickness of quartzites, limestones, slates, conglomerates, sandstones, flags, and probably hornblende schists. In northern Maine the limestones are mostly wanting, the rocks being slaty. There is some limestone in Eustis plantation, and near Masardis and Ashland. The slates border and are interstratified with the Gaspé series. Near Eastport, in Perry, Pembroke, Cutler, Lubec, etc., the sandy slates and grits of this age are very abundant, and well filled with fossils. They cross Passamaquoddy bay into New Brunswick, appearing in several localities, particularly in a long, narrow strip crossing the St. John's river above the city of St. John. Bailey and Matthew's section of this range gives a thickness of about 5700 feet to the series.

Similar rocks occur in Nova Scotia. A typical locality is at Arisaig, which has been considerably explored by Dr. J. W. Dawson and Rev. Dr. Honeyman. These and others represent in Nova Scotia the greater part of the Upper Silurian of New York and England, possibly as low as the Medina, certainly the Clinton group.

This review of the Cambrian and Silurian strata of the St. Lawrence valley and the hilly region to the east, will enable us to compare them together. 1. The former are mainly sea-beaches and oceanic calcareous deposits; the latter, thick slaty and sandy sediments, sparingly calcareous, probably occupying largely the space between the littoral and pelagic regions of original deposit. Except for the fossils, there is rarely any lithological similarity between the formations of the two regions. 2. There is nothing yet known in the more eastern region of the formations between the Quebec and Medina. 3. The Upper Silurian is scarcely known in the Upper St. Lawrence valley, while it predominates in the east. It will be seen very soon that the Devonian and Carboniferous are entirely confined to the eastern district. 4. Metamorphism has operated to some extent upon the strata in the east, and not in the valley.

Devonian. The lowest member of the Devonian or the Oriskany sandstone is well developed in Maine, between Parlin pond and Masardis, crossing the upper end of Moosehead lake. At its southern extremity the formation rests upon granites, gneisses, and Huronian schists. These strata consist of slates, slaty grits, and sandstones, having a thickness of 2880 feet along the Canada road, the structure being that of a shallow synclinal. On Moosehead lake the Cauda-galli grits have a considerable development. The same formation is found in Nova Scotia, in Annapolis county, bordering the Bay of Fundy. The iron ore of Nictaux comes from this group. I understand that there are small areas of this formation in New Brunswick, which have not yet been described by geologists.

On Lake Memphremagog there are extensive developments of the Upper Helderberg limestone. The formation can be traced continuously as far south as Montpelier, Vt., and it occurs at several localities at the north-east, as at Dudswell, Lake Aylmer, on the Touffe des Pins, a tributary of Chaudière, etc. These rocks evidently are not the same with the Helderberg strata of New Hampshire.

On the Gulf of St. Lawrence is a great development of Devonian sandstones, called Gaspé by Sir William Logan. They are 7000 feet thick, the upper portions having a red color. The whole series presents analogies with the Upper Devonian formations of New York, as both contain similar plants. The map shows two large areas of the Gaspé sandstones north of the Bay of Chaleur. In northern Maine there seem to be several small areas of the same formation. Near St. John, N. B., the Upper Devonian sandstones have been studied with considerable care by Bailey, Matthew, and Hartt. Their most recent conclusions present the following arrangement: first, the Bloomsbury conglomerate, 500 feet thick; second, the Dadoxylon sandstone, 2800 feet thick; third, the Cordaite shales and flags, 2400 feet thick; fourth, the Mispec conglomerate, 1800 feet thick—total, 7500 feet. In the western part of New Brunswick, and at Perry, Me., are limited patches of red sandstones belonging to the Upper Devonian, and closely related to the Gaspé and St. John series. Dr. Dawson has described nearly a hundred species of plants from these Devonian sandstones.

Carboniferous. The Carboniferous rocks are essentially in two basins, the one in Massachusetts and Rhode Island, the other occupying portions of New Brunswick, Prince Edwards island, Nova Scotia, Cape Breton, and Newfoundland, the greater portion of it underlying the Gulf of St. Lawrence. The coal of the first basin is anthracite, and the second is bituminous. According to my own explorations,* the Rhode Island system consists of

First, coarse conglomerate, with distorted pebbles, . . .	300 feet.
Schists and slates, ...	473 "
Second, conglomerate, ...	464 "
Coal measures, ...	3500 "
Third, conglomerate, ...	50 "
Total, ...	4787 feet.

There are eleven beds of anthracite in these measures at the north end of the island of Aquidneck.

The Carboniferous outcrops along the Bay of Chaleur consist of conglomerates and sandstones, called the Bonaventure formation by Logan, 3000 feet thick. The extensive field in New Brunswick consists of comparatively thin deposits spread over a large surface, and contains very little coal. The coal measures and millstone grit combined are 600 feet thick, according to Bailey and Matthew. In Nova Scotia is exhibited one of the most remarkable sections in the Carboniferous of any part of North America. Dr. Dawson arranges the whole Carboniferous series as follows:

(1) The lower coal measures.

* *Proc. Amer. Ass. Adv. Sci.*, vol. 14, p. 112.

(2) The Carboniferous limestone.

(3) The millstone grit series, 5000 to 6000 feet thick.

(4) The middle coal formation, 4000 feet thick.

(5) The upper coal formation, 3000 feet thick.

Logan's section at the Joggins gives 14,700 feet thickness to the whole Carboniferous series. At Pictou it has also a thickness of 16,000 feet. J. P. Lesley thinks these thicknesses must be exaggerated.

Triassic. Three well-marked areas of the Triassic formation appear on the map. The one best known occupies the Connecticut valley in Massachusetts and Connecticut, the area being about 2200 square miles. The formation is at least 5000 feet thick, divided into three sections. The lower part consists of coarse red sandstone; the middle, of fine sandstones, shales, flags, etc.; the upper, of reddish sandstones and conglomerates. Over most of this area a mass of dolerite divides the middle from the lower section. The two upper divisions contain the footmarks of birds, which have given the Connecticut River sandstones their well-known celebrity.

The second Triassic area occupies the shores of the Bay of Fundy. A very large amount of trap containing native copper occurs in connection with it. The third area occupies nearly the whole of Prince Edwards island.

Cretaceous. This formation appears at the southern extremity of the map, on the northern shore of Long island. It is a continuation of the plastic clay of New Jersey. It is a fresh-water deposit, containing lignite and a few shells. Its character suggests the existence in the early Cretaceous period of a long, narrow, fresh-water lake, necessitating the presence of very different physical conditions from those now existing in that vicinity.

Cenozoic. The tertiary and alluvial deposits represented on the map occupy a place outside the Cretaceous, between New York and Cape Cod. Their absence north-east of Massachusetts has suggested the theory of the submergence of the middle and northern sections of the Atlantic district in very recent times. Possibly Sable island, off Nova Scotia, and the great banks of Newfoundland, may indicate the position of the place of these Cenozoic deposits, and consequently the outer limit of this portion of the continent at the close of the Tertiary period.

Sections.

I present herewith three sections passing across the most important parts of the field of the map. Taken in connection with the map, they will afford a correct notion of the geology of this district.

Geological Section from Plymouth, Mass., to Whitehall, N. Y.

This section is 180 miles long, and exhibits the older rocks of eastern Massachusetts, the Atlantic group in New Hampshire and Vermont, the so-called Taconic rocks in western Vermont and eastern New York, the Adirondack or Laurentian series, and several less important groups.

Underneath the drift of Plymouth and Kingston there lies a broad band of granite, the north-eastern extremity of the range continuous from Little Compton, R. I. The descriptions given of it are not sufficient to enable me to compare it directly with any of the New Hampshire groups, though there are suggestions in favor of a reference of certain portions to the Bethlehem and Labrador groups. Nor is it known how this band stands related to the sienite, which appears next in Pembroke. The Carboniferous system which succeeds is the northern extremity of the New England anthracite coal-field. The strata are largely slates and sandstones, with a moderate northerly dip, and rest upon a floor of sienite. No beds of anthracite are known in this neighborhood; and the few exposures may belong to the lower part of the group. It is the newest formation exhibited upon the section.

The sienite is the fundamental rock of south-eastern Massachusetts. It comes to the surface four times in our route of travel. Being an eruptive rock, it is evidently newer than some of the neighboring gneisses, either the New Bedford range (which may possibly touch the end of our section) or that which appears between Sudbury and Harvard. Not all this rock, however, is to be regarded as eruptive. It merges into the hornblendic gneiss of Wayland and Sudbury, and is often traversed by divisional planes very suggestive of strata. The group also contains beds of limestone and serpentine, and there are conglomerate portions. As the limestones of this series and the gneiss of Bolton carry the organism *Eozoön*, the whole series is evidently allied to the Laurentian. The geographical situation of the sienite and eozoönal gneisses naturally suggests a Laurentian age, for they may belong to the Acadian ranges of these older rocks, and they certainly lie to the east of all the debatable metamorphic formations. The similarity of the sienites to rocks among the White Mountains, described elsewhere as cutting the Labrador sediments, as if at the termination of their period of formation, affords reasons for supposing them to be of the same age. Thus we are confronted with two theories of the age of the sienite. Were it possible to decide the question of age without further field-work, it might be said that the apparently stratified portions may be of Laurentian age, while the other masses may have been erupted in the Labrador period coeval with Red hill and Tripyramid. The probability of the greater antiquity of the gneiss has led to the representation of a folded anticlinal between the two hornblendic bands in Sudbury.

The concentric structure of the Boston basin is very obvious, and is shown partly in the section. There is first a grand sweep of gneisses from Andover and Billerica, in a south-westerly and then southerly if not south-easterly direction into Rhode Island. They then pass under the coal-field and the waters of Narraganset and Buzzard's bays, to come up in the New Bedford range. This V-shaped area encircles in similar form a broad but narrower band of hornblendic gneiss and sienite. Within the sienites is a band of compact feldspars and porphyries. A little north-west of Hydepark one member of this series is a very coarse conglomerate. The section crosses the southern part of this range obliquely, and thus magnifies its thickness. It does not crop out notably next the sienite in Waltham or Watertown, but may be seen in the same geological situation between Melrose and Swampscot. It has been suggested that these felsite beds are of Huronian age. Similar rocks occur abundantly in the New Brunswick areas of this age, though very rarely about the Lake Huron or Vermont terranes. Within the red felsites is a series of Cambrian rocks, showing the characteristic *Paradoxides* in slates near the base. Below are conglomerates of limited extent; but above is the well known Roxbury conglomerate, used extensively for building purposes in Boston. To the north of this is another set of slates. Prof. N. S. Shaler estimates the thickness of the lower conglomerates or sandstones at several hundred feet. The Braintree slates, together with the lower beds, may be not far from one thousand feet thick. The Roxbury conglomerate is estimated from twelve hundred to two thousand feet and more. The upper slates,—called "Cambridge slates,"—are thought to be three hundred feet thick.* All these Cambrian rocks dip northerly, from fifteen to twenty degrees.

From all that I can learn respecting the structure of this Boston basin, from the writings of J. F. and S. L. Dana, my father's reports, Prof. Shaler's papers, and original observations of a limited character, in this and the analogous basin of Parker river,† I conclude that the monoclinal dip of the Cambrian rocks about Boston is not altogether the primal condition, but the result of an overturn. If this be a correct induction, the Roxbury conglomerate will be found to be at the summit of the series.

The next conspicuous set of rocks on the section is the Merrimack series, occupying the valley of Nashua river. The lower portion consists of mica schists of various textures and micaceous quartzites, with occasional beds of indigenous granites. In Groton and in Rockingham county, N. H., a bed of soapstone is present. In Harvard the granite is unusually abundant, connected with an interesting conglomerate considerably altered by metamorphism. The resemblance of these beds to what I have thought to be Huronian rocks, near Portland, Me., makes the suggestion worthy of consideration whether the Merrimack group of my annual reports should not be regarded as nearly the equivalent of the Huronian. Hydro-mica schists are rarely met with in the Merrimack valley, but the synclinal basin of schists is overlaid by clay slates not unlike

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* *Proc. Boston Soc. Nat. Hist.*, vol. xiii, p. 172. † *Proc. Amer. Ass. Adv. Sci.*, 1860, p. 118.

strata of the same name in New Hampshire, Vermont, and Canada, overlying the Huronian. The latter may merge into the andalusite variety cropping out on Mts. Monadnock, Kearsarge, the east side of Washington, etc.

In the south part of Lunenburg the section crosses an interesting band of white quartzite over fifty feet wide. This band I have traced directly to Nottingham, N. H., the rocks becoming more micaceous and schistose north of the state line. Lithologically, it closely resembles two bands of the same rock crossed farther north by our line. The outcrop is on the track of the Fitchburg Railroad.

The section next crosses a broad belt of gneiss supposed to belong to the Atlantic system, and to consist mostly of the Lake division. Four well marked anticlinals have a place in it before coming to Monadnock. The first is the Wachusett anticlinal, figured by my father in his final report, and not observed on the line of section, perhaps for lack of outcrops. As it occurs on both sides, it must be continuous across the section, while there is evidence to suggest the erosion of its eastern portion. Mt. Wachusett lies on the eastern flank of this axis. The next anticlinal makes the dividing ridge between the Merrimack and Connecticut waters in Ashby, Mass., and New Ipswich, N. H. The fourth axis brings up the underlying porphyritic gneiss. Between the main water-shed and Monadnock is the stratigraphical place for two remarkable bands of white quartz. These have been described and mapped in the annual report for 1873. As their outcrops have been traced almost continuously from Temple and Mason to Allenstown, if not Strafford, no doubt can remain as to their persistency. A protracted search has so far been unavailing to bring them to light in New Ipswich, most of Mason, Rindge, or Sharon, but two similar bands appear in Royalston, Mass., along the same north-east-south-west line;—so that the theory is admissible that the nearly horizontal mica schists of New Ipswich, Ashby, and Temple may conceal the underlying quartzes for a considerable distance. The same bands come up again between Keene and Connecticut river.

Mt. Monadnock seems to be an isolated contorted synclinal of andalusite mica schist, resting upon the upturned edges of the gneisses. The vicinity of the mountain is a plateau (Vol. I, p. 209), so that these schists suggest an incredible amount of erosion. The little map in this chapter shows the extension northwardly of a series of these outliers.

The Montalban division makes its appearance between Monadnock and Keene.* At Troy village the dips are easterly, so that the older rocks beneath Monadnock are arranged in synclinal form, showing that the andalusite schists were deposited along an original depression. The "Concord granite" of Marlborough succeeds, with essentially the same position.

Near Factory Village, in the north-east part of Swanzey, the Lake division of the Atlantic group makes its appearance, and continues to the newer rocks of the Connecticut valley. In the south part of Keene the dips conform to the overlying Montalban

* The facts stated concerning the strata between Monadnock and Connecticut river are furnished by J. H. Huntington, from recent field-work.

of Marlborough. On ascending the ridge west from Keene, we find the Cheshire Railroad has cut through the ledges very extensively, thus affording excellent means for determining the position. In the first considerable excavation the strata are extremely variable in position and character. First, there is a reddish gneiss. Next, a quartz band breaking into jointed rectangular fragments. Thirdly, there is a chloritic rock, standing nearly vertical. In the "mile cut," in the south corner of Surry, the first rock is hornblende schist, dipping N. 60° W. The second is chlorite schist; then twenty or thirty feet thickness of quartz. Gneiss succeeds, with numerous irregularities, but with the more common dip of 20° N. 60° W. The Coös rocks are mainly quartzites, with a high north-westerly dip, and they are unusually well developed in Westmoreland.

The facts concerning the section between Connecticut river and New York are derived from the Vermont report, mainly from Sections IV and V. In Putney, late observations indicate the presence in the clay slate of an anticlinal axis, showing that this formation is probably older than the adjoining schists. Upon this theory, the easterly dip of the western border of the slate must be an overturn. The two axes in the Calciferous mica schist are given from the appearance in Sections I, II, and III, and the Black Mountain granite is represented in the ridge of the anticlinal. Next succeeds the Atlantic gneiss,—perhaps Montalban, with several folds. Three important anticlinals appear. The first occurs on each of the six lower sections of the Vermont report. Between the first two anticlinals is a band of Huronian, perhaps a synclinal, as there are magnesian bands near both the borders. It is the main hydro-mica schist range of Vermont lying east of the Green Mountains. In Londonderry the gneiss is more largely feldspathic than usual, and presents some points of resemblance to the Lake gneiss or the Laurentian. The axis along the main range of the Green Mountains in Peru and Dorset is very clearly indicated in the outcrops, thus corresponding with its usual structure, displayed most satisfactorily, however, where the range has been cut down by the passage of the Winooski and Lamoille rivers. This axis is often an overturn, the strata being apparently monoclinal.

After passing the Green Mountain axis, we are brought into contact with what have been known as the "Taconic rocks," and into a region of gigantic upthrows and downthrows, which have occasioned much difficulty in the unravelling of the structure. I may not satisfy all with the interpretation given to the structure of these rocks, but present that view which seems most correct. The quartzites of East Dorset and West Peru dip westerly when in contact with the gneiss. The western border has an easterly dip, so that the structure is synclinal. The eastern part is much more elevated than the western, so that our band itself is inclined, much like the new moon in the position supposed by many to indicate a wet month. The same view of the position of the quartz and its relations to the gneiss is given in Dr. Asa Fitch's section, in his paper in *Trans. N. Y. State Agr. Soc., 1849*. His section crosses the same formations in Winhall, the next town to the south of our section. By way of further confirmation, it may be said that Emmons figures a similar state of things about twenty miles to the south in Sunderland, agreeing with the representation on Section III of Vermont. The relative positions of the formations are the same all along this line. This quartzite carries the *Scolithus linearis*, and on that account was believed by Prof. James Hall to be of Potsdam age. Billings regards it as the *lower* Potsdam, as the *Scolithus* is a different species from the one common in this sandstone in Canada. Logan represents this rock as of the same age upon his maps of 1868 and 1869, but I understand he more recently expresses the opinion that it belongs to the upper part of the Quebec group. Others sympathize with this view. Granting the correctness of our section, in accordance with the early views of Hall, it would indicate the presence of two shore lines in the Cambrian period, in this part of the country. The one beach reposed upon the west flank of the Green Mountains. The other, possibly connected by deep sea sediments of the same age with the first, was deposited at the eastern base of the Adirondacks, especially in the neighborhood of Lake Champlain.

The next formation is the Eolian limestone, probably of the Quebec group. In the North Dorset valley a segment of it has been thrown upon end, but the normal position appears in Eolus and Danby mountains, where about two thousand feet of limestone repose horizontally, overlaid by talcoid schists. The basal layers approximate to quartzite, some observers insisting that they have identified the latter rock among them, which is made to appear beneath the surface in our representations. The upper part of the limestone consists of the two thick layers of white marble, for which Vermont is celebrated. Farther north, later studies indicate that the marble caps the limestone series. Billings describes unmistakable Chazy fossils from near this marble layer in West Rutland. The continuation of the beds to the extreme north also connects them with layers abundantly charged with characteristic fossils of the lower Quebec group. The rock is the same also with the Auroral limestones of Pennsylvania.

The top of Danby mountain, shown a little farther to the south, consists of the same schists, apparently, with those of Haystack mountain. These latter beds have an apparent dip beneath the limestones. It is therefore necessary to believe in the existence of a fault in the valley between the two mountains. This is the more easy, since the Danby Mountain limestones and marbles do not continue uninterruptedly to Rutland. The enormous lateral pressure caught the thick Taconic sediments in a most powerful vise, as it were, between the Adirondacks and Green Mountains. Hence the intervening valley is filled with faults and upheavals, usually very marked in the limestones, because they are not so strong as the schists, and give way more easily. The Eolus and Danby Mountain mass, like the precisely similar synclinal piles of Equinox, Anthony, and Greylock mountains, happened to be forced upwards in the shape of an immense cuneiform segment. The Danby marble layer is more than twelve hundred feet higher than the same bed in Wallingford, four or five miles distant.

The limestone often crops out to the west of the Haystack range, though never so extensively as on the east. It is most extensively developed in this position at the northern extremity of the schists near Sudbury. The stone is filled with veins of calcite, so as to make the name of "sparry" appropriate. The limestone of this kind on

Haystack does not belong to this band, but there is reason to believe it lies beneath the mountain. This thicker range of schist also carries large beds of conglomerate.

The schists are succeeded by a thick deposit of beautiful clay slates, from which are taken annually thousands of bright colored roofing shingles. It is the Georgia slate of the Vermont report, supposed to belong to the lower Postdam group. The dip is easterly, but the irregularities are great enough in Wells to allow the existence of an inverted anticlinal axis. A somewhat similar band occurs in the eastern part of Whitehall. It is not clear whether these two bands are united by a synclinal beneath the schists next west, or whether the eastern belt has been elevated in connection with a fault.

The anticlinal in the schists west of the R. & W. R. R. is copied from Mather's report, p. 424, pl. 28, fig. 1. Mather did not accept our representation of the slates to the west of this hill, believing there were successive uplifts of Calciferous sandrock, underlaid by the Potsdam sandstone. This anticlinal explains why there should be a broad expanse of the thin Calciferous sandrock, Chazy and Trenton limestones in West Haven, Vt., north of the Poultney river; for all the northern prolongation of New York is entirely occupied by Taconic rocks, which disappear wholly north of the bend of Poultney river. Probably further search will develop the continuation of the Chazy east of this anticlinal, between West Haven, Vt., and Hartford, N. Y. The elevation has been considerable, but patches of this limestone may have escaped denudation in some sheltered spot. The lower slates carry *Olenellus* and other characteristic lower Potsdam fossils a few miles to the south. These slates agree in age with those holding the *Paradoxides* in Braintree. The evidence seems to confirm the observations of Emmons,* near Whitehall, to the effect that the Calciferous sandrock rests upon the slates east of the village, the white sandstone having thinned out eastwardly. But it extends a great distance southerly, and there are also a few outliers of this sandstone in the same direction, indicating the greater lateral spread of the original beach materials in that direction. The Potsdam rests unconformably upon a very silicious rock west of Whitehall, but more especially in West Haven.† This may correspond with the quartzites in Dorset, as well as to the lower Potsdam sandstone of the Northwestern states.

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* *Agriculture of N. Y.*, vol. 1, pl. 18.

† Most observers have passed by this quartzite, as if it were undoubtedly Laurentian. The section showing it is in the Vermont report, vol. i, p. 265. I observed it in 1857, and well remember my speculations respecting it; but, as it was my first view of the world-renowned Potsdam, I could not expect my youthful observations entitled to credence, were any startling generalizations proposed. I said in my note-book,—"Here is a case of unconformability in the Potsdam sandstone; the formation is not a simple one, as is universally described, but represents ages so diverse as to be separated by an unconformability of 25 degrees." In my published description, I have not ventured to suggest so much, expressing the opinion that "the rock with the greater dip is as distinctly quartz as the other; and there is also a large ledge of quartz rock upon the west side of Lake Champlain, with the same inclination. Hence the sudden change in the dip is to be regarded as a safer distinction between the Silurian and Laurentian series, than a difference of lithological character."

Since 1857, the recognition of the western Vermont quartzite as lower Potsdam, by Billings, and the formal separation of the St. Croix and Potsdam in the north-west, bring to mind my early speculations, and excite the anticipation that further researches will develop the older group, with its fossils, along the outer line of the Laurentian in the Adirondacks.

Plate II, illustrating the position of the formations described above as constituting Section I, will be found represented upon page 15 of this volume.

Section II. From Portland, Me., through Mt. Washington, to Abercromby, P. Q.

This section is 205 miles long. It passes through the highest pinnacle of the White Mountains, intersects the Green Mountain anticlinal axis in Canada, traverses the long plain of Utica slate, near Montreal, and terminates in the Labrador system.

The first exposures in the islands of Casco bay, off Portland, are of mica schists, quartzites, soapstone, pyritiferous, plumbaginous, and hornblende schists, referred by us to the Huronian.* The prevailing dip is north-westerly; but a careful examination of the dips, in the neighborhood where the bay does not conceal the outcrops, indicates the existence of at least six folds in this basin. The main synclinal line is situated a short distance to the north-west of Portland. The formation is essentially the same with that traversed by Section I, in the Merrimack or Nashua River valley, save that its lithological characters are more suggestive of Huronian affiliations.

The relations of this to the adjacent gneiss of Atlantic age are plain, while the dips of the newer group are the steepest. In Deering, where the formations join, they possess the same inclination of sixty degrees south-easterly. The rock of Phippsburg is gneiss, and is probably continued beneath the ocean to connect with the exposures at the Isles of Shoals. Hence there may be an outer vein of gneiss, embracing the Huronian schists as closely as the corresponding formation on the north-west side, as exhibited in the section. Perhaps the fact of a usually low dip to the gneiss is not well shown. Two suggestions may explain it: first, the rock may have been formed, metamorphosed, and elevated before the deposition of the Huronian system, and, at the later period of elevation, the slates being more easily moulded, were forced into the steeper inclination; or, secondly, a portion of the less inclined strata may belong to our later division, called, for convenience, the Rockingham mica schist, which may easily be confounded with the Montalban series.

Our information respecting the dips of the rocks to the north-west of Portland, in Maine, is very meagre. The whole distance has been hastily traversed. A synclinal axis is revealed just before reaching Sebago lake; after which only a south-easterly dip appeared as far as the state line. The ledges are greatly concealed by drift all the way. When more carefully studied, inverted dips will probably be found in many places. There would seem to be one important anticlinal between the Maine and White Mountain divisions of the Montalban area.

One of the striking peculiarities of New Hampshire geology next makes its appearance, as revealed upon Mt. Pequawket. Three kinds of granite, with limited masses of slate, compose the mountain. The lowest or Conway granite apparently lies horizontally upon the upturned edges of the Montalban schists. This outcrop is the edge

* *Proc. Amer. Ass. Adv. Sci.*, 1873, p. 163.

of an extensive field, not less than four hundred square miles in extent. The Albany granite, or the second horizontal layer, is thinner than the first in this locality, but is as thick in other parts of the basin. Both the granites are thinner at this outer edge of its area, and thicker in a westerly direction, the first to the greatest amount in Bartlett, along the section line. Above the Albany granite are found two masses of clay slate, somewhat indurated and much contorted, the one on the south and the other on the north side of Pequawket. These are of too limited extent to find place on our section, but are important in the history of the mountain. The formation is identical with the andalusite slate on the east side of Mt. Washington, represented in the Plate. It is to be presumed that the outcrops were formerly directly connected, though their nearest exposures are certainly ten miles removed, the disappearance being probably due to denudation. This slate is apparently much more modern than the Conway and Albany granites, possibly of Paleozoic age.

The igneous material of the upper and principal portion of Mt. Pequawket is more recent in origin than this slate, since fragments of the slate are disseminated through it. The lower portion is mostly a breccia, made up of the slate fragments, which gradually diminish in quantity in ascending the mountain. The igneous paste is feldspathic, and approaches the Albany granite in lithological structure. The same granitic rock composes the main bulk of the Mote mountains, on the opposite side of the Saco river. Very likely the two mountain masses were connected at the time of the eruption of the unstratified material, and the broad valley between has since been excavated by atmospheric agencies. No other localities of this Pequawket granite have been discovered, save a few feet thickness of breccia on Mts. Willard and Tom, near the Crawford house.

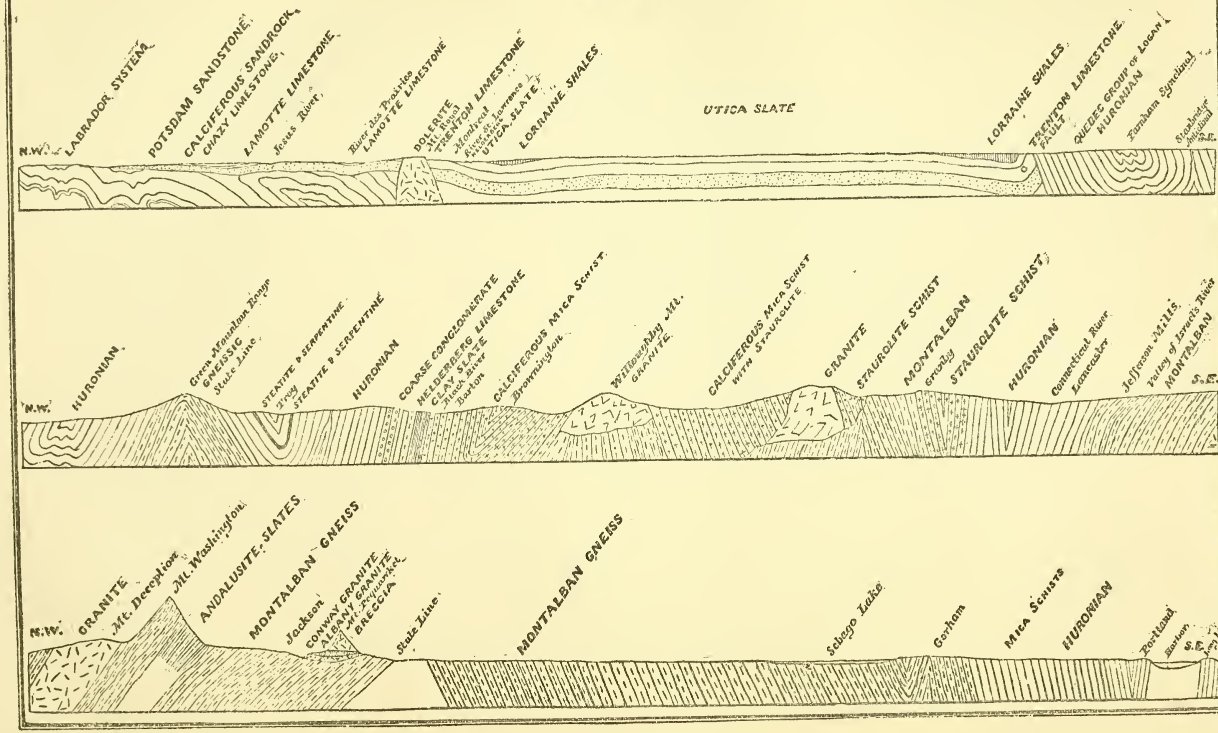
The Montalban schists, from Jackson to the west base of Mt. Washington, have a north-westerly dip, with innumerable local contortions. I advocated the doctrine that Mt. Washington is an inverted anticlinal, in the annual report of progress for 1870. A collation of all the dip observations upon the mountain indicates the presence of a few easterly inclinations upon the eastern side, where erosion had spared the upper layers. A common phenomenon is the occurrence of a low, undulating, south-easterly dip, observable for several rods, which changes suddenly into a nearly vertical north-westerly pitch, folding underneath the first. When we descend into the deeply excavated ravines of Tuckerman and Peabody river, west branch, the latter inclination is the common one, since the surface undulations have been washed away, and only the folded strata remain. This phenomenon occurs mainly in the andalusite slates, as seen along the carriage-road. Full details concerning the variations will be found in the description of Section IX. Furthermore, the general position of these evidently newer slates is monoclinal, with no corresponding repetition, on the eastern side of the valley, of similar strata exhibiting a dip in the opposite direction, as would be expected should the theory of a folded axis be set aside.

At the west base of Mt. Washington is a large amount of granite, carrying long, slender crystals of orthoclase, which give somewhat of a porphyritic aspect to the rock.

PLATE III.

SECTION FROM MONTREAL, P.Q. TO PORTLAND, ME.

No. 2.



It is evidently a part of the Montalban series, as may be possibly the coarser but still rather fine-grained granite of Mt. Deception. The succeeding formation in Jefferson is more nearly allied to the Lake than the Montalban division of the Atlantic system, though not so labelled upon Plate III. On Jefferson hill and at the mills the rock is a common gneiss, with a plenty of feldspar, and usually but slightly inclined to the horizon at the surface exposures. The deeper portions are represented as very highly inclined, in order to make the dips conform to the supposed position of the Huronian rocks which succeed.

Our information respecting this Huronian band in Lancaster and Guildhall is meagre. The first met with is mostly a quartzite, with slight signs of stratification. The portion in Vermont can be readily referred to both the Lyman and Lisbon divisions of the formation, and there are certainly two folds. In this area the usual copper belt of these green hydro-mica rocks has been discovered. This group is followed by a synclinal of Coös staurolite schists in Granby, which is supposed to be the continuation of the Connecticut River range of this formation, though on the west flank of the underlying Huronian. It is connected with the main Coös group in the north part of the Coös and Essex district, which is entirely on the same side of the lower group. In the west part of Granby the Montalban series reappear, with an easterly dip. This is supposed to be the repetition of the White Mountain rocks beneath the Huronian and Coös series, and it may underlie the granites of East Haven and Willoughby mountain.

The space between the two granite masses just referred to is occupied by the Calciferous mica schist, with a monoclinal easterly dip, most likely a synclinal fold. A well-defined synclinal structure can be made out in the same rock in Brownington and Barton, which corresponds to the behavior of the same formation for the first thirty miles of its occurrence in Quebec. (See Plate VI.) The clay slate and Helderberg limestone farther west hold the same position with the corresponding groups on Lake Memphremagog, at Owl's Head. Logan thinks they occupy a long, narrow, inverted synclinal trough at Owl's Head, which is apparently the correct theory of their position.

We come next to the beginning of the great development of Huronian, or the metamorphic Quebec group, as designated by Logan. There seem to be first an anticlinal and then a synclinal axis, before reaching the Green Mountain older ridge. Beds of serpentine and steatite appear in Troy. and they dip towards each other, according to the Vermont report. The anticlinal altitude of the Green Mountain range is agreed upon by all observers, though Logan thinks it subordinate to a basin, and that the whole mass of the mountain is newer than the serpentines. Inasmuch as ten out of fourteen sections across this range, according to the Vermont report, have the ridge structure, while the others may be interpreted easily as folded axes, it seems more likely that the Green Mountain gneiss is of the same age with the Montalban series, which it resembles, and that both underlie the adjacent serpentinous rocks, or the Huronian.

The remainder of the section is copied from Logan's representations in the Canada reports. After the first basin there succeed the Stanbridge anticlinal and the Farnham synclinal, before we come to the great fault between the older metamorphic schists and the unaltered Trenton, Utica, and Lorraine * formations of the St. Lawrence valley. There are numerous minute corrugations in the Huronian strata, to the north-west of the gneissic axis. After passing the Huronian, the type of formation is that of the St. Lawrence valley, in distinction from that of the more elevated Atlantic region.

Upon St. Helen's island, in the St. Lawrence, opposite Montreal, is a deposit of Upper Helderberg rocks. The Trenton has been cut on Mt. Royal by a powerful dike of dolerite, which rises back of the city of Montreal in a picturesque manner. To the north-west of this hill appear in order the Trenton, La Motte, and Chazy limestones, the Calciferous sandrock, and the Potsdam sandstone, all lying nearly horizontally, with slight synclinal and anticlinal curves. The last rock on the section is the Labrador system, cropping out in the best known region of its distribution. It probably extends a considerable distance beneath the fossiliferous limestones, and has been much crumpled by lateral forces, being occasionlly inverted.

Section III. From Mt. Desert Island, Me., to Bourg Louis, P. Q.

This section is 220 miles long, and is represented upon Plate IV. The first part is mostly derived from a section from Mt. Desert island to the Canada line, published by myself in the second annual report upon the geology of Maine, in 1862. The other portion is compiled as well as may be from the Canada reports.

The first rock is a sandstone, at Bar harbor, dipping at an angle of twelve degrees. Ripple marks cover the surface of many layers, and curious cylindrical stems tantalize us by their resemblance to fossils. The formation is probably of Cambrian age. The principal part of the island is composed of protogene, with seams resembling strata. Upon the summit of Green mountain these planes dip 60° N. W. At Eagle pond they stand vertically. The first unmistakable strata appear at the north end of the island, consisting of common and talcose gneisses, dipping from 30° to 45° south-easterly and towards Green mountain. The rocks bear a little resemblance to the Bethlehem group of New Hampshire. The water of Frenchman's bay, and a considerable sand in the south part of Trenton, obscure the junction between the gneiss and micaceous schists of Huronian aspect. The dips are at first north-westerly, and south-easterly after passing Ellsworth village. A calculation of the thickness of the strata, upon both sides of the basin, shows them to be 13,000 feet in amount.

Next there succeeds eleven miles' breadth of porphyritic granite. My impression is that the crystals in this granite are larger than is common in New Hampshire, and that their larger axes are not arranged in parallel lines. This band is part of the immensely

* The names of Lorraine and La Motte on the section are used instead of Hudson river and Black river, because the latter do not stand the needful tests of appropriate definition, or of early suggestion. The true Hudson River rocks are now shown to be much older than the place of these shales, as advocated by Prof. Emmons many years since. It is proper, then, as the view so long upheld by Emmons, in opposition to most geologists, has finally been vindicated, that his name of Lorraine should be used when speaking of the slates above the Utica. La Motte limestone or marble was proposed by C. B. Adams, prior to the use of Black river, in the New York reports. The marble is also much thicker in Isle La Motte in Vermont, than along Black river in New York.

long stretch of granite extending from the Bay of Chaleur to St. George, Me., if not beneath the ocean to New Bedford, Mass.

West of the granite there is a considerable quartzite, dipping south-easterly, and then in the opposite direction, forming an anticlinal. Following it is an immense stretch of micaceous schists, showing at least two well marked axes, the first in Kenduskeag, the second in Charlestown. I have been informed that there are smaller subordinate folds along this line not here represented.

A broad band of clay slate succeeds the schists, and shows three axes, the first and most marked being at the crossing of Piscataquis river. The rock is uniformly a clean, soft clay slate, with very few dissimilar strata. A multitude of slate quarries are located upon this band, furnishing the best quality of roofing shingles obtained in any part of the country. There is a narrow band of a pretty conglomerate marking the eastern edge of this formation. The last axis in the slate is on the south-west side of Moosehead lake, near Greenville. Following the lake border, we find a considerable mass of sienite. Squam mountain is mainly composed of slates, with corals on its southern slope, as reported by J. T. Hodge. As far as to the hill opposite Mt. Kineo, the rocks appear to be slaty, and the whole series is probably Silurian, and of more modern date than the clay slates recently passed over. But scarcely anything is known of them. Mt. Kineo is composed of a compact felsite or siliceous slate, whose structure it is not easy to determine. Viewed from the east it presents some resemblance to a crushed anticlinal, and, as this structure is in accordance with the best suggestions possible as to its age, we may accept it for the present as correct. The formation may be Huronian, lying beneath the fossiliferous members on both sides of it.

The rocks on Moosehead lake, beyond the felsite, are better understood, as they contain, first, the peculiar fucoid of the Cauda-galli grit, and then marine forms characteristic of the Oriskany sandstone. Our observations would give an anticlinal structure to this formation, which differs from that ascertained to characterize the same band at Parlin pond. The occurrence of this well-established fossiliferous horizon in the midst of the crystalline schists is of great importance, since it enables us to say decidedly that the two classes of rocks are not interstratified with each other, and that therefore the latter are older than Paleozoic.* Beyond the lake, on the west branch of the Penobscot, the rock verges into a slate, whose cleavage planes may obscure the stratification. While these dip at an angle of 60°–70° north-westerly, it is very likely the strata dip only 10° or 12° in the same direction. It is not impossible that these slates represent a different formation, the same which occurs farther on. First, however, our line passes over a few miles' width of the Huronian mica schists, with three or more axes. The slates display, as a whole, the synclinal form, with a small anticlinal in the centre, at Lead-better falls. Other minor or local foldings were observed in them. The formation may correspond with the Upper Silurian slates or Gaspé series of Quebec, as well as with the same range at the Moose River settlement on the Canada

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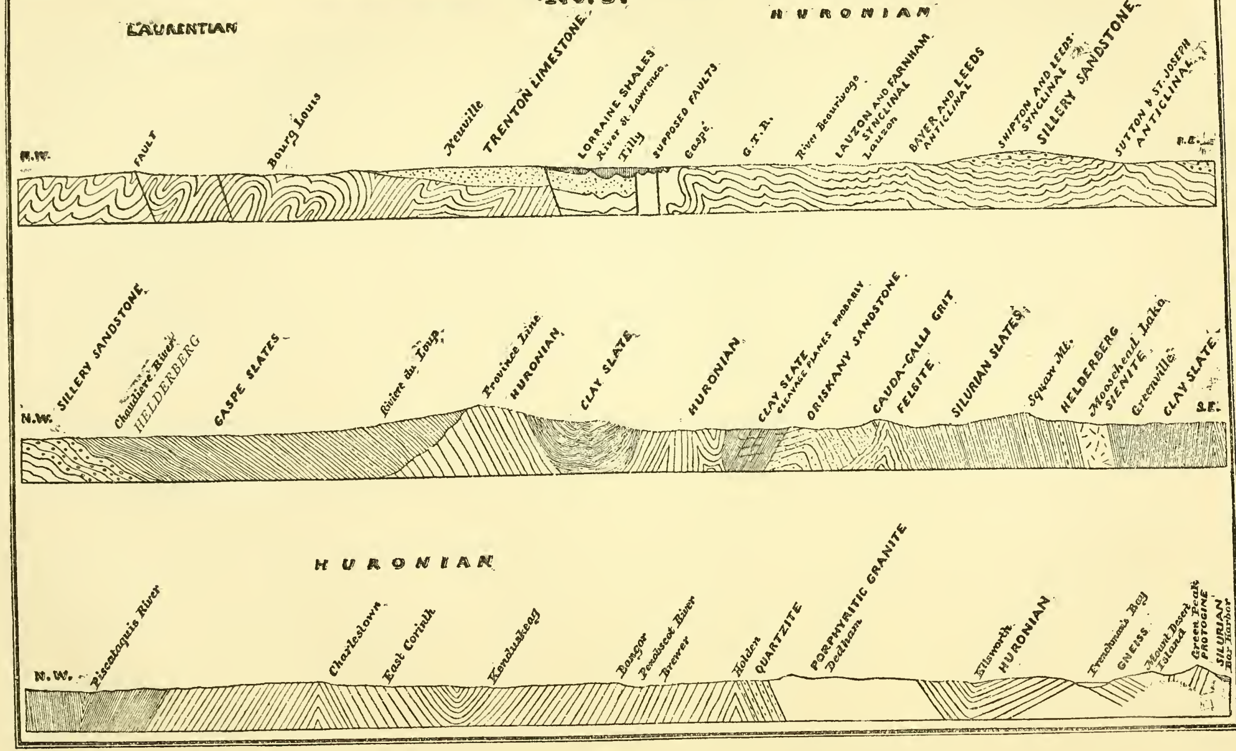
* See paper on geology of the north-west part of Maine. *Proc. Amer. Ass. Adv. Sci.*, 1873, p. 163.

PLATE IV.

SECTION FROM BOURG LOUIS, P.Q., TO MOUNT DESERT ISLAND, ME.

No. 3.



road. In Township No. 4, R. 18, the hydro-mica schists reappear, and form a high ridge, through which the west branch has excavated a deep gorge. The same rock is supposed to continue across the highland boundary between Maine and Quebec into the valley of the Du Loup river, one of the tributaries of the Chaudière.

The first formation in Canada consists of fine and coarse micaceous clay slates, with gray micaceo-argillaceous sandstones, weathering greenish in the air, and turning reddish when exposed to running water. They are supposed to be Huronian. Next succeed the Gaspé slates. The rocks resemble those just described, consisting chiefly of gray sandstones, approaching a coarse mica slate. These sandstones are interstratified with calcareous beds, too siliceous to be used for the manufacture of lime, and crop out along the lower three miles of the course of the Rivière du Loup. They commonly dip 62° S. 37° E. These beds resemble the Calciferous mica schist of Vermont.

The section next crosses a band of fossiliferous Helderberg, having the same position as the preceding formation. The best localities are on the Touffe des Pins and Famine rivers. This would naturally occupy the place of a synclinal in the Gaspé series; and consequently the rocks which follow, extending as far as the parish of St. Francis, a few miles above the Guillaume river, are repetitions of those adjacent to the Helderberg on the south-east. As they all dip south-easterly, those nearest Maine must have been inverted.

The section now runs parallel to the Chaudière river, and, after reaching St. Etienne, follows Section No. 9 of the maps and sections published by Sir William E. Logan to illustrate the report of progress of the geological survey of Canada, from its commencement to 1863. The formation succeeding the Gaspé slates is referred in the Canadian report to the Quebec group of the Lower Silurian, but it is the same with what is called Huronian elsewhere upon this section. The first outcrop is the north-easterly continuation of the ridge from Memphremagog lake towards Sherbrooke. This is followed by the Sutton and St. Joseph anticlinal. The width of the Shipton and Leeds synclinal is about fifteen miles. Magnesian limestones, quite crystalline, occur on both sides of the basin, interstratified with chloritic slates, specular, and hydro-mica schists, epidotic rocks, and red slates. Extensive beds of copper sulphuret are connected with these schists. The upper part of the basin is referred to the Sillery sandstone. The next axis, called the Bayer and Stanbridge anticlinal, is situated in the edge of Lauzon, underlying the Lauzon and Farnham synclinal. The rocks are like those just described; and both these synclinals are represented to be very complex. In Gaspé there is another anticlinal, and the upper division of the Quebec group soon follows. In Tilly occurs the great fault separating the Huronian strata on the east from the fossiliferous formations bordering the St. Lawrence river. The Huronian rocks are apparently above the newer formations, there being an overturn. The formation coming to the surface, and underlying the St. Lawrence river, is the Lorraine group. Following this are the inferior members of the Lower Silurian, resting upon the upturned edges of the Laurentian. These ancient strata are overturned, dipping north-westerly to the end of the section in Bourg Louis.

The Problem to be Solved.

With the preceding general statements in mind, it will be proper now to hasten to the special task before us of unravelling the tangled stratigraphical structure of the New Hampshire formations. That the Atlantic gneisses differ radically in lithological features from the Adirondack schists, is universally admitted; that they differ more markedly from the Paleozoic groups of the St. Lawrence and Champlain valleys will be obvious after detailed comparisons. That there are lithological resemblances between the porphyritic gneiss and hydro-mica schists of New Hampshire, with portions of the typical Laurentian gneiss and the Huronian rocks, every one will admit, and, if the order of their succession in our field of labor agrees with that in the states and provinces adjacent to us, where the structure has been determined, we shall be justified in believing what is suggested by the similarities in mineral composition. The satisfactory reference of our formations to those elsewhere described, or else the establishment of a new series of groups, is the problem before us to be solved. We propose now to describe the rocks in detail, taking in order each of the topographical districts into which our territory may be naturally divided, as stated in Volume I, page 171, beginning with the most northern, and proceeding southerly. After the presentation of all the facts, we shall be better prepared to discuss the correspondences between our formations and those adjacent to us. Though the field may now seem full of perplexity and confusion, we shall undoubtedly discover the clue to complete order, and be surprised at the simplicity of the conception which has determined the building up of our stratigraphical column.

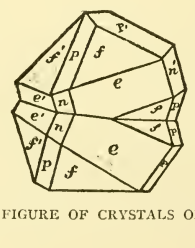


Fig. 2.—Teschemacher's figure of crystals of tin ore from Jackson.

CHAPTER II.

GEOLOGY OF THE COÖS AND ESSEX TOPOGRAPHICAL DISTRICT.

BY J. H. HUNTINGTON.

Introduction.

The geology of the country here noted embraces the northern part of New Hampshire as far south as the White Mountain region, and we have also included parts of Canada and Vermont that are adjacent.

The topography of this section has been briefly sketched in Part I, Chapter VIII, of this report.

We have described the rocks as belonging to certain groups,—the Coös, Huronian, and Montalban.

As there are the same general reasons for assigning the rocks in this section to these groups as for placing similar rocks elsewhere in the state in them, to show the reason why they are so placed would be only a repetition of what has been said; for we see no reason, with our present knowledge, for disagreeing with the general conclusions reached by the state geologist. So far as tracing the boundaries between the different groups is concerned, and making minor subdivisions, the writer is alone responsible.

The general scheme of this report is as follows:

(1) There is given a general outline of each of the groups, with their geographical limits.

(2) We have given the locality where the rocks have been examined and specimens have been obtained, with the dip of the strata.

(3) There will be found a catalogue of the specimens, as arranged in the state museum at the New Hampshire College of Agriculture and the Mechanic Arts.

By this arrangement, a person who desires only a general knowledge of the geology of this section, can obtain that from the outline. A study of the dips will give a person more interested an insight into the stratigraphical relations of the rocks, while a study of these, in connection with the specimens in the cabinet, will enable a person to obtain in a short time a knowledge of the geology of New Hampshire that would require years of study in the field. The names of the rocks that are given are for the most part provisional, as they have been named from their most obvious physical properties, without the aid of the microscope. Where the names of individuals are referred to, they are those found on the county map. Since the inhabitants are constantly changing, the county maps will enable a person at any time, though many years hence, who desires to find the exact locality of specimens, to find them at once, without a long and tedious inquiry.

An article on the drift and the economic geology of this section will be found in a subsequent chapter.

Coös Group.

IN the western part of New Hampshire there is quite a large area where the rocks consist of wrinkled, argillaceous schists, clay slates, and corrugated gray micaceous sandstones. These rocks are, however, more extensively developed in the north-western portion of the state. Both the schists and the sandstones contain small cavities filled with ochrey yellow powder, and frequently there are calcareo-argillaceous bands, with harsh, arenaceous schists, and occasionally siliceous limestone, which weathers to a dark, reddish brown. The area of this rock in New Hampshire is but a very small part of its entire area, in its extension north-west in Vermont and north-east into Canada. This rock is extensively developed in Vermont, east of the Green Mountains, especially in the central part of the state, but southward it becomes a narrow band. Its lithological characteristics were noticed by Prof. C. B. Adams, in his preliminary report of the geology of Vermont, and its geographical limits were by him defined, but he made no attempt to determine its stratigraphical relations. These rocks, in their extension into Canada, have been studied especially by Sir W. E. Logan and Mr. James Richardson, and they seem to form a continuous series from the province line, east of Lake Memphremagog, to the Bay of Chaleur. In the report of progress of the geological survey of Canada for the year 1849–50, these rocks were referred to the Upper Silurian. In the report of 1863 they are described as a part of the Gaspé series, the sandstone of which was supposed to be chiefly Devonian. In the report of progress for 1866–69, Mr. James Richardson describes the rocks in the area between the Chaudière and the Temiscouata road, the boundary on the north-west being the St. Lawrence, and on the south-east the province line. At St. Denis he finds fossils of the lower division of the Potsdam. This corresponds to the Georgia group of Vermont. Then follows what he regards as the middle and upper division of the Potsdam; then there is a fault, south of which he finds the Sillery sandstone; and then, south of what he makes an anticlinal, follow, resting on these metamorphic Quebec rocks, the slates so well developed in the Chaudière from St. Francis to Lake Megantic. These last, according to Richardson, overlie the Lauzon.

The metamorphic Quebec rock of Logan, now recognized as Huronian, occurs in New Hampshire east of the rocks just mentioned, except that there intervene bands of schist and gneiss containing andalusite and staurolite, which may be more recent. These Huronian rocks, as they occur in New Hampshire, may be described as follows: Green chloritic rocks, in which the lines of stratification are obscure. These often contain scales of chlorite. Variable greenish feldspathic sandstones, with intercalated bands of siliceous limestone. In these sandstones there are sometimes developed large crystals of feldspar, and elsewhere they contain an abundance of hornblende, and frequently epidote, argillaceous quartzite, green chloritic schists, stratified diorites, serpentine, and sometimes soapstone. The rocks immediately underlying the Calciferous mica schists, which contain staurolite, andalusite, and allied minerals, we regard as a part of the Coös group. Looking over the large area occupied by both groups of rocks just described, we find that, overlying these and occupying beds in this rock, there are several small areas of fossiliferous rock, which are generally referred to the Lower Helderberg. Beginning on the south, we have the fossiliferous band at Bernardston, Mass., with its immense crinoid stems; and, going north, at Littleton, N. H., we have a limestone, with brachiopods, corals, crinoid stems, etc. At Lake Memphremagog, on the border of the Calciferous, we have a similar band, and at Dudswell, on Famine river, and other localities in Quebec province, we find fossils of a similar character. In Flagstaff, Me., there is Helderberg limestone, associated with rocks very similar to those found at Littleton, N. H. Sir Wm. E. Logan regarded the Calciferous mica schist as Upper Silurian, from the fact that the fossiliferous bands were so associated with it that these metamorphic rocks seemed to be only altered strata. But we have in New Hampshire and Maine fossiliferous rocks of Lower Helderberg, resting on or associated with rocks which he referred to the metamorphic Quebec group.

We now give in detail the lithological characteristics of the rocks of the Coös group, and its geographical limits in northern New Hampshire.

If we draw a line from a point on the boundary, two and a half miles east of Third lake, and have it run nearly parallel with Perry stream, continuing it south, it will cross the east end of Back lake, will pass half a mile west of D. Blanchard's, and cross the road running along the Connecticut near the house formerly owned by T. Blanchard. Extending it south through Clarksville, it will cross the Dead Water stream a mile east of the terminus of the road that runs east through the town, then, bending a little to the east, it passes half a mile east of Alden Fletcher's in Stewartstown, thence southward to J. Young's, near Bear rock, thence directly south across Colebrook and Columbia, almost to Sims stream, then, turning nearly at a right angle, it extends to the Connecticut. We have the eastern boundary of the Coös group in the towns through which the line is run. An extension of the line northward into Quebec province would cross the north end of Lake Megantic. Near the mouth of Sims stream it seems to have been crowded out by the sienite. Before following the line where this group comes up south of the sienite, we shall describe the rocks included in the northern section. They consist for the most part of argillaceous schists. In places, and perhaps more commonly near the eastern border, the strata are so wrinkled and corrugated that it is often difficult to determine the dip. In many places, interstratified with the wrinkled masses, are strata in which the laminæ are thicker, and, when separated, present a smooth surface. This has almost invariably small cavities disseminated through it, which are filled with a brown powder, resulting, probably, from the decomposition of a lime mineral, containing protoxide of iron: the lime being removed, the iron would be converted into a peroxide, whence the brown color. This brown powder is so abundant that it sometimes gives a coloring to the whole rock. While more abundant in the rocks that have a regular cleavage, yet sometimes the cavities are scattered through the wrinkled varieties. In some cases the schist that has an even cleavage contains an abundance of iron pyrites, the cubes being half an inch or more in diameter. A remarkable locality is on the east branch of Indian stream, about nine miles north-west of Connecticut lake. On the northern border of the Colebrook Academy grant the rock is more fissile, and approaches nearer to a common black slate than it does elsewhere, but it contains the cavities just described, everywhere disseminated through it. Two miles north-west from the mouth of the west branch of Indian stream the rock becomes more micaceous, and the thin, wrinkled laminæ are wanting, but, what is more important, the dip changes. It is possible, however, that it is only a fault. Northward, in Quebec province, we find both classes of rocks just mentioned, and both have the same dip. The line where the dip changes runs through the east part of Newport. On the branches of Indian stream, three and a half and four miles from the boundary, gold has been found to some extent, but it will be alluded to more fully when we describe the drift. The rock here is the same as that at Ditton, where gold has been so successfully washed. The rocks of this group, which we have thus far noticed, had to be studied for the most part while we were traversing a dense forest; but, going south, we come to the settled portion of Pittsburg. At Mrs. Tabor's, on Indian stream, just east of the house where a few years ago a hurricane swept away the forest, there is a fine exposure of the wrinkled schist. On Hall's stream, just above the line, there is another outcrop of the same rock, and, being near the road, it is more accessible. This rock extends south, and it is the principal rock in the settled portion of Clarksville. The more compact is everywhere interstratified with that which is wrinkled and corrugated. There is an extensive area of the compact schist just east of the road through Clarksville, a mile south of the bridge that crosses the Connecticut. After passing the height of land in Clarksville, going south, the rock becomes more calcareous, and is identical with the formation which, in the report of the Vermont geological survey, is called Calciferous mica schist, but it lacks for the most part the siliceous limestone, which is an accompaniment of that rock in Vermont, except in two or three cases, which will be noticed. It differs from the rock north along Indian stream in no respect lithologically, except in the greater abundance of lime. Under the bridge that crosses the Connecticut at West Stewartstown there is a siliceous limestone in which there is a large per cent. of lime, while on the hill east we find the wrinkled schists. On the road just below the county farm the rock is almost as fissile as slate, and on it are drift striæ which are remarkably distinct. On Piper hill there is a broad band of compact schist, containing cavities filled with a yellowish brown powder. The same rock southward outcrops on Sargeant hill. Passing into the valley east, at the saw-mill on Bishop's brook, we have a good exposure of the schist containing lime as an incrustation. On account of the fragile nature of the rock and the lime incrustation, this schist everywhere readily decomposes. Although the ledges are often near the surface, it is seldom that they are seen except along the streams, and then frequently the harder portions are mingled with those that are partially decomposed. This is particularly noticeable in the vicinity of J. Poor's, but in many places elsewhere in Stewartstown it can be seen. North of J. Poor's we found in the fragments of the schist the mineral ankerite, also galenite. On the farm of Mr. A. Fletcher we found the ankerite in a ledge; and possibly a few blasts might develop galenite. As this calciferous rock so readily decomposes, it is constantly supplying the lime that is necessary to produce a fertile soil; hence, also, the scarcity of boulders in the towns where this rock is found. A fine example of the wrinkled schist, interstratified with the more compact varieties, can be seen near J. M. Kidder's. The east part of Stewartstown, as well as Clarksville, is still covered by the primeval forests; yet there are probably very few places in any state that are more inviting, on account of the fertility of the soil, than is this section of New Hampshire.

Colebrook, except a small area in the south-west corner of the town, and a strip on the east side, is composed of the schist containing lime. The high hills north-east from Colebrook village, and extending east along the Mohawk, are characteristic of this group of rocks. On Beaver brook, at the falls, we find siliceous limestone, which is found so abundant in this group in Vermont. The argillaceous schists, with which the calciferous strata are interstratified, extend south to Sims stream, and east nearly to the road running north and south through East Columbia. In the north-west corner of Columbia, fifty rods north-east from the Jude Fairnam place, there is a gray and drab colored limestone, interstratified with the schist, "the strata running north-east and south-west, and inclined to the south-east 55°. The bed is 30 feet wide, and will furnish a weak lime, since it contains only about two thirds of its weight of pure carbonate of lime. If burnt very carefully, it slacks with difficulty into a granular mass, but if the heat is raised to whiteness, it melts into a slag or glass, owing to the formation of silicate of lime."* The extensive deposit of marl in Lime pond will be noticed under alluvial deposits.

Along the Connecticut, south of Sims stream, there is a small area of this group of rock. It begins in a point one fourth of a mile south of the stream. The outcrop of the rocks can be seen from the road, and where it begins the strata seem to have been pushed to the west, as the strike will readily be seen to run in a different direction from what it does a few rods south. The area increases in width as we go southward, until it is about two miles wide; then it becomes narrower, and, in the south part of the town, it is not far from one mile. The rocks are micaceous and argillaceous schists and siliceous limestone. Near Mrs. Ross's the limestone is noticeable from the road, on account of its dark color, as, in weathering, the lime is removed, and only the siliceous portion of the rock is left.

In the north-east part of Pittsburg, in the area between the Connecticut and the Magalloway, there is a band of the Coös group. These rocks form the water-shed between the head waters of these streams; and it is a very noticeable fact, that these Coös rocks here form a synclinal axis, and both on the east and west we have Huronian rocks, which here consist of greenish siliceous schists with epidotic nodules.

In Vermont, opposite Columbia, the Coös group is developed. It extends southward, and probably terminates near the south line of Bloomfield. Northward, it outcrops in Canaan, and extends west to Little Averill pond, where it is interrupted by an intrusive granite, but it appears again in Holland, whence it extends southward through Vermont. An interesting area of this group is found in the south-east part of East Haven, and it outcrops again in the vicinity of the church in Granby. In both these localities it forms beds in the older rocks.

Where Specimens were Collected, and the Dip of the Strata.

At the north end of Lake Megantic, in Quebec province, the strata, both of the Coös and Huronian groups, stand nearly vertical. The rocks

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* Jackson's final Report, p. 106.

of the Coös group here are mostly yellowish ochrey sandstones, that frequently contain crystals of pyrite. With the sandstone there are bands of a fissile argillaceous schist, in places not distinguishable from common black slate. On the border of New Hampshire, in Ditton, the rock is an ochrey argillaceous schist; and at the gold mines the strata dip S. 44° E. 70°. In R 4 L 20 the rock is a mica schist, and dips N. 26° W. 68°. Going west to Newport, the rocks become decidedly calciferous. In R 12 L 19 the mica schist dips N. 22° W. 65°. Between the church and North river bands of slate are interstratified with bands of calciferous mica schist, that dip N. 21° W. 72°. There are numerous outcrops of the same rocks, in the vicinity of East Clifton, that dip N. 41° W. 64°. In the south part of Clifton, in the vicinity of Charles Sawyer's, the rocks are less micaceous and more fissile. In Hereford, a mile north of J. Lambert's, the rock is an argillaceous schist, and it dips S. 36° W. 43°. In the south part of Hereford, near Hall's stream, there is a corrugated and wrinkled argillaceous schist. At one point it dips N. 66° E. 80°, and, a few rods distant, it dips in the opposite direction. Along the lower part of Hall's stream this rock is everywhere nearly vertical. In Auckland, half a mile north of the west branch of Hall's stream, the argillaceous schist dips N. 18° W. 65°. On the boundary, at the head of Hall's stream, the rock is an arenaceous clay slate, and dips N. 46° W. 65°. On Hall's stream, opposite the west branch, an argillaceous schist dips N. 22° W. 74°. Crossing over from Hall's stream to the west branch of Indian stream, the rocks have a dip quite uniform, which is N. 36° W. from 70° to 80°; and the difference in texture is slight, everywhere an argillaceous schist, in places more fissile than in others, and occasionally containing an ochrey powder. The same rock, with a dip N. 36° W. 78°, was seen two miles up the west branch of Indian stream. Between Hall's and Indian streams, on an old "tote"-road from Pauquetteville in Hereford to M. K. Day's, the rocks are as follows: Half a mile east of Hall's stream there is an argillaceous schist; the strata stand nearly vertical, sometimes having an easterly and then a westerly dip. A mile from Hall's stream the rock is an ochrey argillaceous schist, and dips N. 62° E. 65°. Between this and Day's the rocks are argillaceous, but frequently contain some mica; and, everywhere they were examined, the inclination of the strata was nearly uniform with the last. In the Colebrook Academy grant, north of this, numerous observations were taken; but, as a section giving the rocks in detail across the grant will be described, these observations are omitted. It will be noticed that the dip of the rocks, in the country between Hall's and Indian streams, is almost uniformly to the west. This seems to be due to a fault.

Between Indian and Perry Streams.

On some of the most northern branches of Indian stream, where gold has been obtained by washing, the rock is an argillaceous schist, that is sometimes ochrey. The dip, three and a half miles north of the east branch, is S. 34° E. 70°; two miles north, S. 18° E. 75°. On the east branch, about a mile from where it flows into Indian stream, the rock is an argillaceous schist; but interstratified with it are bands of a hard micaceous schist, which dips S. 22° E. 80°. On the old "tote"-road, from the forks of Indian stream to Connecticut lake, a little more than a mile from the forks, the rock is an ochrey argillaceous schist, some of the strata showing lime incrustations. The general dip is N. 54° E. 75°. Toward Perry stream the schists are micaceous, and the dip, three fourths of a mile west of this stream, is N. 68° E. 70°. These rocks extend southward; and, near M. K. Day's, a wrinkled argillaceous schist dips N. 50° E. 73°. North of Bowen pond, and west of H. H. Johnson's, there is an argillaceous mica schist. The strata are bent in many places, but the general dip is N. 88° E., and the inclination is exceedingly variable. Almost directly south, near H. B. Schoff's, the rocks are decidedly arenaceous, and have the character of the hard bands that are interstratified with the Calciferous mica schist; the dip is S. 44° E. 65°. These hard bands extend southward, and outcrop on the road from Indian to Hall's stream. In the extreme northern part of Pittsburg, and directly east of Third lake, there is a small area of the Coös group, that appears to form a synclinal axis in the Huronian. At one point, half a mile from the lake, the dip is S. 34° E., variable, and in places the rocks are so bent and contorted as to suggest that this basin of newer rocks has been compressed by the older and harder surrounding Huronian.

These are the chief outcrops of the Coös group in Pittsburg; but there are still two outcrops in the south part of the town that deserve notice. Between the church and the road, going north to D. Blanchard's, the rocks resemble more the Calciferous than those found elsewhere in the town, and they dip S. 54° E. 75°, though the dip is by no means uniform. The other outcrop is just west of Mrs. E. B. Tabor's, where the rock is a wrinkled argillaceous schist, and the strike is N. 41° E. The bent strata sometimes make the dip quite uncertain. This wrinkled argillaceous rock outcrops in Hereford just north of the Vermont line, where it has both an easterly and westerly dip, and it crosses over into Stewartstown at the mouth of Hall's stream. Near the village of West Stewartstown, on the south-east, the argillaceous schist dips N. 88° E. 80°, and, a mile east of the village on the road south of the Connecticut, the same rock outcrops, but more wrinkled than at the village, and dips N. 65° E. 80°. This rock, with the exception of quartz, retains the drift striæ better than any other in the state.

Coös Group in Clarksville.

On the road that runs south through the town, from the Connecticut nearly to the height of land, the rocks are decidedly arenaceous, and have an easterly dip. Near the eastern limit of the Coös, in the vicinity of W. W. Chamberlain's, the rock is a wrinkled argillaceous schist, and dips S. 41° E. 75°. The strata being so nearly vertical, and the rock so similar to that at West Stewartstown, and the intervening rock so decidedly a calciferous mica schist, it suggests very strongly the idea of a synclinal axis. At J. Gethercole's the rock is a calciferous mica schist, and dips S. 40° E. At G. Tirrell's, very near the house, the rock is an argillaceous mica schist, and dips N. 66° E. 82°; but north of this there is an intrusive diorite. The dip of the rocks elsewhere will be given on the section passing through the town.

Stewartstown.

North-west of a line drawn from near the mouth of Bishop's brook, to a point on the Connecticut just south of C. L. Morse's, the rock is a wrinkled argillaceous schist. The central part of the town is a calciferous mica schist. On the west side of Piper hill the rock is an ochrey mica schist, and it has an easterly dip; but here, as southward on the road towards Colebrook, the strata are quite irregular. On Sargent hill the calciferous mica schist, with hard, compact arenaceous bands, dips S. 58° E. 68°. At a saw-mill, a little north of west from the "Hollow," the rock is a calciferous mica schist. Directly north, at J. Poor's, the lime, as an incrustation on the schist, is very abundant. Fragments of quartz in the soil are also very abundant, and these sometimes contain galena. Near M. Fletcher's the rock dips S. 56° E. 62°. The characteristic calciferous mica schist continues east nearly to M. Harriman's, where it becomes somewhat arenaceous, and dips S. 51° E. 64°. At A. Fletcher's, which is farther east and on the confines of the forest, we find argillaceous bands, with argillaceous mica schist that dips N. 82° E. 70°. This is near the eastern limit of the Coös group. South, at J. M. Kidder's, the argillaceous schist resembles that east of Dead Water in Clarksville; here it dips S. 44° E. 80°. At J. Young's the rock is argillaceous and fissile. The calciferous mica schist outcrops on the road from Bear rock to South hill, and dips S. 46° E. 75°.

Colebrook.

The principal rock of the town is calciferous mica schist. On the road up Beaver brook, near J. E. Stevens's, the dip is S. 54° E. 60°. At the Falls there is a band of siliceous limestone. At D. Heath's there are numerous outcrops of calciferous mica schist. North-east of Factory Village the calciferous mica schist dips S. 50° E. 78°.

Huronian Group.

East of the line limiting the Coös group, in the northern part of the state, there are two prominent bands of rocks that belong to the Huronian. The first is confined chiefly to this section, and consists of stratified diorites, diabase, hornblende rocks, greenish schists, containing nodules of epidote, arenaceous and chloritic schists. This band of rocks begins, on the south, in Columbia, and extends northward until it passes out of the state near Third lake. Where this group of rocks begins in Columbia the green schists predominate, but in Colebrook, just west of H. Gould's, the diorite begins, and northward it is accompanied either by the green or the arenaceous schists. The most prominent rock of this group is the diorite. In many places it appears to be a massive rock, without any marks of stratification, but elsewhere it is plainly stratified, and interstratified with it is a whetstone grit or arenaceous sandstone schist. It forms the ridge in Colebrook known as Bear rock. In Stewartstown it can be seen half a mile east of Alden Fletcher's. In Clarksville it outcrops a mile west of J. Gethercole's. In Pittsburg it forms a prominent ridge on the east of the rock, where it leaves the Connecticut river and turns northward. From this point to Connecticut lake the outcrops are frequent, also along the road north of the lake, and it forms the high hill west of Round pond. Going north there are numerous outcrops along the old "tote"-road to Third lake, and north of this lake it is the principal rock of one of the high points on the boundary. It is a dark gray rock, often has a greenish tinge, and, in some specimens, the hornblende is quite distinct. It is extremely hard, as every one who has attempted to work it will testify. In some localities it decomposes by the action of the atmosphere, probably on account of the presence of lime, for in some places it contains a sufficient amount of lime to effervesce when acid is applied. In no part of New Hampshire is there better pasturage than where this is the prevailing rock; but frequently, on account of the great number of boulders, the land is not desirable for tillage. The following analysis by Prof. Seely, though probably imperfect, shows the chief constituents of this rock:

Silica,	49.51
Protoxide of iron,	21.42
Alumina,	14.88
Lime,	8.52
Magnesia,	4.86
	99.19

This rock forms nearly all the boulders of Pittsburg east of its outcrop, and they have been carried far to the south-east, one having been seen east of the Magalloway. It contains very few veins, and those seen were of vitreous quartz.

The green schist does not seem to be continuous, but where it does not outcrop it may be concealed by drift. It is a prominent rock in the south part of Columbia, just east of a starch mill on Sims stream. In Colebrook it outcrops on the road west of Young's mill, then on the road near C. F. Hardy's. In Pittsburg it is a common rock, and it comes in contact with the argillaceous schist on the road along the Connecticut, just before the road turns north. It is the rock of the east end of Connecticut lake, and it can be seen on the two small islands of that lake, as well as on the adjacent shore. On the farm north of the lake, formerly owned by E. Day, ledges of this rock are very prominent, and it contains numerous nodular masses of epidote, and, not unfrequently, there is lime associated with the epidote. North of Second lake there is a considerable area occupied by it.

The whetstone grit in the south is first seen north-west of Bear rock, near T. Paul's. Although the cleavage of this rock is not such that it can be easily wrought for scythe-stones, yet, on account of its excellent grit, farmers sometimes get them here, as also in the vicinity of Connecticut lake. Along the line of the diorite the whetstone grit frequently outcrops. In Clarksville it is a common rock in the woods east of the settlements. In Pittsburg, on the farm formerly owned by J. P. Quimby, this schist is interstratified with the hornblende rock; and in the forests south-east of J. T. Arny's there are several ridges where this is the underlying rock, and some of the outcrops present a surface of twenty or thirty feet, nearly perpendicular. West of Connecticut lake, for a mile, there are several places where there are ledges. Often the drift striæ are remarkably distinct, and many can be seen in the vicinity of the outlet of the lake. Northward, this rock appears in outcrops all the way to the boundary. There are prominent ledges of it on the west shore of Third lake, where it appears massive enough for grindstones, while northward, on the boundary, the cleavage is such that whetstones could be easily wrought.

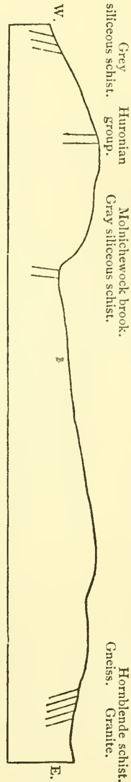
All the rocks which we have described as embraced in this belt have their strata at a very high angle, but sometimes they dip towards the east, and, again, they dip westerly. The high angle at which they dip, the disturbed strata, and the character of the rock indicate that they are older than the rocks on the west;—but this will be more fully discussed elsewhere. East of the band of rocks just described there is a large area in which are found hydro-mica schists, serpentine, diorite, quartzites, and indurated schists. These rocks are not confined to New Hampshire, but they extend northward, and constitute the metamorphic Quebec group of the Canadian geological survey. At the extreme north-east corner of the state, at Crown monument, we find a fine-grained mica schist. Two miles south-west of Crown monument there is a band of serpentine, a rock exceedingly rare in New Hampshire, but which is here found in the large basin from which flow so many streams that form the Magalloway. It is of a greenish black color, mottled with olive green. It is asbestiform where joints occur, and weathers to a reddish brown. It is undoubtedly a metamorphic rock, and probably formed from preëxisting silicates. There is also in this basin a green schist; but going south-east, the ridge that forms the water-shed between the Magalloway and Connecticut is composed of gneiss. Following this ridge southward, we come to Mt. Carmel, which is a stratified diorite; the flanks of the ridge, running north-east toward the Magalloway, are gray siliceous schists. Going south-west from the water-shed just mentioned, we pass over Stubb hill, the ridge of Bosebuck mountain, Diamond ridge, and Magalloway mountain. All of these are composed of siliceous schists. Some of these schists have the appearance of a dark quartzite, but particularly on the west, in the joints, they contain lime as an incrustation.

Lyman Group.

On the line of Maine and New Hampshire, between the heights of Mt. Carmel and Mt. Prospect, there is an axis. The rock is a gray siliceous schist, which in places approaches novaculite. Though the strata are nearly vertical, yet on Mt. Carmel the dip is northward, and on Mt. Prospect it is southward. The distance between these points is 920 rods. In consequence of the southerly dip on Mt. Prospect, we have a mountain with a precipice almost perpendicular on the north side, something exceedingly rare in New Hampshire. On Mt. Bosebuck, about the same distance south of Mt. Prospect that Mt. Carmel is north, the dip is northerly; so that Mt. Prospect, with Mt. Bosebuck, forms a syncinal axis, or there is a series of folds, and there has been an immense downthrow north of Mt. Prospect. These rocks correspond to the Lyman group, which is the upper member of the Huronian. Between Mt. Carmel and Mt. Prospect there is a deep valley, and on the Little Magalloway, that flows through it, there is a band of clay slate; while near Mt. Carmel, and forming the east end of the mountain, there is a greenish, indurated rock, probably diorite. While the strike is only a little south of east on the state line, as these rocks extend west and south, the strike becomes more southerly. On the old "tote"-road, from Connecticut lake to the Magalloway, it attains a great width; and the general strike is N. 20° E.

On Diamond ridge the rock is very much jointed. It may be the same as the rock northward, only more indurated, but as the same rock occurs on Magalloway mountain, some two and a half miles to the south, and dips in an opposite direction, this may be an island of older rocks. A small area of a gneissic rock between the two points also very strongly suggests the same thing. Almost directly south from Magalloway mountain, about two miles, on a branch of the Little Dead Diamond, there is an outcrop of clay slate, but, it is so intimately associated with the gray schist, it is quite evident that they are stratigraphically the same. The gray siliceous schist is found on the western slope of Mt. Pisgah, while to the south the slate outcrops on the branches of Cedar stream in a synclinal axis. On the water-shed between Cedar stream and the Swift Diamond there are argillaceous bands. A short distance south of this water-shed the gray siliceous schist is the only rock, but as it extends southward it changes somewhat its physical characteristics. The rock at Dixville notch differs from the gray siliceous schist northward more in its cleavage than in any other characteristic. The general features of the Notch have already been described.* The rocks here form a monoclinal axis, and the strata are nearly vertical. A peculiar cleavage causes it to split into longitudinal fragments, and leaves high vertical walls on the sides of the Notch. At one point there is a good profile, the outline of which is seen in Fig. 10. Where the schist comes in contact with the granite, on the east side of the Notch, it shows clearly the effect of pressure. This band of rocks below the Notch has a south-easterly trend. The argillaceous rock in Millsfield, east of the ponds, belongs probably to this group.

Fig. 3.—SECTION FROM THE ANDROSCOGGIN,—LINE OF CAMBRIDGE AND ERROL,—TO THE MAINE LINE SOUTH OF UMBAGOG LAKE.

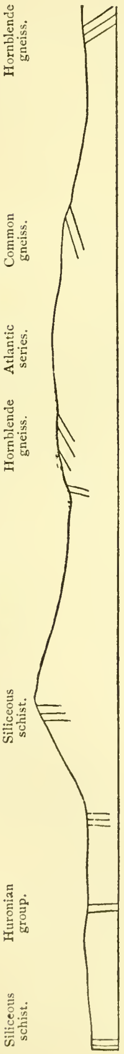


The Huronian rocks on the west, as a whole, appear to form a monoclinal axis, though the strata are nearly vertical. Between the height of land and the Molnichewock there is evidently a synclinal. On the east we have the rocks of the Montalban group, the dip of which may have been affected by the intrusive granite south of the lake.

* Vol. I, p. 641.

South-west of Millsfield ponds, within the limits of Millsfield, the rocks consist chiefly of very dark siliceous slates, while south-west of Newell brook it is followed by gray gneisses of the Montalban group. East of the Androscoggin, on the line of Errol and Cambridge, we have the light gray siliceous schist characteristic of the Huronian. In the central part of Dummer, immediately east of the Androscoggin, there is an outcrop of chlorite and siliceous schist; but west of the river, especially in the valley of the stream that flows from Dummer ponds, there are no outcrops of rock, but a mile south-west of the Dummer ponds there are many extensive outcrops of gray siliceous schist. At West Milan it is interstratified with hornblende schist. It outcrops a mile and a half south-east of West Milan, and its extension west to Stark water-station gives to the rock here a great width, but its nearly vertical state suggests that it is made up of numerous folds, as we can trace both synclinal and anticlinal axes. The western group of Huronian rocks begins near the north line of Stratford, where they consist of dark siliceous schists. Extensive outcrops are found at the head of Bog brook, along the west side of Percy peaks, on the south of Potter's pond in Stark, the east side of the Devil's slide and Mill mountain, on the east side of the hill south-east of Groveton, and between Mt. Lyon and the Pilot range. On the Connecticut, in the south part of Stratford, is the light gray siliceous schist, and this extends eastward and outcrops on Nash stream. From near the north line of Northumberland, and southward through Lancaster and terminating in the north part of Dalton, the rock consists of feldspathic chloritic schists. These frequently have hornblende and epidote as accessory minerals. In Dalton the

Fig. 4.—SECTION FROM STARK WATER-STATION, G. T. R., TO MILAN.



On the west we have the Huronian strata, standing nearly vertical; and these are followed on the east by rock of the Atlantic series probably older than the Montalban group.

Huronian rocks consist of light gray siliceous schists and clay slates; but the band of argillaceous sandstone of Dalton mountain is probably a much newer rock.

Other Huronian Rocks.

There is a band of rocks extending from the Magalloway river through the Academy grant, and occupying a large area in the Dartmouth College grant, which consists chiefly of light gray schists. It is frequently, however, of a dark gray color, and sometimes it passes into shades of olive green, and it resembles the hydro-mica schists of Vermont. Its limit on the state line north is not known, but south it extends about a mile below the north-east corner of the College grant. Near the south line of the Academy grant, and west of the Little Dead Diamond, it forms high hills and ridges, often jutting out in high overhanging cliffs. The Little Dead Diamond, in places, has worn deep channels in this rock. One of these, not far from the north line of the College grant, is from twenty to thirty feet deep, and extends nearly four hundred feet along the stream. Here the rock contains an abundance of small crystals of magnetite. It extends south in the College grant nearly to the mouth of Linnell brook. Its south-western limit has not been determined. Everywhere the strata are nearly vertical, but they are generally inclined to the west. Succeeding this rock on the south-east is a mica schist containing garnets. On Linnell brook the garnets are of a deep red color, often translucent and very abundant. On the Swift Diamond the rock is more gneissic, and contains staurolite. The crystals are half an inch thick, and from one and a half to two inches in length. On the high hills, near the Magalloway and north of the Swift Diamond, the mica schist, with garnets and staurolite, is interstratified with hornblende schist, and the strata stand nearly vertical. On Mt. Dustin the schist contains staurolite. The crystals are small, being from one to two lines thick, and three fourths of an inch in length. Eastward, extending perhaps a mile east of the College grant, we find mica schist, and southward it is found west of Wentworth pond. Between Aker's pond and the Androscoggin the outcrops of mica schist are very numerous. Between the road to Upton and Umbagog lake, particularly towards the south end of the ridge, the schist is very much contorted. West of Bragg's bay, and south of Clear stream, the rock in Errol is entirely mica schist, often containing garnets, and the strata everywhere are nearly vertical. The mica schist extends into Millsfield, but east of Millsfield ponds there is a band of schist that probably belongs to a newer group. This is perhaps half a mile in width. West of the ponds the mica schist again outcrops; and the dip varies greatly as we approach the granite in the west part of the township. The mica schist of the character just mentioned does not extend south of Millsfield in this section of the state.

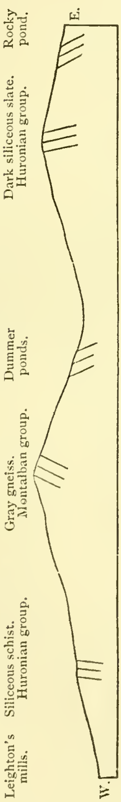


Fig. 5.—SECTION FROM LEIGHTON'S MILLS, DUMMER, TO ROCKY POND, MILLSFIELD.

The Montalban group in this section, having the characteristic rocks of the White Mountain series, forms an anticlinal axis, and the Huronian rocks dip away from it at a high angle.

Huronian in Vermont.

Directly south of North Stratford, on the west of the Connecticut, the rocks consist of dark siliceous schist, that sometimes contains crystals of a rare variety of andalusite. Through Maidstone, along the Connecticut and southward to Waterford, we find the same rock as that described as occurring in Northumberland and Lancaster. West of this rock, in Guildhall, we find the gray siliceous schists that extend southward through Lunenburg, and they terminate in Concord.

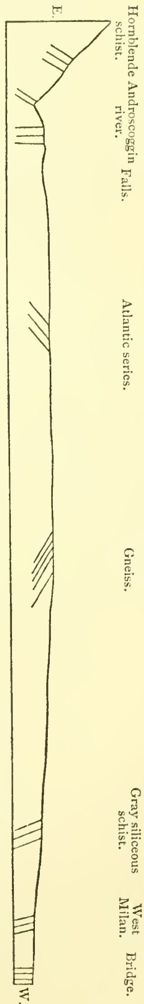
Atlantic Series.

We give here the outline of the Atlantic series. The rocks belong chiefly to the Montalban group. While these rocks are developed very extensively in New Hampshire, they occupy a very large area in Maine and a small but important area in Vermont. For the area in Maine, the reader is referred to the preceding chapter. In New Hampshire its most northern outcrop is at the southern extremity of Umbagog lake, where the rock is a gray micaceous gneiss and hornblende schist. It extends southward through the east part of Cambridge. In Success the Montalban group gradually extends eastward. Southward, the rocks in the whole area of the towns of Shelburne and Gorham, except in the north-west corner of the latter, are Montalban.

The gray micaceous gneiss of the Montalban group outcrops in Dummer, south-west of the ponds, and there is a considerable area in Odell. The relation of these rocks to those adjacent is shown in Fig. 5.

The common gneiss of Milan, which is probably an older rock than that just mentioned, has its most northern outcrop on the Androscoggin, near the north line of the town. Its eastern limit is in the extreme south-east corner of the town, and its western limit is on the Grand Trunk Railway, a mile above the Milan water-station. A dark gneiss, that sometimes contains hornblende and epidote, outcrops two miles above Milan water-station, and extends northward west of Milan hills. A similar rock outcrops at Berlin falls. The common gneiss outcrops at Jefferson hill, and it is quite probable that it forms a continuous outcrop through Berlin to Milan. There are several outcrops on the road from the Waumbek house to Lancaster, and it extends to within a mile of the village; thence it extends southerly, and sweeps around the south-east base of Mt. Pleasant. Its western limit southward in Lancaster is near Blood pond. It occupies a great part of the town of Whitefield, and the extreme east part of Dalton.

Fig 6.—SECTION FROM THE SOUTH-EAST CORNER OF BERLIN, THENCE ALONG THE G. T. R. TO THE BRIDGE WEST OF WEST MILAN.



On the east we have hornblende schist, probably Huronian; at the Androscoggin river and west, the older gneisses, and at West Milan the siliceous schists of the Huronian group.

Vermont.

The Notch mountains in Brunswick are well-marked rocks of the Montalban group. The rocks of Bluff mountain, north-west of Island pond, are probably Montalban, but they are separated from Notch mountains by an extensive area of intrusive granite. South of Notch mountains there are outcrops of the Montalban at Maidstone lake. North-east, between the Montalban and the Connecticut, there is a small area of intrusive granite, which, in lithological characteristics, corresponds to the area west of the Montalban group in the valley of the Ammonoosuc.

Where Specimens were obtained, and the Dip of the Strata.

At Crown monument the rock is an arenaceous schist, that dips S. 79° E. 76°. On the state line, a mile and a half from Crown monument, there is a greenish siliceous schist that dips S. 82° E. 65°. The rock, two and a half miles south-west of Crown monument, is serpentine, but the strata are quite obscure. Across the boundary in Chesham, in R. III, in L. 4, 6, and 7, there is an arenaceous sandstone that dips N. 70° E. 20°. This rock forms the boundary north of the lake which is the source of the west branch of the Magalloway. At Magalloway lake, which is not far from three and a half miles south-west of Crown monument, and less than half a mile from the boundary, the rock on the south side is a mica schist, that dips N. 41° E. 56°. At the outlet of the lake the dip is N. 39° E. 76°. Four rods from the outlet there is a cascade that has a fall of twenty feet. Three fourths of a mile from the lake there is a greenish mica schist, the strike of which is N. 38° E. The dip is exceedingly variable, but westerly. Passing over the Coös group, going south-west, we strike Huronian rocks in the vicinity of Third lake. On the west shore of this lake the arenaceous schist dips N. 42° E. 80°, but the stratification is quite indistinct. On the south shore of the lake there is a green siliceous schist, that dips N. 50° W. 85°; and on the east there is a greenish, stratified diorite. North, on the watershed that is the boundary between the state and the province, the arenaceous schist splits into thin laminæ, is somewhat variegated, and the strata are vertical. The highest part of the ridge is diorite, which forms cliffs of considerable height. South-west, one fourth of a mile from the lake, the diorite outcrops, and three fourths of a mile, the arenaceous sandstone, which dips N. 28° E. 80°. On the old "tote"-road, a mile and a quarter from the lake, the diorite outcrops, and dips N. 40° E. 78°. A mile and a half south, on the north border of a tract where there was a hurricane many years ago, the diorite outcrops, while fifteen rods south the schist appears, and dips N. 40° E. 76°; and forty rods south, where the hurricane stopped, the diorite again outcrops. Between the "tote"-road at this point and Perry stream the diorite alternates with the arenaceous sandstone schists, which, near Perry stream, dip N. 36° E. 75°. Southward along the old "tote"-road the diorite alternates with the schist. The general dip is N. 34° E. 78°, and both rocks are quite alike in texture, except that for a mile and a quarter, a little east of north from the Fletcher place, the diorite is more schistose than along the "tote"-road. The dip here is N. 37° W. 75°. West of Round pond there are immense masses of the diorite. The high hill to the west and north-west is composed of diorite and arenaceous sandstone schist. The schist on the north side of the hill dips N. 48° E. 78°. This extends twenty-five yards; then a band of diorite has a width of five hundred yards. This is succeeded by a schist that dips N. 38° E. 85°.

Northward.

We have already called attention to the fact that the green chloritic schist is intimately associated with arenaceous sandstone schist. Two and a half miles above Second lake, near the Connecticut, the arenaceous schist dips N. 26° E. 82°. Towards Second lake, but to the west on Cobble hill, where the arenaceous schist is largely developed, the dip is N. 47° W. 68°. Near the lake, south-east of Cobble hill, the same schist dips S. 50° E. 77°, thus forming an anticlinal axis. A mile and a half north of Second lake, between the Connecticut and East inlet, there is a ridge of green chloritic schist, that dips N. 50° W. 68°. On a hill south-west of the lake the same schist dips N. 47° W. 68°. In the small area of green chloritic schist on the head waters of the Magalloway, east of the Coös group, the rock dips S. 47° E. 65°.

In the gneissic area on the ridge north-west of Mt. Carmel, on account of the jointed structure of the rock masses, it is difficult to determine the dip; but, as there is a similar area west of Parmachena lake, it is quite probable that this is a lower member of the axis embracing Mt. Carmel, Mt. Prospect, and Mt. Bosebuck.

On Spring hill, two and a half miles east of Second lake, a gray siliceous schist dips N. 57° W. 70°. On the Little Magalloway river, three fourths of a mile from the state line, an argillaceous schist dips S. 31° E. 80°. The same distance north of this stream, towards Mt. Carmel, the schist dips N. 48° W. 65°. A mile and a half north of the stream the gray siliceous schist dips N. 24° W. 80°. On Mt. Carmel, at the west end, the dip is N. 41° W. 75°. On the summit a greenish, stratified diorite schist dips N. 48° W. 78°. On the north side a gray siliceous schist dips N. 44° W. 78°. On the ridge extending north-east from Mt. Carmel the rock is a gray siliceous schist, the general dip of which is N. 35° W. 80°. On Mt. Prospect the gray siliceous schist dips S. 25° E. 82°. On the old "tote"-road from Connecticut lake to the Magalloway, seven miles from the former, a gray siliceous schist dips S. 53° E. 80°; six miles and a half from the lake, S. 82° E. 76°; four and three fourths miles, a siliceous schist, with bright yellow mica, S. 30° E. 68°; four miles, a greenish gray siliceous schist, S. 20° E. 48°; a mile and a half, a green chloritic schist, N. 62° E. 78°. Nearly a mile south of the last, and two miles from the lake, the same schist dips N. 53° E. 58°. On the islands, near the east shore of the lake, a green chloritic schist dips N. 60° W. 65°; the same schist, three fourths of a mile a little south of west of the lake, dips N. 60° W. 75°. On Magalloway mountain the rock is chiefly a siliceous feldspathic schist, that dips N. 48° W. 70°; and on the east side the fragments have fallen down so that there is a steep slope, having an area of several acres, on which there is no vegetation except lichens. On Diamond ridge the rock is the same as on Magalloway mountain, but it is everywhere cut by numerous joints, and has a dip of N. 70° E. 85°. On a low ridge, about ninety yards from the Little Diamond, between Diamond ridge and Magalloway mountain, the dip is N. 82° W. 76°. The rock of Bosebuck and Stubb hill is a gray siliceous schist. On Stubb hill the dip is N. 50° W. 65°. A mile and a half south-east of Magalloway, on the Little Diamond, the gray siliceous schist dips N. 60° W. 80°, and, farther south, it dips N. 72° W. 75°. A little west of south from Magalloway mountain, on a branch of the Little Diamond, are the falls described in Volume I, page 641. At the top of the falls the rock is a gray siliceous schist, and dips S. 75° E. 85°. At the base of the falls the clay slate, with pyrite, dips S. 80° E. 65°. These rocks, with those on the Little Diamond, form a synclinal axis. To the south-west towards Mt. Pisgah the gray siliceous schist dips N. 85° W. 72°. On the west side of Mt. Pisgah are gray siliceous schists, which dip N. 85° W. 82°; then, on the western slope of Mt. Pisgah, the rock is somewhat argillaceous, probably Coös, and dips N. 52° W. 76°. In the valley of Cedar stream, between Pisgah and the Connecticut, an argillaceous schist, passing into clay slate, forms a synclinal axis.

Connecticut Lake and Southward.

At the north end of the lake, near the house formerly owned by E. Day, the rock is a chloritic schist, which dips N. 28° E. 85°. At A. S. Huggins's, we find diorite. Half a mile west of the Col. S. Huggins place the arenaceous sandstone schist dips N. 47° W. 75°. A mile west we find diorite, and, at S. K. Danforth's, the arenaceous schist. At D. Day's there is diorite, and towards R. W. Danforth's there is a green chlorite schist which dips N. 48° E. 72°. At the outlet of Connecticut lake an arenaceous schist dips S. 80° E. 50°. At the saw-mill on Perry stream a chloritic schist dips S. 65° E. 75°. The diorite and arenaceous schist extend southward along the road toward Canaan, Vt. West of J. W. Heath's and J. P. Quimby's there are extensive outcrops of arenaceous schist, with easterly dips. There are prominent ledges of diorite on the road south of the red school-house.

East Part of Clarksville and the Academy Grant.

Between J. T. Amy's and Cedar stream, going south-east, the rock is an arenaceous sandstone schist. Two and a half miles south-east of Amy's we find a siliceous schist, approaching quartzite, that dips S. 62° E. 85°; four and a half miles, a similar rock, but somewhat gneissic, dips W. 82°. The remaining rocks of this area will be noticed in describing the section.

Dartmouth College Grant.

West of the Little Dead Diamond, on the north border of the grant, there is a hydro-mica schist. On Linnell brook, a mile from the mouth, the same schist dips N. 38° W. 75°. South, a fourth of a mile from the mouth of the same brook, there is a mica schist, containing a great quantity of bright iron-alumina garnets, which dips N. 35° W. 60°. The line between the hydro-mica schist and mica schist, on the boundary between Maine and New Hampshire, is about a mile south of the corner of Dartmouth College grant. On the Magalloway river the hydro-mica schist outcrops seven miles above Wilson's mills, and, with the exception of a gneissic area at Parmachena lake and an argillaceous sandstone schist at Little Boys' falls, the outcrop seems to be continuous at least as far north as opposite Mt. Kent. The dip is westerly where observations were made on the Magalloway. On the east line of the College grant, on a ridge a mile south of the north-east corner of the grant, the rock is a mica schist, with garnets, and dips N. 85° W. 70°. Along the ridge of Half Moon mountain, with the mica schist, there are bands of hornblende schist; the dip is N. 30° W. 75°. On the state line, on a ridge extending east from the Diamond Peaks, mica schist dips N. 85° W. 40°. On a ridge extending to the Magalloway, south of the great bog in the College grant, the rock is hornblende and mica schist. The dip is quite generally W. 75°. On the Swift Diamond, in the narrows at the dam, there is a gneissic mica schist, resting on mica and hornblende schists, that dips N. 30° W. 62°. At the mouth of the Little Dead Diamond mica schist dips N. 78°. This is followed on the west by a granitic gneiss; this is a narrow band. West of this is a band of fine-grained gneiss, resembling the Lagen gneiss of Von Cotta, that contains fine crystals of staurolite. This rock, as we go west, passes into a mica schist, and in the edge of Dixville it contains an abundance of garnets. The rock that succeeds it on the west, as far as our observations extend, is a gray siliceous schist, which is the rock of Dixville notch. In the north-west corner of Dixville there is an area of gray siliceous schist, resembling the hydro-mica schist, that dips generally S. 68° E. 80°. North of the Swift Diamond, two miles from Diamond Pond, a bluish gray siliceous schist dips S. 83° E. 80°. The rock has essentially the same dip to Dixville notch. A mile and a half north-west of the Notch there is a small area of an argillaceous schist, very fissile and containing pyrite, which dips S. 48° E. 75°. On the old "tote"-road from the Notch to the Swift Diamond, just north of the height of land, a gray siliceous schist dips N. 62° W. 72°. On the ridge south of the Notch, and extending into Ervin's Location, the rock is a siliceous schist, that sometimes contains staurolite, and on its southern border it dips south at a high angle, and northward the dip is generally a few degrees east of south, the strata everywhere being nearly vertical. The high ridge south of Cascade brook and west of Clear stream is the same rock as that of the Notch. The hornblende schist at the Whittemore place has been mentioned; its dip below is S. 70° E. 69°.

Millsfield, Wentworth's Location, and Errol.

Between J. C. Sweet's and stream north there is quite an extensive outcrop of chloritic schist. At the falls the rock is mica schist, but it has been largely replaced by a coarse, intrusive granite. Near L. Lovering's there is a pyritiferous schist dipping E. 74°. Near S. Rice's, on the western border of Errol, a coarse, intrusive granite has replaced the schist. Between Corser brook and Wentworth pond, in Wentworth's Location, mica schist, with garnets, dips N. 70° W. 85°; half a mile north-west of the pond mica schist dips S. 30° W. 65°; then a granitic gneiss. East of Aker's pond the strike of the mica schist is N. 30° E., and the strata are vertical. The schist here is full of very small garnets. The rocks immediately south of Clear stream and the Androscoggin will be described on Section XII. On the north border of Wentworth's Location the rock is a mica schist, containing small crystals of staurolite, and dips N. 82° W. 65°. At the base of the Dustin mountain, on the south-east, the rock is a gneissic mica schist and a coarse granite. In Errol, south of the section, in the road from Bragg's bay to Upton, Me., the rock to the height of land is a mica schist; and on the ridge between the height of land in the road and the lake the strata are very much contorted, and, where the rock presents a smooth surface, the bendings of the strata occur on every possible scale. The general dip is S. 60° E., nearly vertical. South, near the town line, there is hornblende schist, with a south-easterly dip. In Millsfield, on the section east of Millsfield ponds, an argillaceous schist was seen. This may be an extension south-east of the gray siliceous schist of Dixville notch. Near the height of land south, in Millsfield, there is a hornblende schist that dips S. 80° E. 58°. South-west of Rocky pond, the most southern of the Millsfield ponds, there is a dark siliceous schist dipping S. 65° E. 58°. A mile and a half south-west this schist passes into a hard, dark, almost black siliceous slate, which in places contains many veins of white quartz. Just north of Newell brook there is a band of hornblende schist.

Cambridge and Dummer.

On the line of Cambridge and Errol, from the Androscoggin and the Molnichewock, the rock is a gray siliceous schist; the dip is quite uniformly N. 30° W. 60°. These rocks extend southward, and outcrop in Dummer opposite T. Wentworth's, where they have a chloritic aspect; also on the north line of Dummer, on the "tote"-road to Millsfield pond, they are somewhat argillaceous. South-west of Dummer ponds there is an extensive outcrop of gray siliceous schist, and it is quite probable that the rock is continuous from west of the Androscoggin on the line of Cambridge and Errol. Two miles north-east of Leighton's mill the dip is N. 40° W. 70°. A mile and a quarter north-east the dip is S. 80° E. 80° Near G. Grapes's the dip is S. 50° E. 72°.

Stark and Milan.

At saw-mill near the mouth of Phillips brook there is a gray siliceous schist, with vertical strata. At Stark water-station the rock approaches novaculite, and dips S. 30° E. 72°. On the road opposite the mouth of Phillips brook the siliceous schist dips S. 50° E. 70°. On the hill north of Long pond the same rock dips S. 70° E. 76°. At West Milan the siliceous schist has hornblende schist interstratified with it; the dip is N. 50° W. 75°. In the railway cut, a mile and a half south-west of the village, the siliceous schist dips N. 80° W. 80°. The rock here in places is pyritiferous, and some bands contain hornblende. At Higgins's saw-mill the siliceous schist dips N. 70° W. 75°.

Columbia and Stratford.

On the high land a mile and a half from the Connecticut, on a tract of land formerly owned by Dr. Lombard, three fourths of a mile from the house, in the Notch towards Sims stream, the rock is a dark siliceous schist, that dips W. 80°. At William Gilkey's, mica schist dips N. 50° E. 65°. The rocks of Lyman brook will be described in the sketch of Section XII. A mile and a half north-east of Mrs. S. Day's a dark siliceous schist dips W. 70°. At North Stratford the mica schist stands in high ledges; one dip was found to be N. 58° E. 85°. But generally in the vicinity of North Stratford the dip is exceedingly variable. Near the mouth of Bissell brook the same rock as at North Stratford dips N. 70° W. 80°. A mile south-east of M. D. Johnson's, and a thousand feet above his house, a hard, dark siliceous schist comes in contact with granite. This siliceous schist, going towards Johnson's house, has a breadth of half a mile; following this, though still siliceous, it has the appearance of an argillaceous schist, and is very much wrinkled. This is followed by hornblende schist. On the road, a quarter of a mile below Johnson's, the wrinkled schist outcrops near the road, and contains staurolite. The siliceous schist is exceedingly variable in its dip, but is away from the granite. The wrinkled schist dips generally N. 60° W. 70°, and the hornblende probably the same way. South, just below Stratford, at B. Merriam's, the strike is east and west, and the dip is S. 80°. At the head of Bog brook, both on the branch that comes from the Notch towards Columbia, and the one from Sugar Loaf, there is a hard, dark siliceous schist. At the south base of Sugar Loaf the dip is S. 70° E. 78°. On the road that runs south from Bog brook, from near the mouth of East Branch, the rock is a gray siliceous schist; near B. Brown's it dips S. 50° E. 65°. A quarter of a mile south of the end of the road it dips S. 70° E. 68°. In the east part of the town, on Nash stream, there is a similar schist, but it extends only a short distance north of Percy peaks, and it dips generally S. 15° E. 65°.

Northumberland and Stark.

Extending around the south-west base of Percy peaks is a dark siliceous schist, the dip of which is exceedingly variable. South of Potter's pond a dark siliceous schist, that by weathering presents a peculiar pitted surface, dips S. 20° E. 72°. On the east side of the Devil's Slide, and also on the east side of Mill mountain, the siliceous schist stands vertical, and is in contact with porphyrite, which forms the mass of these two elevations. The same rocks are on a hill east of Groveton, and they have the same relation. In the valley between Mt. Lyon and the Pilot mountains we have the dark siliceous schist. At the east base of Mt. Lyon the dip is S. 70° E. 72°; near the road the dip is N. 50° E. 70°. East of the road the dip of the schist is N. 75° W. 80°, and it is penetrated by the porphyrite.

The rocks of the Connecticut valley, from the north part of Northumberland to Dalton, although having for the most part the same general characteristics, yet they are exceedingly variable, and so cut by joints that generally it is difficult to determine the dip. In general they may be described as chloritic feldspathic schist.

In the first outcrop, about three fourths of a mile south of the north line of Northumberland, the rock is a feldspathic quartz schist. On the hill east there are large crystals of feldspar. At Groveton and half a mile west we find a chloritic feldspathic schist, and interstratified with this is a greenish siliceous schist, that dips W. 60°. On Jonathan Pond brook, a fourth of a mile above the bridge, we find the feldspathic quartz schist; and north, perhaps a mile from the bridge, there is a siliceous schist that dips N. 60°; this rock in places contains a small quantity of lime. The feldspathic chloritic schist comes in contact with the porphyrite on the west side of Mt. Lyon. The high hill south-east of Northumberland falls is composed of this rock. In the south part of Northumberland, about half a mile a little east of north from the place formerly owned by O. S. Wood, the rock contains a large proportion of hornblende, and with it there is a band of limestone, very siliceous, however—dip N. 60° W. 65°; a mile and a half south, on the road to Lancaster, there is epidote with the chloritic feldspathic schist. On the hill east of the Bellows farm the rock differs somewhat from the rocks elsewhere, except in Vermont opposite, and it resembles a chloritic schist. Near the school on Caleb branch there is a siliceous feldspathic schist; near C. Lee's, a chloritic feldspathic schist; near W. Savage's the rock is hornblendic. On the west side of Mt. Prospect the rock is a siliceous chlorite schist—dip easterly. The rock between Lancaster village and Mt. Prospect is for the most part the same, except that just above the spring that supplies the Lancaster house there is a band of a highly siliceous limestone. At S. H. Legro's the rock is decidedly feldspathic, and in the road, a quarter of a mile north-east, there is an argillaceous mica schist. Mt. Pleasant, and the ridge west, is a siliceous chlorite schist, except at the western extremity, where it slopes towards the Connecticut, the rock is hornblendic. At Z. and J. Dexter's the rock is siliceous and pyritiferous. West of a small pond in the extreme south part of Lancaster the rock is sandstone. Where the siliceous chloritic schist is cut by the railway the rock is somewhat calcareous.

Vermont.

On the first road north of the Lancaster bridge, going west, the chloritic rock, so extensively developed in the east part of Guildhall, extends three quarters of a mile west of the Connecticut; the dip seems to be S. 70° W. 58°. Near Freeman's, of the county map, there is a gray siliceous schist dipping W. 78°. Gray schist on High hill and near C. Joy's dips N. 68° W. 65°. In road opposite A. Benjamin's, gray siliceous schist dips N. 70° W. 80°; half a mile west the same schist is vertical. West of Mill brook the siliceous schist dips easterly. At Royce's the rock is a siliceous mica schist dipping S. 70° E. 70°; and west at a school-house a light gray siliceous schist dips S. 50° E. 70°. South, on Mt. Tug in Lunenburg, the gray siliceous schist dips N. 75° W. 73°. On the road from Lunenburg to Concord there are many outcrops of gray siliceous schist. Near the Baptist church the dip is N. 57° W. 75°; where the road crosses Miles stream the dip is N. 77° W. 72°; at S. Gaskill's—dip N. 80° W. 62°; on the south-west slope of High hill the dip is E. 75°. In the last is a porphyrite, evidently produced by metamorphism from the siliceous feldspathic schist. A mile south-west of West Concord a greenish chloritic schist dips S. 50° E. 62°. This probably extends south to Lower Waterford.

In Fig. 7 we have on the Connecticut Huronian rocks dipping east. On Burnside mountain we have an axis, with slate in the synclinal. Each group of rocks to the west probably forms inverted monoclinal axes.

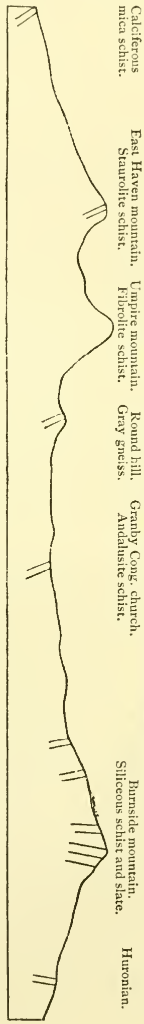


Fig. 7.—SECTION FROM NORTHUMBERLAND FALLS TO THE PASSUMPSIC RIVER, VT.

Montalban Group.

At the south end of Umbagog lake a gneissic mica schist dips N. 65° E. 58°. In the south-east part of Cambridge a hornblende schist dips N. 10° W. The rocks of this group in Success will be noticed in describing the sections that pass through the township.

Shelbur e.

The rocks of Shelburne are remarkably uniform. The gneiss contains quite a large proportion of mica, which is in well-defined plates, and it is often arranged at various angles to the planes of stratification. On the state line between the Androscoggin and Wild rivers, a mile and a quarter from the former, on a high cliff, the dip is E. 70°. On Clement brook, a mile from the road, it outcrops, and has an easterly dip. At the lead mine it dips N. 20° W. 60°. The other rocks are granitic gniesses, and it often occurs interstratified with the other gneisses. There is an outcrop a mile up Clement brook; and there is a conspicuous area a mile west of Shelburne village, where it has been quarried.

Gorham.

At Gorham village gneiss, the same as that in Shelburne, has granitic gneiss interstratified with it, and it dips N. 60° W. 65°. The gneiss outcrops on Mt. Hayes, but it is largely replaced by intrusive granitic veins. The south end of the mountain ridge, south-west of the village, is granitic gneiss, but the mass of the rock composing the ridge is andalusite schist, that dips N. 30° W. 68°. Two miles west of the village, on the Randolph road, there is a hornblende schist that dips S. 40° E. 62°. In the extreme north part of the town, near the Alpine cascade, the hornblende schist dips S. 45° E. 70°.

Dummer and Odell.

In the north-west part of Dummer we find an area of gneiss that has the characteristics of that described in Shelburne; the dip west of Dummer ponds is S. 70° E. 60°. We have also in both sides of the ponds the granitic gneiss of this group. In Odell, in the south-east corner of the town, the dark gray gneiss dips N. 15° W. 35°. This is followed by a granitic gneiss towards Trio ponds. The granitic gneiss also outcrops on Nash stream, near the forks.

The Montalban in Vermont.

In the vicinity of Island Pond, and occupying at least the west side of Bluff mountain, there is a mica schist that very closely resembles the Montalban group, as developed in the White Mountains; the dip is S. 65° E. 70°. In Brunswick, the North and South Notch mountains are Montalban rocks; and in the Notch the dark gray gneiss dips westerly. In the west part of Maidstone, on the east shore of the lake, the characteristic dark gray gneiss dips N. 65° W. 62°. On Round Top hill, in Victory, the dark gray gneiss, with conspicuous plates of mica, dips S. 35° E. 65°. In Granby, nearly half a mile north of a school-house in the east part of the town, there is a band of gneiss that dips S. 50° E. 63°.

Other Montalban Rocks.

In the north-east part of Victory, at the forks of the road east of Moose river, gneiss, with fibrolite, dips S. 60° W. 75°. On East Haven mountain an argillaceous mica schist dips S. 52° E. 58°. In the east part of Burke, at the end of a road going north from the main road, argillaceous mica schist, with staurolite in small crystals, dips S. 44° E. 60°. On the north spur of Umpire mountain there is argillaceous mica schist, with andalusite and fibrolite—dip exceedingly variable; with the schist there is granitic gneiss; in the central part of Victory, on Bog brook, granitic gneiss outcrops. In the north part of Kirby, in the gap between East Burke and Kirby mountains, a mica schist, passing into gneiss containing fibrolite, dips easterly. South of Kirby mountain gneiss, with fibrolite, dips N. 54° E. 70°. On Miles mountain, in Concord, the rock is gneiss, with fibrolite. In a cleared field, on the south-west side, the dip is N. 40° W. 28°. The rock is very siliceous and is somewhat calcareous. In the woods above the field just mentioned the dip is N. 62° E. 55°; top of ridge, dip N. 58° E. 70°; at the summit of the mountain the dip is W. 80°.

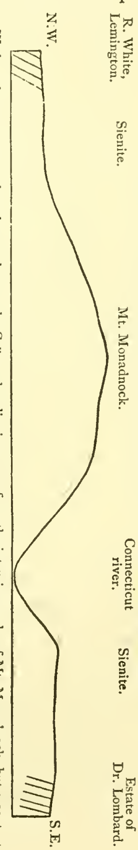


Fig. 8.—SECTION ACROSS MT. MONADNOCK, VT., INTO COLUMBIA.

We have here represented on the north-west the Coös rocks, dipping away from the intrusive rocks of Mt. Monadnock, but a contact of the rocks was not seen. It is not absolutely certain that the sienite extends across the valley, but it seems to be quite probable that it does, and that it has been worn away, and the valley filled with drift. On the south-east the Huronian rocks are included between masses of intrusive sienite, and the dip has been undoubtedly affected by these. See page 69.

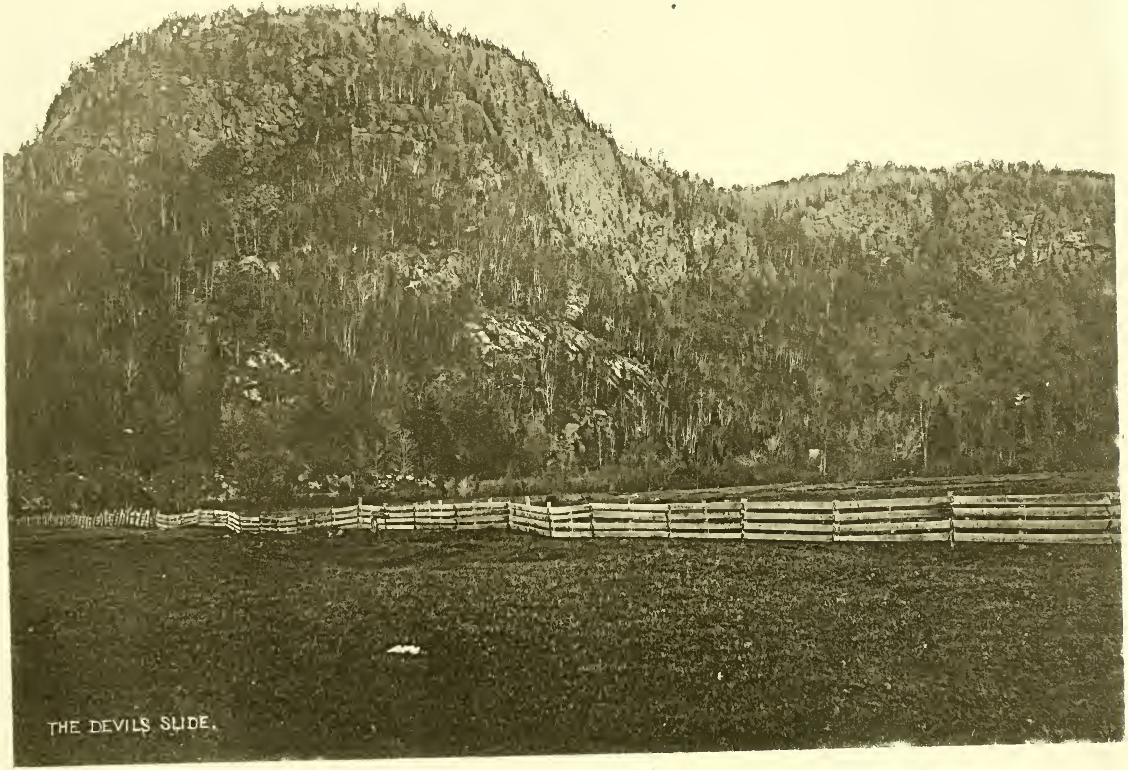
Older Rocks.

The rocks of the Atlantic series here described are probably older than the Montalban. In the north part of Milan, on the river road, near a school-house, the rock is gneiss. Here it contains a greenish mica, and dips N. 50° W. 58°.

South, at D. Evans's, the quartz forms such a prominent feature in the gneiss that the rock has the appearance of being a conglomerate; the dip is N. 15° W. 20°. At a saw-mill in the south-east corner of Milan, common gneiss dips N. 70° E. 65°. East of this in Success, on the cart-road to the meadows, and half a mile from the west line of the township, there is a granitic rock, probably gneiss, the quartz of which is quite friable. North on the Chickwalnepy the rock is a hornblende schist—dip N. 30° E. 66°. On the Grand Trunk Railway, opposite Nay's pond, there is a hornblende gneiss that contains epidote, in nodules, and veins of calcite; the dip is N. 20° W. 50°. South, towards Milan water-station, common gneiss dips N. 20°. At a saw-mill on Dead river, common gneiss dips S. 30° E. 20°. North of Dead River pond there is a granitic rock that contains a compact feldspathic rock. On Berlin heights a pyritiferous schist dips N. 40° E. 67°. At Berlin falls a hornblende schist dips S. 45° E. 60°; and in a railway cut below the station there are folds in the common gneiss, the strata being nearly vertical. There is gneiss on Randolph mountain; and at Jefferson hill it dips N. 10° W. 18°. The same rock and nearly the same dip were observed within a mile and a half of Lancaster village, on the road from Jefferson hill. On the road south of Mt. Prospect the common gneiss dips N. 20° W. 18°. South, near Blood pond, where it comes in contact with the harder Huronian rock, the dip is N. 10° W. 50°; and the strata are crumpled and contorted. There is common gneiss on Bray's hill in Whitefield; and in the east corner of Dalton the same rock dips N. 15° W. 18°. There is a fine-grained gneiss west of Round pond, and it dips N. 42° W. 60°. Southward, the common gneiss outcrops on Mann's hill in Littleton.

Intrusive Rocks, Sienite, and Porphyrite.

The most northern limit of the sienite in New Hampshire is in the extreme southern part of Colebrook, near G. and M. Parsons's. It is composed chiefly of feldspar and hornblende. The feldspar is of a light flesh color, passing into a light gray. This largely predominates, the hornblende being only a small proportion of the mass of the rock. A few blocks have been quarried. It seems to be easily worked, and it makes a beautiful stone. If polished it would no doubt be ornamental for pillars, to which use some of the sienites and granites that contain



THE DEVILS SLIDE.

little mica and are wrought with facility, are applied. The area of this rock is limited, being confined to the point of land between Sims stream and the Connecticut. In Columbia, south of Sims stream, the high point of land that is so noticeable just before we cross that stream going south, is composed of sienite, but it is of a very dark color, either from its being colored with manganese, or from the decomposition of the feldspar. On the side towards the stream numerous boulders have been detached, and the angular blocks lie on the steep hillside; some of them are so poised that apparently only a slight force is needed to send them to the bottom of the valley. It seems quite probable that this mountain mass south of Sims stream was once connected with Mt. Monadnock, on the west side of the Connecticut, possibly with that north, and that the intervening rock has been worn away. This seems more probable, since this area of sienitic rocks, including those north and south of Sims stream and Mt. Monadnock, are surrounded by schistose rocks. To the south-east in Stratford we find a rock similar to that south of Sims stream, largely developed. The summit of Sugar Loaf mountain is a solid mass of rock two or three hundred feet in length and half as wide, and so precipitous that there are two or three places only where it is possible to reach the summit. Specimens of the rock from this mountain can hardly be distinguished from those south of Sims stream. South-east, but still in the town of Stratford, we come to Percy peaks. The rock here differs somewhat from that of the localities just described. The feldspar is more of a flesh-color, is not so abundant, and also contains some black mica and a smaller proportion of hornblende. It also contains quartz, and besides, what is quite uncommon, the quartz is frequently crystallized; and, though generally distributed equally through the mass of the rock, crystals of smoky quartz have been found having a diameter of six inches. These peaks, so symmetrical in their outline, with their bare, white summits, form a marked feature in the scenery. In Stark, approaching the railway station either from the east or west, the mountain ridges project by each other so that there seems to be an impassable barrier. On the south is Mill mountain, and on the north there is a precipitous mountain bluff known as the Devil's Slide. These rocks are separated from the granitic region northward by a band of schist. The rock of the Devil's Slide is chiefly sienite, but it is unlike that of Percy peaks or Sugar Loaf, but it resembles somewhat that at Colebrook. The difference is chiefly in the color of the feldspar, that of the Slide being light gray. The face of the Slide is a precipitous wall of rock, from one to two hundred feet in height, above the *débris* that has fallen down at the base of the cliff. The wall itself forms an immense amphitheatre,—hence there is a fine opportunity for studying the rocks. On the west, near the railway at the base of the cliff, the whole mass of the rock is sienite; in places it is discolored, but generally it is composed of a light-colored feldspar, of quartz that is light gray, and hornblende. In places the hornblende is wanting, and elsewhere the rock seems to be composed almost altogether of feldspar. This is particularly the case towards the summit of the cliff. When we have passed two thirds of the way around the amphitheatre, we find a schist. The strata are generally vertical, or nearly so, and they are in contact with the sienite; in places are penetrated by it. There is a similar arrangement of rocks on the north-west side of Mill mountain. Towards the east side of the amphitheatre there are several dykes of diorite of considerable interest. It is often amygdaloidal, and the cavities contain calcite. The heliotype shows most prominently the west end of the Slide; and, although the whole bluff is precipitous, near the centre of the picture can be seen the perpendicular wall of rock. On the extreme right is the point where the sienite is succeeded by the schist. A close inspection will show the Grand Trunk Railway, where it passes along at the base of the cliff.

Porphyrite.*

Porphyrite is quite a common rock in northern New Hampshire. The most northern locality where it is developed is in Stratford. East from Connecticut river and south of Lyman brook, there is a range of mountains, one of the highest points of which is known as Lightning mountain. It can be seen from the vicinity of North Stratford, and it is the only peak in the range that is without trees. On the south side of this mountain there is quite an area where there is an exposure of a dark granitic rock, composed chiefly of feldspar, which gives to it a greenish color; there is also in the rock a small proportion of a dark vitreous quartz.

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* Rocks classified and described by B. Von Cotta. English edition, by P. H. Lawrence, p. 168.

On account of this rock having formerly been quarried,—for it was used in the construction of the piers of the railway bridge at North Stratford,—we were able to examine large detached masses, which revealed the true character of the rock. Weathering affects this rock to a great depth. The color of the feldspar is changed to dull gray, though it has no decided tendency to crumble. The whole aspect of the rock is so unlike the original, that one would hardly suspect that a rock so compact and of such a color should be found beneath the weathered surface.

Immediately south of the Grand Trunk Railway there is a large area that embraces several mountains of considerable height. The mountains are known generally as the Pilot range. The highest peak is Starr King, and it is just north of the Waumbek house. Embraced in this area is the country extending from Stark station south nearly to the Waumbek house in Jefferson, and east from the Connecticut, from a point just above Northumberland falls, to the head waters of the Upper Ammonoosuc. Everywhere there are high mountain ridges covered with forests, and often these ridges rise in sharp conical peaks, while in many places there are steep slopes and precipitous walls of rock. So marked are these ridges and mountains, that one can hardly be mistaken as to those that are composed of porphyrite, although they are many miles distant. There are two small areas of porphyrite on the west, that are separated by a band of schist from the larger area eastward. Mt. Lyon, formerly known as Cape Horn, and a hill immediately east of Groveton, are the areas indicated. Mt. Lyon, though not so high as some of the other peaks, yet is more noticeable, since it stands out so prominently from the other mountains, and the valley of the Connecticut westward makes it seem to rise abruptly from a plane. It can be seen from Mt. Moosilauke, and from many places along the Connecticut valley. The whole mass of the mountain is a compact feldspar porphyry; and on the east side there is a precipitous wall of rock, from fifty to two hundred feet in height, extending for nearly a mile. The jointed structure of the rock gives it the appearance of stratification, and the composition is as follows:

Silica, ...	62.2
Alumina, ...	28.
Iron oxyd, ...	tr.

Lime,	4.6
Soda,	3.34
Potash,	6.

On the hill east of Groveton the character of the rock is nearly the same as that of Mt. Lyon. On the north side, however, the *débris* has fallen down so that no outcrop appears until we get nearly to the top. On the east side of this hill there is a schist, which is almost a quartzite,

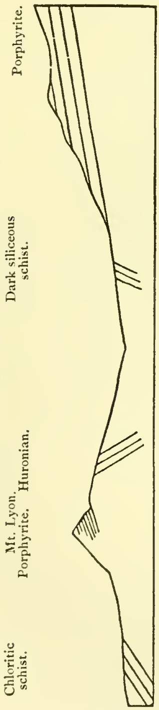

Fig. 9.—SECTION FROM NORTHUMBERLAND FALLS TO PILOT MOUNTAIN.

On the east we have the feldspathic chloritic schist. Mt. Lyon is porphyrite; and east the dark siliceous schist forms a synclinal axis. East of the schist we have porphyrite, extending to the top of Pilot mountain.

that comes immediately in contact with the porphyrite. Between Mt. Lyon and the porphyrite east, there is a band of schistose rocks, which perhaps may be properly called an argillaceous quartzite. This band forms a synclinal axis between the porphyrites. The view of Mt. Lyon, from which the heliotype was made, was taken at a point near Groveton, and its pointed summit shows a characteristic of our porphyrite mountains. East of the road from Groveton to Lost Nation, and three fourths of a mile from it, the porphyrite outcrops, and from thence to the head waters of the Upper Ammonoosuc it appears to be continuous. The porphyrite of this region seems to be spread out in nearly horizontal layers. The lower portion is a dark, compact rock, with few distinct crystals of feldspar, and it always weathers whitish. The upper portion, which caps the summits of nearly all the higher peaks, is a light-colored porphyrite, and the crystals of feldspar are always distinct. The only one of the higher mountains that is not thus capped is the one that is known as South peak, a sharp, conical mountain, that can be seen looking south from Stark station. While the succession of rocks is so nearly the same, in so many different localities, it has been taken as presumptive evidence that these rocks are stratified; but as there are so many places where the porphyrite penetrates the rocks with which it comes in contact, the intrusive character of this rock cannot be doubted. The same reasoning in regard


Mt LYON.

to the succession of rocks applies equally well to the granites in the region south of the Notch. On the north-west side of Mill mountain, half way up, the porphyrite penetrates the dark siliceous schist, as also at the Devil's Slide. Boulders from the Slide can be seen near Hickey's mill. On the south-east side of Mill mountain the porphyrite comes in contact with a schist that is similar to that which is found in contact with the rock on the hill east of Groveton; but here the schist is everywhere vertical. As in the valley of Mill brook boulders of labradorite are common, it is quite probable that this rock may be mostly covered up by the porphyrite. On the south side of the area, half a mile above the Waumbek house and west of a small stream from the mountain, the porphyrite penetrates the gneiss. The rocks that we have seen in contact with the porphyrite are a siliceous schist almost a quartzite, a feldspathic chloritic schist, and gneiss. On the west we have the rock that is found along the Connecticut, through Northumberland and Lancaster, which was probably originally a sandstone, though its character as such is generally obliterated. This rock is everywhere on the west, and generally a short distance from the porphyrite, but at the south end of Mt. Lyon it comes in contact with it, and extends around on the south as far as Jefferson. This is succeeded by a gneiss,—a rock that is extensively developed in Whitefield,—that extends through Randolph into Berlin. There are several places where the gneiss comes in contact with the sandstone, and underlies it. The rock on the north-east is a common granite, while on the north there is a small area of a schistose rock, which is an argillaceous sandstone schist.

Granite and Granitoid Gneiss.

Rocks composed only of quartz, feldspar, and mica, and in the proportions found in typical granite, are very rare in northern New Hampshire. In the Atkinson and Gilmanton Academy grant there is a band of granitoid gneiss from half a mile to a mile in width, and it forms the height of land between the Little Diamond and Magalloway. It is composed of quartz, feldspar, and mica, both black and white, and is a rock of very fine texture. On the west there is a narrow band of mica schist, and this is succeeded by hydro-mica schist; and on the east there is also a hydro-mica schist. The apparent dip is towards the north-west; that, also, is the dip of the schist.' Southward, in the Dartmouth College grant, on the Swift Diamond, and about two and a half miles west of the Magalloway, there is a band of granitoid gneiss perhaps three fourths of a mile wide. It is not quite so fine in texture as the last mentioned, but otherwise it closely resembles it. On the west there is a staurolite gneiss, which rests upon it. On the east there are mica and hornblende schists, the strata of which are almost perpendicular, but they have evidently been much distorted.

The granitoid gneiss outcrops in Wentworth's Location just west of Wentworth pond; and boulders of this rock, or one very similar, can be seen along the road south of Bragg's bay. It is one of the most beautiful building stones to be found in the state. In Errol, north of the road and extending into Millsfield, a rock similar, but not so even in its texture, can be seen. A rock in which the marks of stratification are very obscure, but which in its characteristics closely resembles a granitoid gneiss, outcrops in Dixville just at the gate of the Notch on the east. In Millsfield, west of Millsfield pond, and in the north part of the town of Odell, and in the central part extending nearly to Trio ponds, there are extensive outcrops of granite. In the west part of Millsfield there is a high mountain ridge of granite, rather fine in texture, the feldspar of which is white. Westward in Odell there are three parallel granite ridges. Here the texture of the rock is very similar to that of Millsfield, but the feldspar is flesh-colored. West of Odell in Stratford the rock changes; and here we find a very coarse granite, composed mostly of feldspar and quartz, but there is a small quantity of black mica, and there is hardly any doubt but that this is a genuine eruptive granite, and it is newer than the stratified rocks along the Connecticut, since in Lyman brook, where they come in contact, it has penetrated the schists in numerous veins and beds. On the east shore of Umbagog lake there is a kind of granite unlike any found elsewhere in northern New Hampshire. It is a dark gray rock, and it is composed chiefly of quartz and brownish mica. A similar rock is found in Vermont, near Island Pond.

In Jefferson, near the Mt. Adams house, there is a granitoid gneiss that contains a flesh-colored feldspar, light gray quartz, and minute scales of black mica, unevenly distributed through the rock. The same kind of rock is found on Cherry mountain in Carroll, while just east of the mountain, in the south part of Jefferson, at a saw-mill, there is an exceedingly hard granitic rock, composed of feldspar and quartz. In the south-west corner of Randolph, at a saw-mill, there is a similar rock, very much jointed. East of this and south of the last there are outcrops of granitoid gneiss. In Randolph the granitoid gneiss, composed largely of granular quartz, extends along Moose river, nearly through the town. At Gorham a rock like Concord granite outcrops near the village, where it is interstratified with the White Mountain gneiss. In Shelburne there are several extensive outcrops. Three fourths of a mile west of the village, large quantities of this rock have been quarried. It appears also south of the village, and extends a mile or more up Clement's brook. In Martin's grant it can be seen along Peabody river, and it extends up that stream to Mr. H. D. Copp's. It is likely to be found in many places interstratified with the White Mountain gneiss. In Milan, three fourths of a mile south-west of Higgins's mill, there is an outcrop of granite on the stream that flows into the Upper Ammonoosuc, near the mill. On the line of Milan and Kilkenny, on the mountain ridge known as Green's cliff, there is a coarse, eruptive granite, composed of light flesh-colored feldspar, dark gray quartz, and black mica. On the south-east side of this ridge there is a precipitous cliff, from one hundred and fifty to two hundred feet in height. At the base of the cliff there are boulders of immense size, that have fallen down. One of these boulders contains over thirteen thousand cubic yards. The granite extends probably a mile and a half south-west from Green's cliff, and is followed by porphyrite.

In the west part of Stark, between the Upper Ammonoosuc and the Grand Trunk Railway, there is a granite quite unlike that found elsewhere in northern New Hampshire. The feldspar is of a deep flesh-color, which gives to the rock a reddish cast. East of the high hill where it outcrops, up the valley, there are numerous boulders of this rock, some of which have been used in the construction of abutments to the bridge at Stark station. It seems to be wrought with facility, and is the only workable granite found in ledges anywhere in this section of the state west of the water-shed between the Androscoggin and the Connecticut.

Veins and Dykes.

Almost every one has noticed, where eruptive rocks come in contact with those that are stratified, near the line of contact, they often send off veins into the surrounding strata. These veins do not differ from the general mass, except that they are generally finer grained. Dr. Hunt describes what he calls granitic veinstones, and he regards them as concretionary. These are not, however, on the borders of great areas of eruptive rocks. "They are," he says, "to the gneisses and mica schists, in which they are generally inclosed, what calcite veins are to stratified limestone; and although long known, and objects of interest from their mineral contents, have generally been confounded with intrusive granites." The theory as to the way in which veins have been formed has been a matter of controversy from the time of Agricola, who, in 1546, was the first to propound a theory of veins. He supposed that the principal agents were water, which dissolved the enclosed rock, heat, and cold. Werner was the first to fully develop the aqueous theory. The fissures he supposed to be caused by contraction, in consequence of drying and various other causes; and the vein to be formed from a wet and mostly chemical solution, which covered the region where the fissures existed. Lasius supposed that the material was introduced in a state of aqueous solution, as mineral water; Lehmann, that the material was brought into the fissures by ascending steam; Becher, that the matter was introduced in a gaseous condition by sublimation; Fournet, that the material has been introduced by an igneous and purely anhydrous fluid injection, and solidified in the fissures. Scheerer conceives the congealing granite mass to have been impregnated with a highly-heated aqueous solution, "which, under great pressure, oozed out, penetrating even the stratified rocks in contact with the granite, filling cavities and fissures in the latter, and depositing therein crystals of quartz and of hornblende, the arrangement of which shows them to have been of successive growth."

According to Elie de Beaumont, the coarsely crystalline granitic veins were injected. He supposed the material to be derived from the congealing granitic mass. The veins which are characterized by a symmetrical banded structure he regards as concretionary. Von Cotta is in doubt whether the veins which occur at Johanngeorgenstadt are concretionary or igneous-fluid injections. "The general character of the lodes is so like that of granite, that they might be considered to have been injected in an igneous-fluid state; with which, however, do not agree their slight breadth, and at times banded, even though not exactly symmetrical texture, as well as the irregular distribution of ores in them. Since feldspar and mica may be formed in that way, a decision can only be arrived at with great difficulty."*

Dr. Hunt thinks it probable that "a great proportion of quartzo-feldspathic veins are of aqueous origin, and have been deposited from solutions in fissures of the strata, precisely like metalliferous lodes. This applies especially to those granitic veins which include minerals containing the rarer elements. Among these are boron, phosphorous, fluorine, lithium, rubidium, glucinum, zirconium, cæsium, tin, and columbium, which characterize the mineral species, apatite, tourmaline, lepidolite, spodumene, beryl, zircon, allanite, cassiterite, columbite, and many others."† He thinks that these elements, which are found only in minute quantities in the mass of the sedimentary deposits, have been eliminated from the great mass, and have been accumulated here by deposition from water. The argillaceous, wrinkled, corrugated schist in Pittsburg, Clarksville, and Stewartstown is remarkably free from veins, and only those of quartz are found, but these all seem to be of one type, and rarely ever more than three or four inches in thickness, and very rarely do they contain any metalliferous deposits. The veins often contain peculiar longitudinal cavities, which give to it a fossiliferous appearance. Veinstones of this character are common between Indian and Perry streams. The veins are more numerous in the schist containing lime than elsewhere. The more compact portions do not, as far as we have observed, contain veins of any kind. In the green schist, where it contains veins, the quartz has more or less of the mineral ripidolite, a species of chlorite, associated with it. The whetstone grit rarely contains veins. The diorite rock, extending from Colebrook through Stewartstown, Clarksville, and Pittsburg to Quebec province, has in a few places veins of quartz, though they are nowhere very numerous, and often for a long distance it has

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* Von Cotta's *Treatise on Ore Deposits*, Prime's translation, p. 124. † *Geology of Canada*, p. 476.

none. A place where they are the most numerous is in the vicinity of Mud pond, in Pittsburg, and the quartz is remarkably white and vitreous. On a hill east of J. Young's, in Stewartstown, where there are veins, chlorite is found associated with the quartz.

At Dixville notch there are several interesting trap dykes. Near the height of land in the Notch there are large, loose blocks, which have come from a dyke above. The rock is basaltiform, and contains large masses of augite and glassy feldspar, and resembles, according to Jackson, volcanic rocks more than any other found in the state. A similar rock is found in the wall of Huntington cascade, south of the road below the Notch. At the Flume, north of the road, just at the gate of the Notch, there is a trap dyke, somewhat porphyritic, with feldspar crystals. It is probable that, by the disintegration of this dyke, the Flume has been formed. These dykes have cut through the schist and granite, without apparently having disturbed or changed it.

In Millsfield, south of the road near J. C. Sweatt's, a vein a foot in width cuts through the green chloritic schist. It is composed of feldspar, very white, mica, nearly colorless, vitreous quartz, and occasionally crystals of tourmaline and garnets. A fourth of a mile east of Sweatt's, at the falls on Clear stream, is a vein four feet wide cutting the schist. Here the feldspar is white, the quartz smoky, the mica has a greenish tinge; and, besides garnets with a resinous lustre, there are also small crystals of beryl. Near M. Haynes's, in Stewartstown, there is a trap dyke four feet wide, which we were able to trace a quarter of a mile. It runs nearly parallel to the strike of the schist.

Near the head of Blodgett brook, in Columbia, there is a dyke of trap cutting the granitic rock. It is amygdaloidal, and contains epidote and calcite, and, in places, distinct hornblende crystals. In the southern part of the town, near W. Kimball's, where the granite comes in contact with the schist, it sends off veins into the surrounding strata. These veins are finer grained than the granite mass. This is supposed to result from the more rapid cooling of the mineral constituents. At Groveton, on the Grand Trunk Railway, there is a vein of hematic iron ore, which, with the quartz, forms a kind of breccia. In Stark, in the wall of the Devil's Slide, near the eastern extremity, there is a dyke of diorite which is unlike any that we have seen elsewhere. It is porphyritic; and the feldspar is of a triclinic variety. At the saw-mill on Phillips brook there is a trap dyke six feet in width.

In the vicinity of Berlin falls, veins and dykes are very numerous. The schistose rocks at the village, and just above, along the railway, have been replaced by coarse granitic veins, consisting of vitreous quartz, feldspar, and patches of black mica. In the railway cut just below the station there are several trap dykes. In the second cut there is one twenty feet wide, and it is separated from another four feet wide by a band of gneiss a foot in width. The general direction of the dykes is north-east and south-west. In the road just below the village there is an extensive dyke, and at the falls below the bridge one four feet wide extends along the river. It is porphyritic, and its direction is N. 80° W. Near the falls there is also a granitic vein, containing magnetic iron ore, and it is so mingled with the rocks as to form a metalliferous porphyry.

In Berlin, on a high bluff north of Dead River pond, there are several veins or beds, the rock of which, though it has the appearance of jasper, is really a compact feldspar, as a partial determination of its constituents shows. It contains silica 69.2, alumina 19.6, lime 3, and its color is greenish brown, striped with bands of reddish brown. The beds vary in thickness from a few inches to several feet. At one point there is quite a cave; its length is fourteen feet, and it is nine feet in height and six feet wide. On the floor of the cave there is an accumulation of vegetable mould, which contains fragments of the felsite. It has been thought by some that this cave was excavated by the Indians, to obtain the rock for making arrow-heads. The entrance to the cave has somewhat the appearance of having been excavated by human hands; but, as the vein of felsite at the entrance is not more than a foot in width, and within a few feet of the entrance on the east there are several veins much wider, which appear never to have been touched, that they would have removed a large mass of granite to get this particular vein does not seem probable. The presence of fragments of felsite in the cave similar to those found where felsite is known to have been wrought by the Indians, makes it probable that they visited this cave, and it is possible that they may have enlarged it somewhat; but the origin of the cave must have been a fissure in the rock.

The Map.

The map (Plate V) that accompanies this chapter embraces the extreme northern part of New Hampshire, with a small portion of the adjacent territory on the west. Its southern limit is the beginning of the White Mountain region. A few lines have been drawn to show the area of the principal formations.

The larger figures show the locality where the rocks of the sections were collected. The smaller figures show where specimens were collected, to illustrate the geology of the entire area. In some places, on account of the large number of specimens collected, the figures have been crowded away from the exact locality where they should have been placed. The area west of the line running through Pittsburg, Clarksville, Stewartstown, Colebrook, and Columbia belongs to the Coös group. The line southward from Columbia, nearest the Connecticut river, separates the Huronian rocks from the sienites, granites, porphyrites, and gneiss to the east. The latter occupy a part of Jefferson, most of Kilkenny, a part of Northumberland, Stark, Odell, Millsfield, Stratford, Columbia, and a small area in Dummer, Milan, and Berlin. East of the Coös group and this granitic area the Huronian rocks occupy most of the remaining territory, and are conveniently divided into several groups, one of which is separated from the rest, and is included in the lines beginning at the eastern boundary, near the north-east corner of the state, and ending in Milan. Each of these areas has been already described.

Many errors will undoubtedly be found in the map, as must necessarily follow from the limited time given to work where so many figures are concerned. Figure 10 in Section XII should be where 9 is, and that figure should have been put farther east; 285 in Odell should be 385; while 42 of Section XI should be near the line of Stark and Northumberland.


PLATE V.
VERMONT
CANADA
MAINE
COOS
DALTON
WHITEFIELD
LANCASTER
NORTHUMBERLAND
JEFFERSON
STRATFORD
COLUMBIA
COLEBROOK
STEWARTSTOWN
CLARKESVILLE
PITTSBURG
STARK
ODELL
RANDOLPH
BERLIN
MILAN
DUMMER
MILLSFIELD
DIXVILLE
ERROL
GORHAM
SHELBURNE
SUCCESS
CAMBRIDGE
COLLEGE GRANT

Catalogue of Specimens,*

Chiefly from Coös County, as arranged in the State Museum at the Agricultural College. Plate V, which is a photo-lithograph from the county map, shows where each specimen was obtained.

HURONIAN GROUP.

1, 16, 38, 39, 44, 84, 85, 87, 93, 94, 99, 116, Arenaceous sandstone-schist.

2, 6, 8, 9, 19, 40, 64, Greenish siliceous schist.

3, 14, 45, 97, Argillaceous mica schist.

4, 5, Serpentine.

7, Mica schist, with irregular texture and quartz veins containing pyrite.

10, 11, 12, 13, Argillaceous schist.

15, Banded arenaceous sandstone-schist.

17, Light gray siliceous schist.

18, 26, 28, Gray argillaceous mica schist.

21, Gray argillaceous slate.

22, Very fine-grained gneiss.

23, Gneissic schist.

24, Fine-grained diorite-schist.

25, 30, Light gray argillaceous schist.

27, Argillaceous sandstone.

29, 43, 65, 92, 105, 119, Gray argillaceous schist.

31, Grayish-green diorite-schist.

32, 33, 75, 76, Clay slate.

34, 35, Gray siliceous schist—Novaculite.

36, 89, 95, 100, Porphyritic diorite.

41, Greenish chloritic schist.

42, Argillaceous schist.

66, Quartzose mica schist.

67, Siliceous feldspathic schist.

68, Gray mottled siliceous schist.

69, Steel-gray siliceous schist.

70, Argillaceous sandstone-schist.

71, 72, 73, 74, Greenish-gray siliceous schist.

77, Quartzose gneiss.

78, Fine-grained gneiss.

79, Gneiss rich in quartz.

81, Chloritic schist, with nodules of epidote.

80, Greenish schist, with gneiss interstratified.

82, 83, 90, 91, 96, 98, Chloritic schist.

86, Diorite.

117, Grayish diorite-schist.

118, Argillaceous schist.

COÖS GROUP.

46, Arenaceous clay slate.

47, 48, 51, 53, 54, 56, 61, 62, 103, 104, 106, 107, 112, Argillaceous schist.

49, Argillaceous mica schist with pyrite.

50, 55, 97, 109, 110, 111, Argillaceous mica schist.

52, 63, Ochrey argillaceous schist.

57, 59, Ochrey argillaceous mica schist.

58, 101, 102, 113, Calciferous mica schist.

60, Argillaceous schist—wrinkled.

115, Argillaceous schist—much contorted.

COÖS GROUP.

120, Ochrey argillaceous schist.

121, Quartz—a veinstone.

122, Argillaceous mica schist.

123, 128, Clay slate.

124, 125, Calciferous mica schist.

127, Calciferous slate.

129, Argillaceous schist.

130, Quartz, a veinstone with sphalerite and galenite.

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* For the nomenclature we have used the reader is referred particularly to *Rocks Classified and Described*, B. Von Cotta, English ed., P. H. Lawrence, and the *Geology of Michigan*, vol. ii, 1873.

131, Quartz schist.

132, Argillaceous schist—ferruginous.

133, Argillaceous schist.

134, Argillaceous schist—contorted.

HURONIAN GROUP.

135, Hydro-mica schist, with magnetite.

136, 137, Hydro-mica schist.

138, 139, 148, Hydro-mica schist.

140, 141, 144, Hornblende schist.

142, 145, 149, Mica schist.

143, Mica schist, with staurolite and garnets.

146, Garnetiferous mica schist.

147, Hydro-mica schist, with magnetite.

150, Mica schist, with small crystals of staurolite.

151, Granitic gneiss.

152, Fine-grained gneiss, with staurolite.

153, Mica schist, with staurolite.

154, 155, 156, Mica schist, with garnets.

157, 158, Granitic gneiss.

160, Coarse granite.

161, Gneissic mica schist.

162, Gneiss.

163, 164, Aplite—feldspar and quartz.

165, 166, Mica schist.

167, Mica schist, fine and even in texture.

168, Granitic gneiss.

169, Granite—a veinstone.

170, Coarse granite, a veinstone with garnets and beryl.

171, Chloritic schist.

174, 175, 176, 180, 181, 200, Gray siliceous schist.

177, 179, Hydro-mica schist.

178, Dark gray siliceous slate.

182, Argillaceous siliceous mica schist.

183, 184, Argillaceous siliceous schist.

185, 186, 187, 188, "Trap."

189, Granite.

190, 191, Argillaceous schist.

192, Quartz—a veinstone.

194, 196, 198, Argillaceous mica schist.

195, Mica schist.

197, Mica schist, with staurolite.

199, Arenaceous sandstone-schist.

201, Dark gray argillaceous siliceous schist.

202, Hornblende schist.

108, 173, Arenaceous sandstone-schist.

172, Clay slate.

COÖS GROUP.

203, 206, Argillaceous mica schist.

204, Argillaceous schist—wrinkled.

205, Mica schist.

207, Diorite—intrusive.

208, Calciferous mica schist.

209, Quartz—a veinstone.

210, Argillaceous schist.

211, 216, 227, 228, 231, 232, 236, 237, 245, 246, 251, Calciferous mica schist.

212, 234, 252, 261, Argillaceous schist.

217, 262, Argillaceous schist—wrinkled.

215, Clay slate.

218, 255, 257, Ochrey mica schist.

226, Arenaceous mica schist.

230, 235, 242, 253, 258, 263, Argillaceous mica schist.

229, Argillaceous mica schist—calciferous.

233, Argillaceous schist—calciferous.

238, Quartz, with ankerite.

256, 260, Mica schist.

259, Siliceous mica schist.

HURONIAN GROUP.

213, Diorite.

214, Calcareous diorite.

219, Diorite—slaty.

222, Arenaceous sandstone-schist.

223, "Trap."

224, Fine-grained quartzose gneiss.

225, Gneissic mica schist.

221, Granite—intrusive.

COÖS GROUP.

241, 243, 244, 247, 248, 250, Calciferous mica schist.
240, Mica schist.
249, Siliceous limestone.
264, Argillaceous mica schist.
239, Protogine—intrusive.
265, Sienite.
266, 267, Limestone.
268, Mica schist with limestone.

HURONIAN GROUP.

271, Dark gray mica schist.
275, Argillaceous mica schist.
276, 277, Arenaceous mica schist.
280, 285, 287, 288, Mica schist.
284, Pyritiferous mica schist.
286, Chloritic schist.
278, Gneiss.
281, Fine-grained gneiss, rich in quartz.
282, Fine-grained gneiss.
272, 279, "Trap"—intrusive.
269, 270, Sienite—intrusive.
283, Granite.
385, Granite.
386, Siliceous schist.

Vermont.

289, 290, Mica schist.
291, Argillaceous mica schist.
292, Granite.
293, Fine-grained, reddish granite.
294, 295, Mica schist.
296, Contorted mica schist.
297, 298, Mica schist.
299, 301, Hornblende schist.
300, Dark gray gneiss.
302, 303, 304, 305, 306, 307, Gray siliceous schist.
308, Gray siliceous schist.
309, Gray siliceous schist.
310, 311, Fine-grained mica schist.
312, Chloritic schist.
313, Chloritic hornblende schist.
314, Quartz.
315, 316, 317, 320, 322, Granitic gneiss.
318, Granite.
319, 325, 330, Hornblende schist.
321, Granular quartz.
323, 326, Gneiss.
324, Siliceous slate.
327, Grayish-black quartzite.
328, Quartzite—plumbaginous.
329, Grayish-black siliceous slate.

MONTALBAN GROUP.

331, Coarse, dark-grayish gneiss.
332, 333, Coarse grayish gneiss.
334, 335, 337, Dark grayish gneiss.
336, 338, Granitic gneiss.
339, 340, 341, Grayish gneiss.

HURONIAN GROUP.

342, Light-gray siliceous schist.
343, 344, Gray siliceous schist.
345, Hornblende schist.

ATLANTIC SERIES.

346, 347, 349, 352, Common gneiss.
348, Protogine gneiss.
351, Hornblende schist.

HURONIAN GROUP.

353, 354, 358, 359, 362, 363, 364, 365, 366, Gray siliceous schist.
355, Mica schist.
356, 361, 367, Hornblende schist.
357, Argillaceous mica schist, with acicular crystals of hornblende.
360, Hornblende gneiss.
368, Granitic gneiss.
369, Dark gray gneiss.

MONTALBAN GROUP.

370, 387, Fine-grained gneiss.
371, Greenish-drab siliceous schist.
372, Dark gray gneiss.

373, 374, 378, 388, Granitic gneiss.
375, 376, 379, 383, 385, Granite.
377, Gneiss rich in quartz.
380, 381, 384, Light gray gneiss.
382, Reddish granite, with dolerite.
386, Siliceous schist.

HURONIAN GROUP.

389, Drab siliceous schist.
390, Siliceous schist.
391, 392, Bluish-gray siliceous schist—Novaculite.
393, Siliceous schist, with hornblende.
394, Light drab siliceous schist.
395, Siliceous schist—argillaceous.

INTRUSIVE ROCKS.

396, 397, 398, 399, 403, Sienite.
400, Felsite—a veinstone.
401, Breccia.
402, Granite.
404, "Trap."
405, Diorite.
407, 408, 409, Reddish granite.
416, Sienitic granite.

HURONIAN GROUP.

412, 413, 428, Dark gray quartz schist.
414, Trap with epidote.
415, Argillaceous sandstone.
427, Quartz.
418, Feldspathic quartzite.
419, 420, Siliceous limestone.
421, Quartzite.
422, 423, 433, 436, Siliceous schist—argillaceous.
424, 426, Feldspathic quartz schist.
425, Gray siliceous schist.
429, 431, 448, 451, Quartz schist.
430, Mica schist rich in quartz.
434, Argillaceous mica schist, with staurolite.
435, Hornblende schist.
437, 452, 453, Argillaceous mica schist.
438, Ferruginous mica schist.
449, Fine-grained dark mica schist.
450, Fine-grained mica schist.
454, Coarse granite.

INTRUSIVE ROCKS.

432, 445, 446, Sienite.
439, 440, 441, 442, 444, 447, Granite.
443, Aplite.

VERMONT.—HURONIAN GROUP.

455, Granitic gneiss (M).
456, Dark gray gneiss (M).
486, Sandstone—friable.
490, Mica schist.
491, Granitoid gneiss.

COÖS GROUP.

458, 468, 474, 479, Calciferous mica schist.
459, Hornblende mica schist.
460, 461, 466, Mica schist.
462, Quartzite.
463, Quartz—a veinstone.
464, Granitic gneiss.
467, Quartz with hornblende.
469, 470, 475, Argillaceous mica schist.
471, A veinstone with Vesuvianite.
472, Vesuvianite.
473, 476, Siliceous limestone.
477, Quartz.
478, Hornblende.

INTRUSIVE ROCKS.

465, 480, 483, 484, 485, 487, Granite.
481, Reddish granite.
482, "Trap."
488, 489, Sienite.

ATLANTIC SERIES.

Berlin.

492, Gray micaceous gneiss.
493, 510, 515, 516, 521, Hornblende schist.
494, Siliceous sandstone.

495, 506, Coarse granite.
496, Dark gray gneiss.
497, 505, 519, 522, Gneiss.
498, Gneiss with epidote.
499, Quartzite.
500, Pyritiferous mica schist.
501, Pyritiferous schist with hornblende.
502, Micaceous gneiss.
503, Mica schist.
504, Granitic gneiss.
507, 508, 509, 526, Felsite.
511, 523, 524, Granite.
512, 518, Common gneiss.
513, Hornblende schist with veins of calcite.
514, Coarse gneiss.
520, Quartz with pyrite.
527, "Trap."

HURONIAN GROUP.

528, 532, Hornblende schist.
529, Drab siliceous schist.
530, 535, Gneiss.
531, 534, 536, Gray siliceous schist.
533, Mica schist.
542, Mica schist rich in quartz.
543, 544, 545, Dark quartzite.
551, Dark micaceous quartzite.
558, Feldspathic epidotic schist.
566, Quartzite—argillaceous.

INTRUSIVE ROCKS.

537, 538, Granite.
539, 540, 541, 546, 549, 550, 552, 554, 555, 556, 557, 559, 560, 561, 562, 563, 564, 565, 568, 569, 570, 578, 579, 580, 581, 583, Porphyrite.
548, Breccia.
549, Felsite.
553, Labradorite.
562, Felsite porphyry.
567, Granite—a veinstone.
571, Schist with porphyrite.

HURONIAN GROUP.

572, 573, 577, Quartzite.
574, 612, 625, Feldspathic siliceous schist.
575, Dark feldspathic schist.
576, Feldspathic schist.
582, Feldspathic quartz-schist.
584, Dark, variegated quartz-schist.
585, Dark gray siliceous mica schist.
586, Gneiss.
587, Mica schist.
588, Chloritic feldspathic gneiss.
589, Argillaceous mica schist.
590, 593, 597, 600, Chloritic feldspathic schist.
591, 611, 615, 616, 620, 621, 622, Chloritic schist.
592, 617, Hornblende schist.
594, Sandstone-schist.
595, Chloritic sandstone-schist.
598, Micaceous feldspathic schist.
599, 601, 624, Magnesian chloritic schist.
604, Feldspathic sandstone-schist.
605, Siliceous limestone.
606, 608, Siliceous schist.
607, Greenish siliceous schist.
609, Green chloritic schist.
613, Epidosite.
614, Chloritic schist with epidosite.
618, Chloritic quartz-schist.
619, "Trap."
623, Chloritic schist.
626, Gneissic schist.

MONTALBAN GROUP.

627, 628, 629, 630, 633, 644, 671, 673, Gneissic mica schist.
631, 632, 637, 640, 643, 646, 647, 666, Granitic gneiss.
635, 636, Fine-grained gneiss.
638, Gneissic schist.
639, Gray gneissic schist.
641, 648, 658, 659, 660, 665, 667, Gneiss.

642, 657, 669, Hornblende schist.
645, Mica schist.
652, Fine-grained dark gneiss.
653, 654, Light gray gneiss.
655, Gray gneiss.
661, 662, Quartzose vein.
670, Siliceous schist.
683, Coarse gneiss.

INTRUSIVE ROCKS.

649, Trappean diorite.
650, 651, "Trap."
656, 663, 664, 668, 674, 678, Granite.
672, Graphic granite.
675, Granitic vein.

ATLANTIC SERIES. — MONTALBAN GROUP IN PART.

700, 716, 718, Mica schist.
701, 702, 704, 706, 707, 708, 709, 712, Coarse gneiss.
703, Granitic gneiss.
705, Coarse reddish gneiss.
710, 711, Hornblende schist.
717, 719, 722, 723, 724, Common gneiss.
720, Hornblende gneiss.

HURONIAN GROUP.

721, Chloritic schist.
725, Hornblende gneiss.
726, 753, Gray argillaceous schist.
727, 741, 748, 755, 760, Chloritic schist.
728, 731, Quartz.
729, Hornblende schist.
730, Greenish mica schist.
732, 734, Mica schist.
733, Chloritic schist and quartz.
736, 744, 750, 751, Clay slate.
737, Slate.
740, 745, Drab clay slate.
752, Chloritic quartz-schist.
753, Gray argillaceous schist.
754, Calcareous chloritic schist.
756, "Trap."
757, Chloritic sandstone-schist.
758, Quartz with pyrite.
759, Quartz with pyrite.

HELDERBERG GROUP.

739, 747, Argillaceous sandstone.
742, 743, 746, Argillaceous schist.

VERMONT.—HURONIAN GROUP.

762, Chloritic schist.
763, 767, 768, Gray argillaceous schist.
764, A vein quartzose.
765, Gneissic schist.
766, Feldspathic schist.
769, Quartz.
770, 773, Argillaceous schist.
771, Arenaceous schist.
772, Clay slate.
774, Argillaceous mica schist.
775, Greenish argillaceous schist.
776, Greenish mica schist.
777, Gneiss.

Sections Crossing the Coös and Essex District.

PLATE VI.

Section XIV.

Section XIV, the most northern measured, extends from a point on the eastern boundary, three and a half miles south of Mt. Carmel, directly west, and strikes Hall's stream at the mouth of West Branch. The country between these points is an unbroken wilderness, save where Second lake breaks the forest, or the streams follow down the valleys. The height at the Maine line is 2090 feet. The rock is a stratified

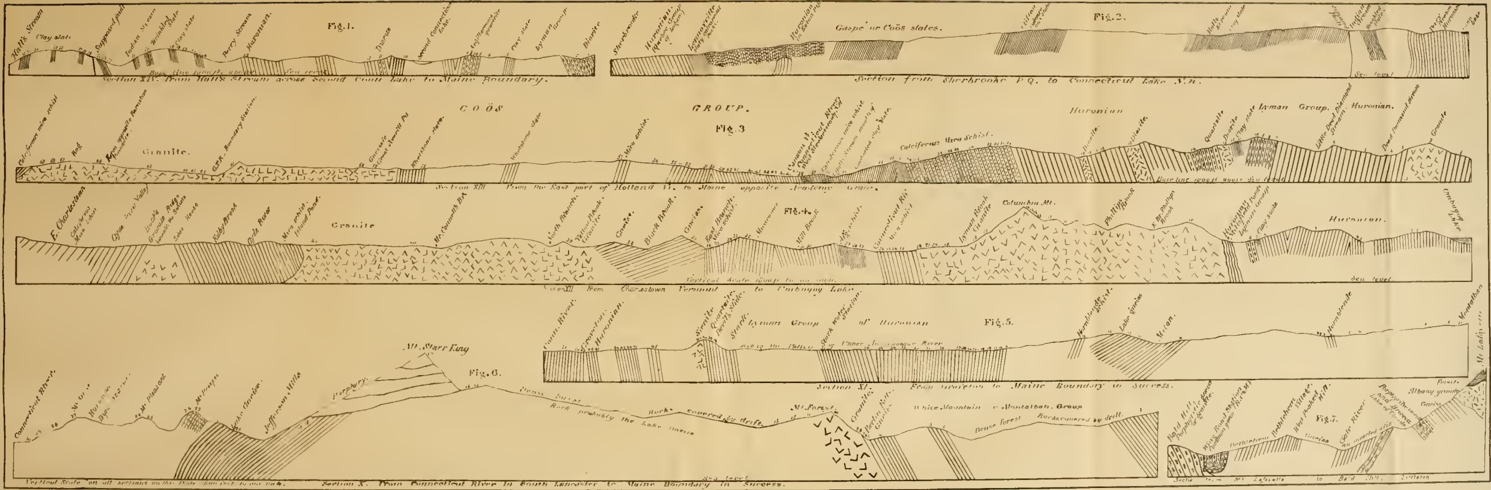


Fig. 1.
Section XIV. From Hall's Stream across Second Conn. Lake to Maine Boundary.
Fig. 2.
Gaspe or Coös slates.
Section from Sherbrooke P.Q. to Connecticut Lake N.H.
COÖS GROUP.
Fig. 3
Huronian
Lyman Group. Huronian.
Granite.
Calciferous Mica Schist.
Section XIII From the East part of Holland Vt. to Maine opposite Academy Grant.
Fig. 4.
Granite
Columbia Mt.
Huronian.
Sea level.
Section XII From Charlestown Vermont to Umbagog Lake.
Lyman Group of Huronian
Fig. 5.
Section XI. From Grafton to Maine Boundary in Success.
Mt. Starr King
Fig. 6.
Porphyry
Dense forest
Rock covered by drift.
Mt. Forest
White Mountain or Montalban Group
Sea level
Section X. From Connecticut River in South Lancaster to Maine Boundary in Success.
Fig. 7.
Albany granite
Gneiss
Connecticut River
Jefferson Mills
Mt. Pleasant

diorite; it is of a light green color, is compact, and weathers to a light greenish gray, and has an easterly dip. Two miles west we find a narrow band of clay slate; the strata are nearly perpendicular, but dip westerly 80°. A mile west there is a dark gray siliceous schist, passing into a light gray novaculite-schist; this has also a westerly dip. Following this is a light gray siliceous schist, with an easterly dip. At Second lake there is a compact, green chloritic schist, with a westerly dip. Succeeding this on the west is a variety of diorite, interstratified with which is a whetstone grit. These rocks, where they outcrop on the section, have an easterly dip, but in other places the dip is variable. The diorite, with the whetstone grit or arenaceous sandstone-schist, extends three quarters of a mile west of Perry stream. Then there follows on the west an argillaceous schist; some of the bands are hard and compact, with an even cleavage; but with these there are dark bands, wrinkled and corrugated, and both contain small cavities filled with a yellowish brown powder, and for a little more than three miles these schists have an easterly dip. Three fourths of a mile west of Indian stream the schist becomes more fissile, the harder bands are less frequent, and in places the rock is hardly distinguishable from common clay slate; but here, as in the more wrinkled varieties, we find the same kind of cavities, only they are sometimes larger, and from near the height of land to Hall's stream the strata have a westerly dip: probably the easterly dip is due to a fault. The height at Hall's stream is 1740 feet.

Section XIII.

From the Maine boundary, opposite the Academy grant, for nearly fifteen miles, the primeval forests for the most part cover the entire country, and the surface generally is broken by irregular mountain ridges, and in places there are high, rocky cliffs. On the Maine boundary the rock is a hydro-mica schist. This extends for three quarters of a mile or more up the slope of the ridge to the west, which has an axis of granitoid gneiss. On the western slope of this ridge there is a narrow band of mica schist. This is followed by hydro-mica schist, which extends several miles westward. Where the Dead Diamond cuts this rock it has worn a deep gorge, and the place is known as the Narrows, and here crystals of magnetite are quite common. The valley of the Little Dead

Diamond, from where the stream flows into the Dead Diamond, about a mile above the Narrows, forms a deep, irregular basin towards Mt. Pisgah and the water-shed between the Magalloway and the Connecticut. The hydro-mica schist forms a monoclinal axis, and has everywhere a westerly dip, though nearly vertical. In the basin of the Little Dead Diamond the rock is sometimes quite argillaceous, but, approaching the water-shed, it seems to pass into a gray siliceous schist. On the west side of the water-shed, on the head waters of Cedar stream, there is a band of clay slate perhaps a quarter of a mile in width. It has generally an easterly dip, at a high angle. Following this is an arenaceous schist that extends to Clarksville, but interstratified with it is a band of quartzite and three bands of diorite. All these rocks have an easterly dip. In Clarksville, also extending into Canaan, Vt., there is a series of calcareo-argillaceous rocks, consisting of several folds. In the east part of Clarksville the rocks are both argillaceous and micaceous, and frequently they contain lime as an incrustation. In the north part of Clarksville, particularly in the vicinity of the bridge across the Connecticut, the rocks are mainly micaceous. At Hall's stream there is a wrinkled and corrugated argillaceous schist. This is followed by a calciferous mica schist; and on the Connecticut river at Canaan there is a band of siliceous limestone. West of Canaan village the rocks consist of micaceous schist; probably for the most part they are calciferous mica schist. At Great Averill pond there seems to be a granitoid gneiss; and westward, to the first road in Holland, all the outcrops of rock are granite. Then follows a calciferous mica schist.

Section XII.

Section XII extends from Umbagog lake directly west, and strikes the Connecticut river half a mile north of Lyman brook in Columbia, and extends west to a point about two miles south of East Charlestown. Between these points the country for the most part is covered by forests, and is broken by mountain ridges and cut by deep ravines. The towns traversed in measuring the section were Errol, Millsfield, Odell, and Columbia, in New Hampshire, and Bloomfield, Brunswick, Ferdinand, Brighton, and Charlestown, Vt. Umbagog lake is 1256 feet above the sea level; and on its eastern shore we find a dark-colored granite, peculiar in being composed chiefly of quartz and a dark, rusty brown mica. In the lake there is a diatomaceous earth; and on its western shore is a mica schist, the strata of which are nearly vertical, but generally the dip is from 75° to 80° easterly. The hill between the lake and the Androscoggin is 244 feet above the former. In one specimen from the eastern slope of this hill we noticed a trace of copper. Bragg's bay is fifty feet lower than the lake; and west of the bay the strata are still more nearly perpendicular, and a mile west they dip westerly, and the mica schist here contains garnets. Passing the height of land, and descending towards the Millsfield ponds, on this slope we still find mica schist; but three fourths of a mile east of the ponds there is an argillaceous schist, which has an easterly dip, as, also, the mica schist found on either side of it. The hills south-west of Millsfield pond are mica schist; but the strata seem to have been more disturbed than elsewhere on the section, as we found that the strata dip to the south-east and south. Succeeding this schist on the west, and forming a high mountain ridge on the border of Millsfield, there is a granitic rock, probably a granitoid gneiss. It is composed of a light-colored feldspar, a light gray quartz, and a small proportion of mica.

Leaving the ridge, we descend into the valley of Phillips brook, where there is a considerable space, nearly level, covered with drift. Passing over the height of land west of this brook we come to the head waters of Nash stream; then we pass three apparently parallel ridges, all composed of granite. The rock is fine-grained, of even texture, is compact, rather tough, and it differs from the last in that the feldspar is of a light flesh-color. Between the branches of Nash stream and Lyman brook we find, at the height of land, a coarse granitic rock, and it is undoubtedly intrusive. On the western slope of this ridge there was not seen a single outcrop of rock for a mile and a half; but on Lyman brook, a little more than half a mile above the last saw-mill, there is a coarse granite, but it differs from the last in being very much jointed; sometimes the fragments are not more than three or four inches through. Farther west this peculiar jointed structure was not seen; but the granite is massive, is very coarse, and is composed mostly of quartz and feldspar, but it has also a very little black mica. West of the granite, at W. Kimball's, the mica schist begins, and extends on the line of the section to the

Connecticut. The strata stand at a high angle, and have an easterly dip. Near the granite the strata are everywhere penetrated by veins of granite; but the veinstones are of a much finer texture than the mass of the granite.

West of the Connecticut the first outcrop is an argillaceous schist, with an easterly dip. Where the section crosses Mill brook we have the same rock, but west the rocks become micaceous, and the strata are everywhere nearly vertical. Between East Branch and Yellow brook there is a granitoid gneiss, which appears to have a westerly dip of 15°. Between Yellow Branch and Island Pond there is the same granitic rock that is found at Umbagog lake, and it consists chiefly of a dark gray quartz and brownish mica. This is succeeded by a mica schist, probably of the Montalban group, with a westerly dip.

Section XI.

Section XI passes through Success, Milan, Stark, and Northumberland. This section begins on the line of Maine, near the northern border of Success. At the line the height is 1690 feet. There is, perhaps three fourths of a mile north of where the section begins, an outcrop of hornblende schist; and following the line of the section there are no outcrops of rock for two or three miles, but there is an abundance of boulders of the White Mountain gneiss,—so it is altogether probable that that is the rock underlying the drift. Four miles and a half from the line of Maine, at an old logging camp, there is a hornblende schist which has an easterly dip. This rock continues to outcrop for a mile; thence to the Androscoggin there is nothing but drift, though it is probable that this rock continues to the river. Going west from Milan Corner, the first rock we find is a gneiss that dips nearly north, but generally N. 15° W., and not more than 15° or 20°. The height of Milan hill is 1460 feet. Succeeding this on the west is a hornblende schist, probably a repetition of that on the east of the gneiss, on which it rests unconformably. At West Milan we find a gray siliceous schist, with bands of hornblende schist, the strata of which are nearly vertical. Near the line of Stark there is a slight change, and the rock becomes more siliceous. In places the strata, as on Phillips brook, are vertical. We find, also, that they dip both east and west. Following the Upper Ammonoosuc these rocks extend west to Stark water-station. At Stark station we have at the east end of the high bluff of rock a dark siliceous schist, probably an older rock than the last; and this is followed by sienite porphyrite, portions of which are colored by manganese, but elsewhere it is the most beautiful rock for a building stone that we have seen in New Hampshire. Along the river there are no outcrops of rock for two miles; then we have a rock, apparently an altered sandstone. On Jonathan Pond brook we have a feldspathic quartzite; but a short distance up the brook we have a quartzite, probably an altered limestone, but the first mentioned rock extends two miles west of Groveton.

Section X.

Section X extends from the Maine line, in the southern part of Success, through Success, Berlin, Kilkenny, Jefferson, and Lancaster, and strikes the Connecticut just north of the mouth of John's river. On the Maine line the height is 1940 feet. The rock is White Mountain gneiss, and here it has an easterly dip, and it extends probably two thirds of the way across Success. It is followed by a hornblende schist, on which it rests. This schist, with beds of granitic rock, extends to Berlin falls, at which place it is cut by numerous trap dykes. Mt. Forist, west of Berlin falls, is a coarse granitic rock, more like an immense veinstone than anything else. While at the Falls the rock dips south-east, on the railway below the station the rock is nearly vertical, but we have both easterly and westerly dips. West of Mt. Forist the outcrops of rock are not very numerous. There is a fine-grained, reddish granite east of the Upper Ammonoosuc, and a coarser variety on the hills west.

In the valley, at the head of the branch of Israel's river that has its rise north-east of Starr King, there are a hornblende gneiss and a fine-grained, dark-colored gneiss. The rock of Starr King is porphyrite, and a similar rock is found on the summits of all the peaks of the Pilot range, except that in some instances the mass of the rock is compact instead of being composed of distinct crystals. In Jefferson, near the Waumbek house, we find a common gneiss. The dip of this rock, not only on the section but elsewhere, is 10° to 20° northerly, and generally 10° to 15° west of north. This gneiss extends to Mt. Prospect, just above the road on the east side of the mountain. The rock of Mt. Prospect, Mt. Pleasant, and the ridge west is composed mainly of quartz, though in some places feldspar is abundant, and always a green chloritic mineral; and on the west slope of Mt. Orne there is also hornblende.

Section from Sherbrooke, P. Q., to Connecticut Lake.

This interesting section shows the Huronian rocks on both sides of the Coös group, as well as an island of Huronian in the latter. At Sherbrooke the Huronian rocks consist of greenish hydro-mica schist, with an easterly dip. At Lenoxville we have the beginning of the Coös group, and the rocks consist of calcareous slate resting on the Huronian. To the east the slates have intercalated bands of siliceous limestone. In Clifton the dip is westerly, and the rocks consist of calcareous slates and micaceous ochrey schists. Between Hall's and Indian streams the rocks are chiefly argillaceous schists, and in general they are only slightly calcareous. Near Indian stream there appears to be a fault, and east of this we find an easterly dip. From Perry stream to Connecticut lake the Huronian rocks consist of light gray, siliceous, greenish, chloritic, and arenaceous sandstone-schists, with diorite, and the strata are everywhere nearly vertical.

Catalogue of Sections.

Section XIV.—From the Maine Line to Hall's Stream.

1. Diorite, state line.
2. " one fourth mile west of state line.
3. Slate, two miles west from state line.
4, 5, 6, and 7. Argillo-quartzite, two miles east of Second lake.
8. Greenish indurated schist, a mile and three fourths east of Second lake.
9. " " a mile and a quarter east of Second lake.
10. Hard, greenish schist, a mile and a half west of Second lake.
11. Diorite.
12. Arenaceous schist, half a mile west of the head of Bog brook.
13. Diorite, three fourths of a mile east of Perry stream.
14. Arenaceous schist, half a mile west of Perry stream.
15. " " three fourths of a mile west of Perry stream.
16. Argillaceous schist, a mile and a quarter west of Perry stream.
17. Argillo-mica schist, three miles east of Indian stream.
18. Argillaceous schist, wrinkled and contorted, a mile and a half east of Indian stream.
19. Argillaceous schist, fissile, near last.

20. Argillaceous schist, wrinkled, three quarters of a mile east of Indian stream.
21. Argillaceous mica schist, somewhat calcareous, half a mile east of Indian stream.
22. Wrinkled micaceous schist, half a mile west of Indian stream.
23. Iron-ore breccia, a boulder near the last.
24. Argillaceous schist, wrinkled and spotted.
25. " " " a mile west of Indian stream.
26. " " " a mile and an eighth west of same.
27. " " a mile and a half west of Indian stream.
28. " " spotted and fissile, two and a quarter miles west of Indian stream.
29. " " wrinkled, near 28.
30. " " wrinkled and spotted. [This and the two following are not far from three quarters of a mile from Indian stream.]
31. " " with quartz veins.
32. " " spotted, near Hall's stream.

Section XIII.—From the east part of Holland, Vt., to the Maine Boundary, opposite the Academy Grant.

1. Hydro-mica schist, formerly called "talcose," Maine boundary.
2. Granitoid gneiss, a mile and a quarter west of Maine boundary, and forming the axis of the mountain ridge east of the Dead Diamond.
3. Mica schist, two miles from Maine boundary; contains hornblende.
4. Hydro-mica schist, with crystals of magnetite, the Narrows, Dead Diamond.
5. " " argillaceous, a mile west of the Dead Diamond.
6. " " " about two miles west of the Dead Diamond.
7. Indurated schist, a mile east of water-shed, Connecticut and Magalloway.
8. " " argillaceous and ferruginous, following 7.
9. " " argillaceous and micaceous, half a mile east of water-shed.
10. Compact, indurated schist, quartzose, calcareous, and ferruginous, water-shed.
11. Clay slate, three quarters of a mile west of water-shed.
12. Argillaceous mica schist, with decomposing mineral.
13. Diorite, about a mile west of water-shed. This is interstratified with an arenaceous schist.
14. Arenaceous schist, two and a half miles west of water-shed.
15. Diorite, Clarksville.
16, 17, 18. Arenaceous schist, Clarksville.
19. Diorite, Clarksville.
20. Argillaceous schist, Clarksville.
21. Argillaceous schist, calciferous, Clarksville.
22. " " " "
23. Calciferous schist, Clarksville.
24. " " "

25. Diorite, intrusive, Clarksville.
26. Siliceous limestone, "
27. Decomposing schist, calciferous, Clarksville.
28. Siliceous limestone, Clarksville.
29. Decomposing limestone, Clarksville.
30. Quartz vein, Clarksville.
31, 32, 33. Argillaceous schist, Clarksville.
34. Mica schist, Clarksville.
35. Argillaceous mica schist, Clarksville.
36. " schist, Stewartstown.
37. " schist with ferruginous spots, Pittsburg.
38. Mica schist, north-east part of Canaan.
39. Siliceous limestone, north-east part of Canaan.
40. Arenaceous schist, " "
41. Adamsite schist, " "
42. Mica schist, one mile south-west of Canaan village.
43. Veins of quartz in 42.
44. Mica schist, Canaan.
45. " " a mile and a half from Connecticut river.
46. Argillaceous mica schist, Canaan.
47. " arenaceous schist, about six miles west of Connecticut river in Canaan.
48. Mica schist, Canaan.
49. " " begins to dip west, Canaan.
50. Argillaceous mica schist, Canaan.
51, 52, 53, 54, 55. Mica schist and quartzite, Canaan.
56. Staurolite schist (loose), Canaan.
57. Mica schist (mica black and abundant), Canaan.
58. " " Averill.
59. Granitic gneiss, boundary of Averill and Norton.
60. " " a mile west of Great Averill pond.
61. Granite, half a mile east of Grand Trunk Railway, Norton.
62, 63, 64. Granite, two miles west of Grand Trunk Railway, Norton.
65. Granite, boundary of Norton and Holland.
66, 67, 68, 69. Granite, Holland.

Section XII.—From East Charlestown, Vt., to Umbagog Lake.

1. Mica schist, cupriferous, Errol.
2. " " a mile and a half west of Umbagog lake, Errol.
3. " " Bragg's bay.
4. " " one fourth of a mile west of Bragg's bay.
5. " " with garnets, half a mile west of Bragg's bay.

6. Mica schist, a mile and a half west of Bragg's bay.
7. Argillaceous schist, east part of Millsfield.
8. Hornblende schist, " "
9. Mica schist, one fourth of a mile west of Millsfield pond.
10. Granitoid gneiss, near west line of Millsfield.
11. " " Odell.
12. " " "
13. " " west part of Odell.
14. " " east part of Stratford.
15. " " " "
16. Schist, quartzose, " "
17. Granite, mountain, head of Lyman brook, Stratford.
18. " near " " "
19. " a mile above saw-mill, Lyman brook.
20. " near W. Kimball's (west), Stratford.
21. " veins, with mica schist, near W. Kimball's.
22. Mica schist with granite, near W. Kimball's.
23. " " " " " " (east).
24. " " one mile east of Connecticut river.
25. " " three fourths of a mile east of Connecticut river.
26. " " half a mile east of Connecticut river.
27. " " one fourth of a mile west of Connecticut river, Bloomfield.
28. Argillaceous schist, slaty, half a mile west of Connecticut river, Bloomfield.
29. " " " " " " "
30. Mica schist, three fourths of a mile west of Connecticut river, Bloomfield.
31. " " two miles west of Connecticut river, Bloomfield.
32. " " " " " "
33. " " near M. Fuller's, Bloomfield.
34. " " between Fuller's and East Branch.
35. " " " " "
36. " " East Branch.
37. Gneiss, one mile west of East Branch.
38. " three fourths of a mile west of Black brook.
39. Granite (with a triclinic feldspar), between Yellow and North branches.
40. " near Grand Trunk Railway, Ferdinand.
41. " near Island pond, Brighton.

Section XI.—From Groveton to the Maine Boundary, near north line of Success.

1. Mica schist, boundary, north line of Success.
2. Hornblende schist, half a mile west of line of Maine.
3. White Mountain gneiss, a mile and a quarter west of line of Maine.

4. White Mountain gneiss, a mile and three eighths west of line of Maine.
5. Schist, chloritic, three miles west of line of Maine.
6. Hornblende schist, three and one eighth miles west of line of Maine.
7. " " " " " "
8. Mica schist, three and three eighths miles west of line of Maine.
9. Hornblende schist, three and a half miles west of line of Maine.
10. Gneiss, three quarters of a mile west of line of Maine.
11. Hornblende schist, F. Bennett's, Milan.
12. Gneiss, G. Russell's, Milan.
13. " B. Flint's, "
14. Hornblende schist, near W. Fogg's, Milan.
13. Mica schist (quartzose), cut, G. T. R., three fourths of a mile south-east of West Milan.
14. Argillaceous schist (quartzose), same as 13.
15. Schist (argillaceous, with hornblende), same as 13.
16. Argillaceous quartzite, same as 13.
17. " " with hornblende, same as 13.
18. " " " " "
19. " " " " "
20. " mica schist, same as 13.
21. " schist with hornblende, near school, West Milan.
22. " " West Milan.
23. " " "
24. Hornblende schist, "
25. Argillaceous schist, "
26. " " "
27. Hornblende schist, "
28. Argillaceous schist, "
29. " quartzite, three fourths of a mile west of Dummer.
30. Hornblende schist, " " " "
31. Argillaceous mica schist, " " " "
32. " quartzite, railway crossing west of Dummer.
33. " " Phillips brook, Stark.
34. " " road opposite Phillips brook, Stark.
35. " " Phillips brook, Stark.
36. " " L. Potter's, Stark.
37. " " Stark water-station.
38. " " (a dyke), Devil's Slide, Stark.
39. "Trap" (a dyke), Devil's Slide, Stark.
40. Sienite, Devil's Slide, Stark.
41. " with micaceous quartzite, Devil's Slide, Stark.
42. Sandstone, three fourths of a mile west of S. Cole's, Stark.

43. Quartzite, Jonathan Pond brook, Northumberland.
44. " micaceous, same as 43.
45. Iron-ore breccia, Groveton.
46. Greenish quartzite, Groveton.
47. Chloritic feldspathic schist, Groveton.
48. Quartzite, Groveton.
49, 50, 51. Chloritic feldspathic schist, Groveton.

Section X.—From Connecticut River at South Lancaster to the Maine Boundary, near line of Success.

1. White Mountain gneiss, Success.
2. " " " "
3. Mica schist, Success.
4. Gneiss, Berlin falls.
5. " "
6. "Trap," "
7. Coarse granite, one fourth mile west of Berlin falls.
8. " " " " "
9. " " half a mile west of Berlin falls.
10. "Trap," Mt. Forist.
11. Gneiss, near Wheeler's mill, Berlin.
12. " half a mile above Wheeler's mill, Berlin.
13. Fine-grained reddish granite, west part of Berlin.
14. " gneiss, Berlin.
15. Hornblende, near line of Kilkenny.
16. Fine-grained dark gneiss, "
17. Porphyrite, summit of Mt. Starr King.
18. Gneiss, Jefferson hill.
19. " Jefferson.
20. " "
21. Gneiss, east side of Mt. Prospect, Lancaster.
22. Chloritic sandstone-schist, north of Mt. Prospect, Lancaster.
23. " " west slope of Mt. Prospect, Lancaster.
24. " " east " " "
25. " " Mt. Pleasant, Lancaster.
26. " " ridge west of Mt. Pleasant, Lancaster.
27. " " Martin Meadow hills, Lancaster.
28. " " Mt. Orne, Lancaster.
29. Diorite schist, west slope of " "
30. " " " " "

CHAPTER III.

GEOLOGY OF THE WHITE MOUNTAIN DISTRICT.

THE outlines of the White Mountain district have been defined in Volume I, page 184. It includes the principal mountainous region between the Connecticut river and the Maine line, embracing the largest areas of the Labrador granites. A reference to the description of the topographical features, as above cited, but more particularly to the map opposite page 171, will serve to fix in the mind the exact limits of the district now under consideration. The leading formations developed here are the following, in the supposed order of their age: 1, Porphyritic gneiss; 2, Bethlehem gneiss; 3, Berlin or Lake gneiss; 4, Montalban group; 5, Franconia breccia; 6, Labrador system or Pemigewasset series of granites, Ossipytes, compact feldspars, etc.; 7, Sienite; 8, Andalusite slates; 9, Pequawket or Mt. Mote granite. The facts relating to surface geology and the utilization of valuable ores and building materials belong to subsequent chapters.

1. Porphyritic Gneiss or Granite.

This rock is always readily recognizable in this district by the presence of large crystals of orthoclase or potash-feldspar scattered through a base of much finer materials. These larger crystals are usually about three quarters of an inch in length, rarely two inches. There is much diversity in respect to their arrangement. Sometimes the crystals are placed in the rock with their longer axes parallel to each other, and this plane is coincident with that of the strata. On the contrary, there is often no arrangement to correspond with the stratification. Owing to scanty exposures, and to the abundant accumulations of decayed rock, earth, and vegetable mould, it is often difficult to determine to which of the two varieties of arrangement referred to above each example belongs. It is obvious that one of these rocks must be a granite, and the other gneiss. In our explorations no distinction has been made between them. The assumption has been that the agencies producing the granite operated with greater intensity, so as to induce a pasty condition in the mass, and obliterate the stratification without destroying the porphyritic aspect of the rock. If the difference in condition involves radical distinctions in the mode of origin or in the time of the fusion, then there are two formations to be considered instead of one. But in that event the second rock was derived from the first, so that the assignment of both to one group at present will not lead to error in respect to the geographical areas occupied by the porphyritic rock.

The mica in this rock is supposed to be muscovite. It is usually black, or of a very dark brown color. Quartz is scarce, varying with the locality, and it is always amorphous. Iron is so abundant that most of the exposures are stained by its oxidation. The texture of the rock is rather coarse, the crystalline particles averaging from one sixteenth to one eighth of an inch in length.

This formation is disposed along two converging lines in the White Mountain district. The first extends from about the line of Carroll and Franconia along the westerly base of the Franconia mountains into Benton, spreading out broadly in Lincoln and Woodstock east of Moosilauke, and sending a spur from Bald mountain in Franconia into the valley of the Pemigewasset, certainly as far as Walker's falls. This is the main range, and it seems to terminate in Campton and Rumney. The second area extends northerly from Ashland and Holderness to Waterville, being a part of a range largely developed in the Merrimack district. Beyond Waterville it may be said to bifurcate, part appearing in the valley of Sawyer's river in Elkins's grant, and part taking an easterly course beneath Mt. Whiteface into Conway.

The western range. Plate VI, Fig. 7, shows the relations of the western range of this rock in Franconia to the adjacent formations, as well as to the outlier of porphyritic gneiss near Wing Road station. There seems to be an anticlinal axis on the west flank of Mt. Lafayette, and hence the two areas may be connected by a synclinal beneath the Bethlehem gneiss in Franconia and Bethlehem. The following are the facts suggesting the existence of the anticlinal. We have no observations of the dip north of the outlet of Echo lake. On Bald mountain, a hill north-west from Echo lake, the dip is from fifty to sixty degrees north-westerly, verging northerly. The rock is coarse; the porphyritic crystals are larger than is common; the mica is black; and the inclination was observed very satisfactorily. Dykes of trap cut across the hill. The cliffs on the north and east sides of Echo lake are composed of porphyritic gneiss dipping about 50° N. 32° W. It is supposed that this rock is continuous to the Lake of the Clouds, north of Eagle cliff, but, on account of the difficult travelling, the actual connection has not been traced out. The ragged cliffs between the Echo and Cloud lakes are conceived to belong to the Franconia breccia, which is an igneous overflow consisting of large fragments torn off from the porphyritic rock, and embedded in a feldspathic paste. At the Lake of the Clouds no doubt exists as to the occurrence of the porphyritic gneiss; and I have the impression that the feldspar crystals lie in horizontal planes, but I cannot be absolutely certain of it. I have noted that the rock makes its appearance half-way between the crest of Eagle cliff, where the new path crosses it, and the lakes, and that the strike may be N. 28° E. both east and west of these small tarns. Physically speaking, there is a broad shelf where this water is situated, which is more than four thousand feet above the sea, from whence water flows northerly and southerly. Following the old bridle-path from the Cloud lakes to the south, the porphyritic gneiss crops out about one third of the way down, with a dip of fifty degrees easterly. To the east of the lakes towards Lafayette a finer-grained gneiss succeeds, which may correspond to one of the overlying formations. I think the dip is easterly in this case. There seem to be outcrops of this rock, also, on the east side of the mountain underneath the Lakes of the Clouds. Thus, although the facts observed respecting the dips are meagre, the easterly and westerly inclinations are clearly known to exist in the proper place to constitute the anticlinal ridge represented upon Plate VI.

It is not necessary to particularize the few localities to the north-east where this formation appears, save that it has not been traced beyond the east line of Franconia. One of our maps will show the exact location of every specimen mentioned in the catalogue; and reference to these sources of information will render unnecessary much detail in the text. An interesting locality lies above Walker's Staircase in the edge of Lincoln, which is supposed to be the direct continuation of the easterly-dipping ledges just described. Coming down from the south end of the Lafayette range towards the Staircase, I found, about a mile back from the road, nearly horizontal masses of a hornblende rock, underlaid by porphyritic gneiss, running N. 2° W., and having nearly vertical strata. The hornblende rock formed a succession of steps, over which the brook fell in a picturesque way, while the porphyritic gneiss did not rise above the base of the cascade. I cannot locate this spot exactly, since I failed to find it in 1873 in the ascent above the Staircase frequented by the summer visitors. About the same distance back from the carriage-road, however, I have noted the occurrence of the porphyritic rock having the same inclination. At the "Lappara falls," also, just above Apron falls, considerably higher than the Staircase, Mr. Huntington found a gneiss resembling the porphyritic rock, save in the absence of large crystals of feldspar, while at the latter locality the gneiss is Montalban in appearance. The other rocks here are of the Conway granite series.

A specimen of loose Bethlehem gneiss from near Mt. Pemigewasset, just back of the Flume house in Lincoln, led to a reëxamination of that eminence in 1873, and the conclusion was reached that the lower part of the mountain consisted of porphyritic gneiss, dipping gently north-westerly, capped by the Conway granite, the twc resembling each other very closely. It is apparently a part of the more eastern range on the west flank of Lafayette.

Further researches in Franconia and Lincoln are desirable in order to determine satisfactorily the limits of the porphyritic gneiss. There is no part of the White Mountains where the travelling is more difficult than here,—hence a considerable time will be required to make satisfactory examinations. Areas requiring a visit are the district referred to this group, extending from Walker's Staircase into the east part of Franconia, and as far on the north flank of Mts. Haystack and Twin as discoveries will warrant.

The next locality where this rock has been observed as the continuation of the Bald Mountain locality is on the northern peak of Mt. Kinsman. An unknown space of about three miles between them has not been traversed at all by any of our parties, but is supposed to be occupied by the same formation. The strata on the Kinsman ridge, a mile north of the summit, dip 50° N. 20° W., and, at a cascade low down the west side, near its western border, they incline 50° N. 32° W. The rock has also been observed by our parties upon the summit of Mt. Kinsman. To the south of Kinsman the formation must contract in width, perhaps passing beneath the northern point of Woodstock, and expanding in the central part of Woodstock wider than is known elsewhere in this range. At the mouth of Moosilauke brook at North Woodstock the dip is 70° S. 37° E. A quarter of a mile farther north the position is essentially the same. Upon Section VIII several specimens of this formation have been collected, proving its occurrence to the west line of Woodstock, and it probably dips beneath Moosilauke to come up again in Benton on the other side of the andalusite mica schist. The outcrops along the section, in connection with a limited area in Wentworth (Specimen No. 1211), constitute all the evidence we have in regard to the existence of a narrow range of this porphyritic rock west of the main range, unless it be in Sullivan county, much farther south. Along the west side of the Pemigewasset valley in Woodstock the porphyritic gneiss constitutes high, bald cliffs. At the post office or central village the dip is 85° S. 57° E. Half a mile east of Elbow pond a rough gneiss, much contorted, dips about 80° S. 32° E. South of J. Downing's in Woodstock a coarse gneiss dips very high S. 87° E. There is a similar rock dipping 75° N. 37° W. at the outlet of Hubbard pond, thus indicating the presence of an anticlinal axis in the south part of Woodstock. In Thornton this rock appears south of Hatch hill, near R. Tompkinson's, also at a saw-mill a quarter of a mile to the south, and at J. Gilman's, where it is traversed by veins of very coarse granite. Many other exposures occur along the valley through Thornton, crossing the river so as to connect with the most southern ledge known of this sort in the very edge of Campton. Our observations in this valley were mostly made before we understood the true character of the rock. Being regarded as granite, no pains were then taken to observe lines of stratification in it which doubtless exist.

The relations of the group to the adjacent Montalban schists, in a section from West Thornton to Welch mountain, are shown in a figure farther on.

From Woodstock centre the porphyritic gneiss branches off southwesterly into Ellsworth and Rumney. That occurring in Ellsworth will be described under Section VII. In the north-east part of Rumney, at a lead mine, the dip is 80° N. 72° W. To the south this range is entirely covered by the mica schists of a much later geological age.

The eastern range. The northern extremity of a very crooked range of porphyritic gneiss enters the limits of the White Mountain from the north-east corner of the Merrimack district, continuing for ten miles, where it is concealed by later formations. It reappears in the deep valley of Sawyer's river, about five miles north-easterly from Cascade brook in Waterville, which is the extreme northern limit of this range in New Hampshire. A spur runs easterly from this range along the south line of Waterville towards Chocorua.

Section VIII crosses the Sawyer's River outcrop of this rock. The most satisfactory exposure is represented by numbers 58 and 59, from the mouth of Carrigain brook. The water falls twenty-five or thirty feet over the smooth ledges of this rock, which seems to dip 75° N. 68° E., cut by a six-feet dyke of reddish feldspathic rock. These exposures show large crystals of a somewhat flesh-colored orthoclase in greater abundance than usual; and there are many small bunches of amorphous, nearly transparent quartz. The rock rings when struck by the hammer. The width of the range must be two miles along this valley. This rock comes up next on Cascade brook in Waterville. The cascades are of granite; but about half a mile above them the porphyritic gneiss appears, with a northerly dip, but the strata are greatly contorted. At two miles above the cascades the dip is 75° N. 80° E. This exposure shows amorphous quartz like that on Sawyer's river. None of the other specimens from Waterville have this mineral present. Those from near the cascades and the summit of Black mountain do not display the large crystals of feldspar. We have no observations respecting the dips of this rock as it is exposed just east of the Greeley hotel, the top of Snow's mountain, Flat Mountain pond, the country between the last two mentioned localities, nor of the large areas of this rock on the western side of Black mountain. The formation is five miles wide as it enters the White Mountain district from the south, or along the route of Section VII. Israel and Sandwich mountains in Sandwich are composed of this rock. Guinea hill appears to contain a different rock, jutting into the eastern edge of the porphyritic gneiss, so that the course of the range is irregular.

Two sets of exposures farther east indicate the extension of a spur easterly from Waterville along the base of the mountain range of Black, Whiteface, and Chocorua. A little west of the usual path up Mt. Whiteface this rock crops out, dipping 25° N. Perhaps the lower eighteen hundred feet of the mountain, in ascending from McCrillis's house, should be regarded as composed of this formation. The top rock is of sienitic character. Little is known of the mountains between Whiteface and Chocorua, so that the extent of the porphyritic rock easterly has not been observed, but, as it constitutes the basis of everything in this part of the country, it may turn up almost anywhere. Near the south-east corner of Albany I found enormous boulders of this rock, enough to make it clear that the ledge must be close by. A very small area is therefore thus represented upon the map.

Forty specimens illustrate these various areas in the museum, as indicated by the catalogue. All rocks found within the porphyritic areas are grouped together in the enumeration, although the igneous dykes are evidently of later origin. It is probable that other bands of stratified rock should be included, as will be developed by further study. The typical field for the study of the porphyritic gneiss is the Merrimack district.

Bethlehem Gneiss.

In 1871 it became evident that between Carroll and Littleton there existed an area of gneiss distinguished from all others by its peculiar stratigraphical position and lithological character. The strike seemed to run nearly east and west; the strata stood almost upon their edges; the schistose character had nearly disappeared, so that we had previously known the rock as granite; and, lastly, a soft, greenish mineral, resembling one of the hydro-micas, was disseminated through it. Hence I ventured to separate this area from all the others then known, and gave it the name of Bethlehem gneiss, from the town where it displayed itself to the best advantage.* Later observations, while modifying certain features of the geographical distribution, and adding new areas to the map, have tended to confirm this original impression.

Inasmuch as the typical area of the Bethlehem gneiss lies partly in three different topographical districts, though principally in the one now under discussion, I have thought it best to describe it entirely in this place. It occupies portions of the towns of Carroll, Whitefield, Bethlehem, Franconia, Littleton, and Lisbon. The specimens, however, are grouped geographically in the White Mountain and Ammonoosuc, as well as the Coös and Essex, special collections. The references will be made to them clearly enough to avoid confusion.

The most characteristic of the rocks composing this formation is a reddish granitic gneiss, the flesh-colored orthoclase predominating, with chloritic or some hydro-micaceous mineral in place of ordinary mica, and amorphous quartz in variable proportions. When this is not present it is not easy to say that the finer-grained gneiss associated with it necessarily belongs to this geological horizon. This second variety is like the finer gneisses of the Montalban group. A third variety is a porphyritic gneiss, sometimes suggesting the older group just described. It differs from that in having smaller crystals of feldspar, which are arranged in nodular bunches in the midst of the finer micaceous layers of the rock. This variety is abundant in Carroll and the west part of Bethlehem, as well as in the Hanover area of gneiss. A fourth variety of rock, which may well be associated with the Bethlehem group, is a feldspathic mica schist having large patches of a black mica, the mineral not existing as plates exhibiting easy cleavage, but being an aggregation of crystalline fibres. Other rocks of a foreign character are beds of chloritic schist, with or without magnetite, nearly compact feldspars, quartz, mica, hornblende, and epidotic schists, and probably beds of limestone.

The following are observations of the position of the strata in the several parts of the terrane.

Locality—Bethlehem.	*Dip.*
North of M. Phillips's,	60° N. 22° W.
East of Peaked hill,	N. 22° W.
South-east side of Round mountain,	Strike N. 48° E.

* See Report for 1871; also vol. i, p. 33.

Location—Bethlehem.	*Dip.*
Top of Peaked hill,	75° N. 32° W.
East side of West Peaked hill,	75° N. 62° W.
Top of the same,	67° N. 42° W.
Near C. C. Clarke's,	80° N. 32° W.
West of Baptist church, on hillside,	75° N. 10° W.
Top of same hill,	80° N. 20° W.
East of T. Twombly's,	70° N. 27° W.
E. B. Phillips's, west corner of town,	55° N. 57° W.
C. Petrie's,	80° N. 40° W.
P. G. Russel's, north line,	80° N. 48° E.
Franconia road, west part of town,	70° N. 27° W.
Littleton.	
East side of Eustis hill,	75° north-westerly.
Near Scythe Factory Village,	Vertical, strike N. 58° E.
S. M. near Lisbon line,	Northerly about 30°.
Whitefield.	
North of M. Bowles's,	75° N. 62° W.
East of G. W. Howland's,	20° West.
West of J. W. Walker's,	West.
Kimball hill, top and south side,	65° N. 67° W.
East of J. Lindsey's,	55° N. 8° E.
Town-farm to N. E. Hutchins's,	20° easterly.
Franconia.	
G. W. Smith's, north corner,	80° N. 27° W.
R. Wallace's,	50°–60° S. 10° W.
W. Wallace's,	Strike N. 53° E.
J. McDonald's,	80° N. 37° W.
Carroll.	
Hill north of Twin Mountain house,	60° south.

An inspection of these positions shows a general inclination to the west of north. In the north corner of Franconia there is a local anticlinal. At the Twin Mountain house the rock dips southerly; and there is a distinct anticlinal in Whitefield. The best interpretation of the structure seems to be that of an inverted synclinal in Bethlehem (see Pl. VI, Fig. 7), and an anticlinal in the spur extending northerly. The north-east part of Bethlehem and large parts of Carroll and Whitefield are so much covered by drift that we cannot make out the structure of this formation in a very important locality. It is easier to regard the porphyritic gneiss of Franconia and the Wing Road region as connected beneath the Bethlehem formation than as newer rocks, partly because the Whitefield branch is overlaid closely by the Berlin or Lake gneiss upon both flanks, without any room for the first-named group. Moreover, the south-west end at North Lisbon is flanked by newer rocks, which follow around the point, although the dip is reversed upon the north-west side, Helderberg strata apparently running under the Bethlehem gneiss. As this is plainly an overturn at North Lisbon, it is probable that the monoclinal dip farther north may be explained in the same way.

The most characteristic localities of the chloritic gneiss occur in Bethlehem, between Pierce's bridge and the Baptist church, or Nos. 76 to 86 of Section IX. Round mountain appears to be one great ledge. Peaked hill shows plenty of ledges high up, the lower portions being generally covered by drift. In all the western part of Bethlehem the ledges occur chiefly on the elevated points of the hills. No ledge has yet been discovered upon the large Beech hill in the north-east part of the town. Neither has any solid rock been found on the Ammonoosuc between the Wing Road station and the falls just below the White Mountain house, save a very obscure outcrop of Lake gneiss east of Mr. W. H. Bean's. The large, loose blocks scattered over Bethlehem hill are mostly of this rock, and will be noticed again, when speaking of a local glacier which once overspread this part of the country. In Franconia every drift hill is crowded with them.

Between Bethlehem station or Pierce's bridge and Gale river there is no direct public road, although the elevation is not great, and the distance to be traversed is only two miles. The stages between the Profile and Crawford houses use instead the circuitous and sometimes dangerous road over Bethlehem hill. But in the absence of carriage-roads we have traversed the area on foot, and find the ledges entirely concealed by glacial drift. The same is essentially true of the area between the highest saw-mill on Gale river and the house of S. Bullock, at the end of a road leading south from the east and west road, a mile and a half towards the station from the Bethlehem post-office. A supposed ledge north of Bullock's shows a strike of N. 48° E., while to the south is the end of a large moraine pointing towards Mt. Washington. This road to Bullock's is situated upon the top of coarse moraine-like materials, and lies near their eastern edge.

The Bethlehem group probably extends north-easterly to the neighborhood of the Pond of Safety in Randolph. The following numbers of the catalogue in Chapter II appear to belong to this series: 665, on Randolph mountain; 667, a mile north of the Pond of Safety—both in Randolph;—the following in the south-east part of Jefferson: 683, near the Mt. Adams house; 685, S. P. Martin's; 686, B. F. Read's. Also, 684, from Owl's Head in Carroll, near the Jefferson line. In Whitefield, Nos. 701–709, 712, 719, and 722 seem to be of this age. Very likely 710 and 711, which are hornblende schist, may be varieties of this formation. The northerly boundary of the formation in Whitefield would seem to extend from the south-eastern part, past J. Lindsey's, south of the village to near M. Bowles's. It then extends southerly, crossing the Bethlehem line about a mile north of the Wing road. Near the south line of the town upon the eastern road the features of the typical rock are as distinct as in Bethlehem. On Kimball's hill the layers nearly touch some of the Coös mica schists. Farther north they come in contact with the Lake or common gneiss. Epidotic and hornblendic masses are contained in the Whitefield area of this formation. Near J. Lindsey's the rock contains hornblende and molybdenite. Near A. D. Sanborn's there is also molybdenite in a quartz vein.

Carroll has not been thoroughly explored. In the north-west portion, near C. E. King's, a great many loose fragments, which must be in place close by, belong to the spotted variety of this formation, corresponding thus to the ledges near the Twin Mountain house. The country between these localities, about five miles in extent, is covered by drift and bordered much by forests, so that much knowledge of the ledges is impracticable. Cherry mountain affords us specimens of this formation, though nothing is known of the position of the strata there. I think there are several ledges upon the east side of Beech hill in Carroll, which remain to be examined.

In the valley or west part of Franconia all the ledges are concealed by drift. Back of J. McDonald's, on the flank of Mt. Haystack, the gneiss is less characteristic than usual, and there are interstratified with it seams of hydro-mica schist, containing magnetite (46, 47) and nearly compact feldspars. The Bethlehem rock is exposed also higher up the mountain, about a mile west of Haystack pond, and also on the peak next the cone of Haystack on the ridge towards Mt. Lafayette. Other localities to the south, whence specimens have been brought by our student assistants, who did not determine the position, are,—first, a problematical spot between Mts. Pemigewasset and Kinsman (50); second, on the south-west side of the Mt. Flume ridge, near its foot and just across the valley from Little Coolidge mountain (51); third, on Big Coolidge mountain, three miles north-easterly from Pollard's, or the last house up the East Branch valley in Lincoln (52); fourth, south of Mr. Pollard's, at the south-east extremity of the ridge south-east of Black mountain. Such of these locations as seem certain will be found represented upon the general geological map.

Nos. 87–95 of Section IX represent what we call the upper member of the Bethlehem group, consisting of dark mica schists, with some gneiss. Its occurrence in other terranes besides that of Bethlehem indicates its importance as a stratigraphical member of the gneissic series. I associate it with the Bethlehem rather than with the Lake group for the present, because it is so closely connected with the Bethlehem and Hanover islands of gneiss, but it is very difficult to separate it from the gneiss of Littleton. In Bethlehem and Lisbon this dark schist envelops the south-west extremity of the range, as if it were another protecting envelope. In certain railroad cuts east of Littleton this member is distinctly gneissic, some of the layers being identical with fragments of rock found in Franconia by Prof. J. D. Dana, and thought by him to be very like certain Laurentian rocks in eastern New York (No. IX—95). In the Ammonoosuc collection this member is represented by Nos. 8, 9, 17–22. No. 58 comes from a locality not far south of the Lisbon-Littleton road-crossing of the Ammonoosuc river, near J. Little's house, and it agrees perfectly with this band of rock, and may be a small island of this schist surrounded by the Lisbon group of the Huronian.

At the east foot of Eustis hill, and on the Ammonoosuc river at the south line of Littleton, the gneiss is spotted. The same is true of specimens in the west part of Bethlehem, upon Section IX. The inversion of the strata at North Lisbon, so as to bring the Helderberg rocks upon both sides, causing newer beds to dip beneath older ones, is illustrated in one of the figures elucidating the structure of the Silurian rocks, in the next chapter. At W. Wallace's in Franconia the gneiss abounds in red feldspar, and shows more than the average amount of quartz. Near the top of the hill, near the town line, there is a mass of soft chloritic schist ten feet thick imbedded in the gneiss. On the very top of the hill there are many micaceous seams interstratified with the ordinary rock. This is the area where a local anticlinal exists.

In the White Mountain collection this formation is represented by Nos. 41 to 54, and 176 and 177, from the height of land in the road between the White Mountain house and Jefferson. By the study of these, in connection with those specified in the Ammonoosuc collection, the Coös and Essex district, and along the route of Section IX, and comparing the locations upon the maps with their dips, one can learn all that it is possible now to present upon the subject.

Topographically, this northern terrane of Bethlehem gneiss is one continuous central ridge, normally the most elevated along the central median line. A ridge commences at the union of the "South Branch" with the Ammonoosuc at North Lisbon. From 667 feet at the railroad it rises immediately to 1000 feet in the hill west of Streeter pond. Falling off a few feet, it attains to 1329 feet on the height of land in the stage-road between Franconia and Littleton; then it rises to form four summits in Bethlehem of 1600, 1600, 1905, and 2042 feet, the last being Peaked hill. Next in our eastward course we find the valley of the Ammonoosuc, 1200 feet, which, on account of long-continued atmospheric grinding and gouging, has excavated a notch through the ridge. On the east is Beech hill, 1800 feet, a gap of 1475 back of the Twin Mountain house, and then the final rise to 3670 feet in Cherry mountain. The excavation of Israel's river in Jefferson, beyond Cherry, where the range is very narrow, brings the level down to 1250 feet before we finally lose the formation near the Pond of Safety at 2000 feet. The Bethlehem ridge is quite a conspicuous one, when viewed either from Mt. Cherry or Mt. Washington; and the wide valleys of Franconia and Israel's river are subordinate to the main line of elevation. The Whitefield spur is also quite elevated, rising considerably above the 1500-feet contour line in the south part of the town, while the 1000-feet level scarcely touches it south of the village, and none of the area in Jefferson goes below 1200 feet.

Fig. 11 will show the relations of the Bethlehem and Lake groups of gneiss between Dalton and Carroll. We present the dips of the strata only where they have been observed; and the spaces where nothing has been discovered are given upon a correct scale. From this figure one gets the impression that the first named is the oldest group. The section should be compared with that on Plate VI, to which reference has been made at the outset. Fig. 11 shows the only locality in the state where the Bethlehem and Lake gneisses are known, at the present moment of writing, to approach each other so closely.

3. Berlin or Lake Gneiss.

To this series I have referred a narrow band of gneiss, extending from the unnamed peak (5) in front of Mt. Hale (vol. I, p. 198) through the south part of Carroll into Franconia. The rock is a fine-grained gneiss, similar to that in the north part of Whitefield and Littleton. The ridge just spoken of is the first hill seen south of the Twin Mountain house, forming the dividing ridge between the Ammonoosuc and its tributary, called Little river. It slopes gradually from mountain (5) to the mouth of the tributary, one or two miles below the hotel. At a dam, more than half a mile above the mouth of Little river, the gneiss dips 35° S. 27° E. The north wall here is high and steep, as if the stream flowed through a cañon. There is a minor undulation half a mile higher, the dip being ten degrees northerly. On top of the ridge, in passing directly from the hotel to Twin mountain, the gneiss dips 50° southerly. About a mile above the junction of Little river with the Twin Mountain branch, a small slide has uncovered ledges of this rock, rather conglomeratic in character, dipping 80° S. 77° E. A quarter of a mile higher up, the extreme easterly point of this band is reached, standing vertically, with the strike N. 20° E. The width of this band is not known to exceed half a mile at any point.

Proceeding from Little river towards Franconia, it is supposed that this band must lie in front of the "Nubble." This hill rises sharply more than three hundred feet, and was found to consist of an enormous vein of very coarse granite. The specimens brought from it remind one of the coarse veins yielding mica in Grafton; but no certain evidence has been obtained to show that the Nubble belongs to this set of strata. Specimens from back of J. L. Rine's in Franconia appear to belong to this range; also, those lying between the porphyritic gneiss and Albany granite, above the Lakes of the Clouds, upon the west side of Lafayette. The connection between this and the larger area of Lake gneiss in Landaff has not been made out, on account of the enormous coating of drift concealing the strata west of the porphyritic gneiss. In the museum, Nos. 315–320 illustrate these rocks. I should add that there is a ledge of this gneiss between Bethlehem hollow and the Wing Road junction, with strata dipping 80° N. 42° W. It belongs properly to another field of description, the Ammonoosuc district.

4. The Montalban Group.

The limits of this formation have been set forth with sufficient exactness in Vol. I, pp. 522–526, so as to render a repetition of the general statements there made unnecessary in this place. The characteristic rock of this formation is a feldspathic mica schist, carrying crystals of andalusite or some closely related silicate. The variations are from mica schist and quartzite on the one extreme, to well characterized gneiss on the other. These schists are commonly quite ferruginous. The mica occurs in small blotches, shining from light reflected at various angles. The ledges of this variety commonly decompose readily.

A not less important variety is a granitic gneiss, with very different degrees of crystalline coarseness. The finer-grained rock often displays no visible marks of stratification, though there is no reason to doubt its sedimentary origin, and, for convenience, this is designated the *Concord granite.* This rock is usually incoherent, tender, and quite friable after decomposition has commenced. It is distinguished from the Lake granitic gneiss by its fineness of texture.

Along Mt. Washington river the gneiss contains many small nodules of feldspar, so as to resemble the porphyritic variety of the Bethlehem group. In Jackson there are a bed of siliceous limestone and layers of compact feldspar. The eruptive members are quite important, consisting of trap dykes, considerable masses of a porphyritic granite, light-colored diorite, sienite, and large veins of quartz. The different ledges of this rock among the White Mountains are well represented in the museum.

Geographically, this formation may be divided into the main range of the White Mountains east of the Saco river; the country to the east of this elevated axis, south of the Androscoggin river and east of the Peabody and Ellis rivers; a few small outliers near the Saco river; and the outcrops to the west of the Saco in "Pemigewasset." We will speak of each of these geographical areas in turn.

The main White Mountain range. The location of this elevated district has been noted in the chapter upon Topography, page 187. The first elevation, known as Pine hill or Camel's Rump, is composed of three kinds of rock,—an approach to the andalusite newer slates at the north end, a fine mica schist near the top, on the west side and on the east, and on the southern slope the Concord variety of granite. A similar rock occurs on the Pinkham Notch road, on the height of land between the Glen house and Randolph. The strata are nearly vertical, with a northerly strike. About Wood's hotel, where the Pinkham Notch road crosses Moose river, the rock is coarse mica schist; and there are large boulders of quartzite, various granites, hornblende schist, and sienite. South of Bowman's old tavern-stand, near the ridge dividing the Moose and Israel's rivers, there are both hornblende schists and fine-grained quartzite. A hundred rods south the characteristic fine and coarse-grained mica schists make their appearance.

The higher peaks,—Mts. Madison, Adams, and Jefferson,—are chiefly composed of the coarse mica schists, with a little feldspar, that are most typical of this group of strata. In ascending Madison, from the summit on the Pinkham Notch road, we observe chiefly an interstratification of these schists with granitic gneisses. The strata stand nearly upon their edges, and the non-feldspathic beds preponderate. At the upper line of trees the mica schists exist alone, with the dip 85° S. 63° W. The rest of the way to the summit is over fragments broken off the ledges by the action of frost. At the very top the rock contains large garnets and andalusite, with the dip 60° S. 58° W. From the summit to the end of the spur running southerly towards the Half-way house, on the carriage-road up Mt. Washington, nearly two miles, the ledges are finely exposed, the whole distance lying above trees, and the dips are very variable. A short distance south of the summit the dip is 60° N. 57° W., which may represent the normal position, but the rest of the way they incline northerly, westerly, easterly, and north-easterly. Two or three of these variations may occur in the distance of one hundred feet. The conclusion to be derived from these facts is, that a powerful pressure has been exerted upon these strata, which has doubled and twisted all the layers in detail, not in the mass like the representations of the Appalachian curvatures by the Professors Rogers. Observations upon Adams, Jefferson, and Washington show the same thing to be true there also, so that this conclusion will apply equally forcibly to the whole range. The extent of the reduplications exceeds anything that I have ever seen in any part of the world.

In descending from this ridge to H. D. Copp's house, in Martin's Grant, the most noticeable feature is the introduction of large crystals of staurolite into the rock. Andalusite had been abundant all the way from the summit of Madison; but at about three hundred feet below the tree line, in an open space, the staurolite has striped the ledges in every direction. The crystals run up to eighteen inches in length; and I think there is scarcely any place in the state where large and showy specimens of this mineral can be obtained more easily, only that they cannot be conveniently transported. It is unusual to find this mineral so abundant among the mountains. Lower down, the crystals are smaller and very distinct, the strata dipping 75° W., and very shortly falling to an average of 28°, continuing thus for a great distance. About three fourths of a mile above Copp's the same staurolite rock dips 50° S. 53° W. The granitic gneiss makes its appearance a little below Copp's.

The general surface features of the path up the north side of Mt. Adams, and the route from Madison to Washington over the ridge, are set forth under the head of Scenographical Geology, Vol. I, p. 613, *et seq.* Mt. Adams has three summits instead of two, as heretofore stated. The more southern one is properly the Quincy Adams, and there is also a small peak between the central peak and the Madison notch. The summit of Adams is very sharp, there being only one small block of stone at the apex. Ridges extend down the north side of the mountain, starting from the two lesser peaks. None of our parties have traversed the north side of Adams, Madison, or Jefferson, so that we cannot describe the ledges there. On the summits and in the notches between them the rock is invariably the feldspathic andalusite mica schist, with the blotchy mica. On Quincy Adams the strata dip N. 20° W. Near the Jefferson-Adams notch the dip is 50° east. Still farther south the dip is N. 62° W.

Messrs. Channing and Hale, assistants of Dr. Jackson, ascended Mt. Jefferson from the north, and make the following statements respecting the ledges encountered by them:* "We travelled up the bed of the stream [Israel's river], and observed that the rocks exposed to view were ledges of granite, becoming coarser as we proceeded, and containing small plates of mica not more than an inch square. Loose masses of hornstone or jasper were observed among the pebbles in the stream." "No [large plates of] mica were found, but an abundance of fibrolite or fibrous kyanite occurs on Mt. Jefferson and Mt. Washington."

The following rocks were found in a trip from Mt. Jefferson summit directly to Ammonoosuc station, following down the ridge north of that on which the railway is located: First, the common White Mountain mica schist; second, the same, extending as low as to the upper limit of trees; third, granitic, like the Concord variety, within the upper forest; fourth, quite a number of ledges of the mica schist; fifth, jointed granite, the third ledge above the station; sixth, Concord granites; seventh, a mixture of the two kinds of rock at Ammonoosuc. Specimens illustrating these varieties are embraced in Nos. 191–200.

Upon Jefferson and Adams there are occasional large veins of white quartz, whose course can be traced among the fragments very clearly, on account of the contrast in color between this and the prevailing variety. Upon Mt. Clay the strata are better defined than is generally apparent upon these summits, the rock approaching an argillaceous schist. They are usually nearly vertical, and much thrown about, as described upon Mt. Madison.

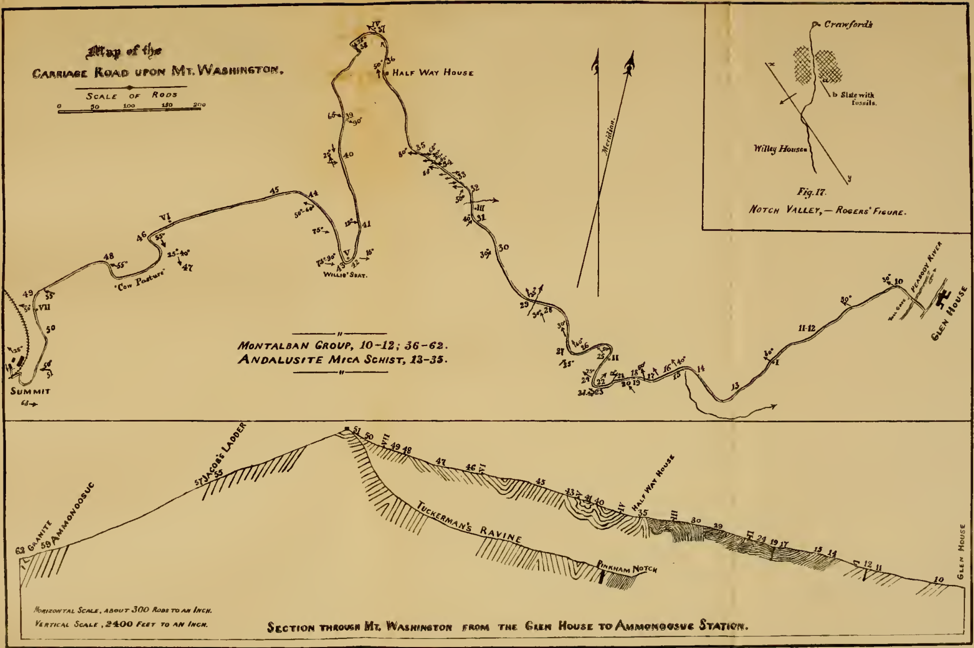
Peabody River valley. At Gorham the rock is a coarse, massive granitic gneiss, dipping 65° N. 72° W. back of the old Alpine house. It continues up the Peabody valley for two miles or more, passing into the Concord variety. This occurs, interstratified with the mica schist, nearly as far as Copp's house in Martin's Grant, dipping five degrees north-westerly. Very near by is a mica schist dipping 65° N. 72° W., which is more like the normal position in this neighborhood. Mica schists and granitic gneisses occur between Copp's and the Glen house, and the latter increase in going towards the height of land southwardly. Upon the west

* *Final Report, Geology of New Hampshire,* by C. T. Jackson, p. 159.

branch of the Peabody river, one of the most important gulfs on this range, the rocks are mainly mica schists (Nos. 201–205), agreeing closely with those found upon the presidential summits, and they all dip westerly, except one easterly, opposite the Half-way house. A ledge at the mouth of this tributary is considerably ferruginous, with shining mica, not in plates, nearly vertical. It is noticeable that none of the newer andalusite slate, such as occurs so abundantly upon the lower half of the carriage-road, was perceived in this great gulf, though there may be a little of it at the mouth of the valley. The ledges near the Glen house, and also by J. Bellows's, have the dip of 30° N. 58° W.

Section through Mt. Washington. This is properly a part of Section IX, and the numbers referred to are those of specimens arranged on Shelf IX in the museum. Special surveys of the Fabyan turnpike and carriage-road having been made under our direction, I have had them reduced so as to be represented upon Plate VII, with all the detail possible respecting the stratigraphical and geographical position of the specimens collected. The positions of the mile-posts on the carriage road are given with great exactness. Those of the specimens taken from intermediate points are located by estimate.

Directly back of the toll-gate is a ledge of greenish, somewhat friable quartzite (No. 10). This and related ledges higher up dip 30° to 40° N. 83° W. At about three fourths of a mile there is a face of gneissic rock exposed, 200 feet long and 40 feet wide, upon which glacial striæ are obscurely indicated. The mica in No. 11 is different in physical aspect from that common to this region. The scales are narrow and much elongated, instead of being roughly roundish. Interesting brecciated dykes are represented by No. 12. These dykes are quite frequent on their eastern slope, and are particularly noticeable at Crystal falls. At the first mile-post the strata are also gneissic, with granitic veins dipping 30° N. 63° W. After passing about an eighth of a mile of drift there is a massive quartzite. No. 13 is an argillo-mica schist, with undulating, shining surface, and roundish, ferruginous spots of some decomposed mineral. A small hill on the north-east side of the road is composed of coarse granite (No. 14), containing large crystals of black tourmaline. It is followed by ferruginous schist (No. 15) dipping 40° N. 23° W. Another mass of granite is represented by No. 16. Between Nos. 14 and 15 there



Section through Mt. Washington from the Glen House to Ammonoosuc Station.

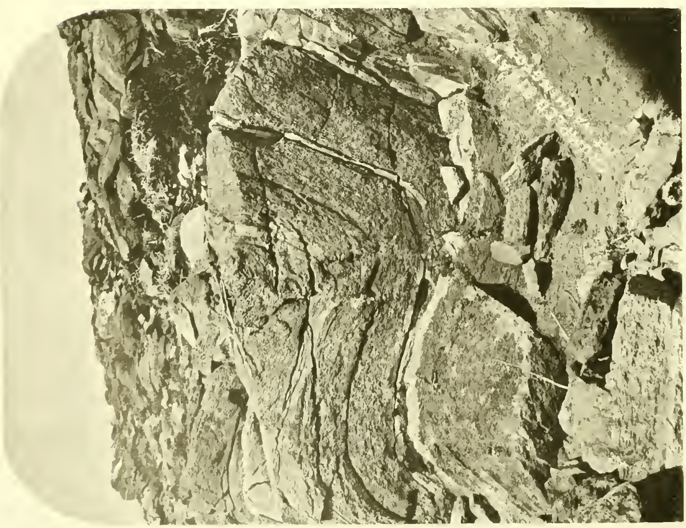
HELIOTYPE

is a small stream running southerly. The next rock (No. 17) is slaty, dipping N. 43° W. Underneath a clayey rock is a sandstone (No. 18), dipping 50° N. 28° W. No. 19 represents a conglomerate trap, cutting the strata, probably, as it is inclined 85° N. 43° W. No. 20 is from a mass of coarse indigenous granite. No. 21 is a slate dipping 20° N. 43° E. It is interstratified with beds of granite, fifteen to twenty feet thick; No. 22, a little farther along, dipping twelve degrees in the same direction. There is a sharp angle in the road here; and minute undulations in the strata are observable, the first of them being much steeper than the rest, or 30°–40° N. 83° W. The rocks are mica schist, six feet thickness of granite, a slaty curve over ten feet of granite, and compact quartzite. No. 24 dips 75° N. 63° W. A little higher up two rock masses join each other, through an interesting fault, the positions being 80° west and 25° N. 38° W. At the second mile-post a massive andalusite rock dips 50° N. 58° W. (No. 25). There is a small hill just beyond, at a sharp bend in the road. No. 26 dips 60° N. 43° W. No. 27 changes abruptly to 25° N. 38° E. at the next bend in the road. The rock is shaly and twisted. Above a long northerly stretch in the road the strata are partly fine sandstones, dipping 30° N. 38° W. No. 28 is rather more slaty, a very fine exposure dipping 30° N. 38° W. This is just below a long bridge over a stream flowing north-easterly. On the upper side of the bridge there is a considerable banded granite (No. 29), in beds two feet thick, dipping 35° N. 38° W. The adjacent schist displays minute corrugations, reminding one of ripple-marks in sedimentary sandstones. Not a great distance higher up there are other thin beds of granite, containing large crystals of black tourmaline. The strata are wavy for a considerable distance, and then plunge into the mountain vertically, the steep dip being the first part seen in the ascent.

Nos. 30 to 35 are taken from a series of ledges about three quarters of a mile in length, most clearly exposed by the recent removal of earth and by blasting. The rock is an argillo-mica schist, quite evenly bedded, well filled with crystals of andalusite, and of the ordinary slate color. The small curvatures in them are endless, and almost baffle all attempts at description. They resemble billows in the ocean, each three or four feet high, and the positions of their crests and hollows are easily determined. There is one special feature among them of importance, viz., that, after a succession of them for forty, fifty, a hundred feet, or more are noted, their lower side disappears by plunging vertically into the mountain, and another series of curves, with the vertical or westward dip, takes their place. There are few places in New Hampshire where these curious phenomena of curves can be observed to better advantage than along this carriage-road.

At No. 30 the dip is 30° N. 12° E., vertical just below. At No. 31, close by the third mile-post and an easterly-flowing stream, the average dip is 35°–40° N. 27° E. The axes of the small curves here run N. 30° W., or transversely across their dip, showing that the smaller curves have been made since the determination of the position of the great mass of the formation. On the upper side of the long bridge over the stream at No. 32 the dip is 50° N. 12° E., and the eastern portion of the ledge is turning very much southerly. In the next fifty feet of linear distance there are three folds. Above them the dip is 80° S. 87° W.; thirty feet above the dip is 80° N. 87° E.; thirty feet farther the dip is 50° S. 87° W. This continues for one hundred feet. Here is a vertical plunge into the mountain, the strata dipping gently in an easterly direction just beyond. Near by the dip is 65° easterly. The last of these ledges that is exposed is midway from the third mile-post to the Half-way house, with the dip 80° S. 87° W. (No. 35). For about a third of a mile the road passes over drift, and no exposures of ledges occur immediately along the path.

This building is very near the upper limit of trees; and atmospheric agencies have acted powerfully upon the ledges, weathering them very much, so that they resemble the Montalban schists upon the surface. Excavations near the house show massive beds of mica schist dipping 50° N. 23° W. At the fourth mile-post, or the most northerly point on the road, and looking across a deep gulf to the south spur from Mt. Madison, the dip is N. 63° W. (No. 37). At a sharp turn beyond (No. 38) the dip is 25° N. 23° W. At No. 39 the dips are 60° easterly and perpendicular. At four and a half miles from the toll-gate the average dip is 60° easterly. At No. 40 there is an interesting complexity of folding. The normal dip of the strata is S. 23° E., followed by a dip in the direction 25° N. 23° W., the other part of a synclinal axis. The southern part of this synclinal basin, or that inclined northerly, is itself folded, the



subordinate curve dipping N. 87° E. This feature is like that already mentioned in the rock near No. 30.

At the fifth mile-post, where the road reaches its most southern limit, there are more undulations in the strata, of which perhaps the average inclination may be estimated as 15° N. 87° E. That their appearance may be properly understood, the reader is referred to the two annexed heliotypes taken of ledges at or very near the fifth mile-post. The bends are perhaps zigzags rather than curves, but they represent the characteristic forms of these phenomena in this portion of the section. This is the andalusite mica schist of the Montalban series, which commenced a short distance above the limit of trees, and continues to the summit as well as to Ammonoosuc on the west side of the mountain. A few rods above the fifth mile-post the dip varies from 75° to 90° N. 87° E. (No. 43). Fifty rods farther the dip is 75° in the same direction. No. 44, at nearly five and a half miles, comes from strata dipping 50°–60° N. 73° W. No. 46 comes from a sharp angle in the road overlooking the Great gulf, where the dip is 55° S. 33° E., on a ledge one hundred and fifty feet long. A rocky knob rises on the south side of the road, just at the lower edge of a sedgy plat, on which the dip is 25°–40° S. 23° E. (No. 47). Ten rods north of mile-post No. 7 the dip is 55° S. 87° W. (No. 48). At the mile-post the dip is 50° westerly; and in certain granitic veins the feldspar is abundant. On a hummock near the summit the dip is 20° N. 48° W. Standing east of the hotel, on the summit, one sees a hill to the right of the road, above the head waters of the Ellis river, where the strata apparently dip about 60° easterly. On the very summit the dip is 25° north-westerly. Just behind the Tip-top house the dip is S. 23° E. On a spur towards the Lakes of the Clouds the dip is 60° S. 47° W. Thus there is considerable variation in the dip at the very summit, a small synclinal eighty feet long showing itself at the highest part of the mountain. The rocks are coarse and fine feldspathic mica schists, with andalusite, beds of granite containing tourmaline, and veins of white vitreous quartz. One specimen shows staurolite.

On the west side, following down the railway, less pains have been taken in observations of the positions, and the ledges are few. The dip is thought to be essentially like that on the summit all the way to Jacob's Ladder. A short distance below the Ladder, in a railway cut, the rock is full of andalusite, and dips 60° S. 62° W. At the first tank (from below) a number of loose pieces of a mica schist, holding delicate crystals of staurolite, are abundant, and they were at first supposed to represent the ledge, but nothing of the kind has yet been discovered in place. At the station the strata are mica schist, granitic layers, and andalusite beds, dipping 60° to 70° N. 38° W. This is the last ledge of the schists observed in this neighborhood, though the granites which succeed seem to have been erupted through crevices in them.

It should be distinctly understood that Nos. 10, 13–36 are regarded as belonging to a much newer system than the Montalban, though they are described above without special limitation.

Ellis river above Pinkham notch. After leaving the granitic gneisses cropping out south of the Glen house, and we begin to ascend the valley of Ellis river from the height of land in the road, we find a compound of quartz and feldspar, granitic in appearance. Next we come to the Crystal falls, where the base formation is a fine-grained variety of the Montalban schists, traversed by enormous dykes of trappean character. The dip is 68° westerly. Half a mile higher the coarser mica schists crop out, with an easterly dip. Ledges are scarce, however, in this valley; and in Tuckerman's ravine the inclination is westerly again. The dip is very steep low down, but only 28° above the snow-bank. High up the side of the ravine, towards the summit of the mountain, the dip is in the direction of N. 83° W. The ledges are finely developed near the snow-arch; and the westerly dip into the mountain may be distinctly apprehended in the photographs of the "Thousand streams," and also in "Raymond's cataract," on the easterly-flowing stream in the next ravine to the north. Dr. J. W. Dawson speaks of the "gneiss" he observed in the depths of Tuckerman's ravine, in his paper on Alpine plants. The absence of the newer series of rocks is as marked along the Ellis as in the west branch of the Peabody river.

South of Mt. Washington. Trips to the south of Mt. Washington, in several directions, afford a few observations. Upon the Davis bridle-path the rock is uniformly the coarser feldspathic mica schist, with occasional small, clearly-cut crystals of staurolite, in addition to the usual sparse sprinkling of andalusite. On the east side of Oakes's gulf, before the path descends much, the dip is from 14°–20° N. 43° W. Four and a half miles north of the mouth of Mt. Washington river the dip is S. 67° W.

Passing from the summit hotels to the Lakes of the Clouds, one walks over immense piles of angular fragments separated from the ledges by intense refrigeration. The north-westerly dips near the point of departure have been mentioned. On a hummock north of the lakes the dip is 5° S. To the south of the lakes the rock is a slaty micaceous quartzite. Beyond it is schistose again, dipping 75° westerly. The westerly dip of the whole mass of Mt. Monroe is distinctly observable from Mt. Washington. The Crawford bridle-path passes around the east side of Monroe; and the schists grow gradually more feldspathic and granitic, so much so that I called them all granite on my first trip over this road in 1858. There are great veins of feldspar associated with them. On the east side of Mt. Franklin there is a slide. Coarsely grained gneisses and mica schists make up the summit of this mountain, dipping 10° west.

A trip down the west side of Mt. Franklin, July 16, 1870, will always be remembered by the party of young men who went with me at that time. We had walked from the "Twin River farm" to the summit of Mt. Washington, and thence past the Lakes of the Clouds to Mt. Franklin, and were exceedingly wearied. The side of the mountain appeared smooth, and we anticipated a pleasant trip back again to our camp. But the beautiful greensward turned itself into an inextricable labyrinth of the short, stiff growth of subalpine evergreens for an interminable distance, and the camp was not reached till quite late in the evening. The last part of the way was through chopped trees which had not been cleared off, and in the pitchy darkness proving to be a more serious obstacle than the scrubby growth of the subalpine region. On reaching the brook between Mts. Pleasant and Franklin the rock was found to be quite ferruginous, but the same granitic gneiss with that on the summit of Franklin. It contains veins of coarse granite, showing a few crystals of feldspar three inches long. This is followed by a width of half to three fourths of a mile of clear, beautiful granite, showing nearly horizontal jointed seams running through it, though their position is not uniform. This is followed by a porphyritic variety of granite.

In the gap between Mts. Franklin and Pleasant the usual schists of this range dip N. 88° W. Mt. Pleasant is always known in scenic views by its dome-shaped summit. [See heliotype, Vol. I, p. 220.] The top is well covered by drift, not of great thickness, nor sufficient to prevent the acquisition of information about the rocks, which are granitic and coarse mica schists, with ferruginous admixtures. Dykes of trap occasionally occur all along the range, one in which numerous jointed seams divide the rock into small pieces. On the south side of Mt. Pleasant, as well as upon Mt. Franklin, there are numerous large concretion-like bunches, two or three feet across, in the common schists. The layers in these bunches usually have a different position from that of the adjoining strata; and the material between is charged with ferruginous compounds. The dip changes at the valley between Mts. Pleasant and Clinton to 68° S. 47° E., and ferruginous strata are to be noted here. Half a mile before coming to Clinton the dip is 80° N. 73° W. Mt. Clinton shows granitic and decomposing gneisses. The dip is N. 73° W. at variable angles, and the direction is also irregular. Between Mts. Clinton and Jackson the rocks stand about 80° N. 67° W., and are coarse feldspathic mica schists. After passing Clinton the following successions of strata occur on the bridle-path: At three and a half miles, near the summit, micaceous rocks, with acicular hornblende crystals; at three and one twelfth miles, granitic gneiss; at three and one sixteenth, granitic gneiss; at two and a half, coarse mica schists; at one and a half, granitic gneiss coarser than the "Concord;" the same at half a mile, with the dip 56° W. and S. 80° W. On the east side of the Crawford house is Gibbs's brook, which falls over ledges of coarse granitic gneiss and grayish mica schists, half a mile or so from the hotel, and the place is known as Gibbs's falls. This location is just below the half-mile station on the bridle-path mentioned previously.

At the Gate of the Notch the rock is the feldspathic mica schist of the Montalban series. The railroad excavations are making the character and position of the rocks much better known here than formerly. The proper dip seems to be 65° S. 80° W. The Elephant's Head is composed at its northern base of a granitic gneiss, which has been extensively utilized for the building of railroad culverts. Other rocks of different ages crowd themselves into the Notch, which must be noticed further on. A trip up Mt. Webster, starting from the road at the Silver cascade, revealed the following facts: Upon the road there are Montalban schists. At the base of the cascade there is a granitic rock, with seams dipping

15° S. 17° W. This possesses peculiar mineral characters, whose description is reserved for another chapter. A small dyke cuts this, and seems to have determined the course of the Silver stream, as may be well seen in the heliotype of this cascade. Two or three hundred feet above the road I observed a mass of mica slate, ten feet long, seven feet wide, and three feet thick, imbedded in the granitic rock, and smaller pieces of the same material may often be seen enclosed in this matrix. Veins of feldspar show themselves higher up. After getting well up on the flank of the mountain, among the small trees, there is a series of pools along the brook where foliated planes of mica schist dip 70° N. 57° E.; but these may not be the lines of stratification. This soon passes into the usual rock of the range, continuing to the crest of the ridge, dipping 70° north-westerly. The route taken may be understood by referring to the heliotype opposite page 79, Volume I. We passed through the Notch, leaving the Elephant's Head to the left, and at about a quarter of a mile below the Gate commenced the ascent, taking a direct course for the highest part of the central mountain in the background. The common rocks of the Montalban group occupy every part of this view to the left of the Gate, and a short distance to the right. The beginning of the steeper slope very near the summit of Mt. Webster indicates the line between the ferruginous mica schists on the left, and the eruptive granites of the Pemigewasset series on the right.

On the top of Mt. Webster the rock is the ferruginous variety observed on Mts. Pleasant and Franklin, traversed by veins of two or three feet thickness of coarse granite and dykes of white-colored trap. South from the north edge of the mountain the dip of the schists is 70° N. 67° E. One can walk along the crest of this ridge and enjoy a fine view of the Saco valley below Mt. Willard. The summit is devoid of trees; and there is a precipice several hundred feet deep which is entirely composed of the schists. At its base the granite begins; and the difference between them is marked still further by a great contrast in color,—reddish-brown against grayish-white. Opposite the Willey house the strata may be said to dip westerly, though, as the dip varies but a few degrees from perpendicular, the occurrence of a leaning to the east or west cannot be of much consequence in the study of the stratigraphical position. The small variations are often due to disturbances induced in connection with large veins of granite, which are very common here. I think the usual granite on the west side of Mt. Webster is the variety to be described as the "Conway;" but my notes speak of the recurrence of the hard siliceous granite of Silver cascade, east of the Saco river, and that it extends as far as the first bridge over the river below the Willey house. The schists do not extend to the south end of the Webster range, their place being taken by the granite which occurs upon Mt. Washington river, about as far north as the latitude of the Willey house.

Mt. Deception range. There remains to be noticed a triangular area to the north-west of Ammonoosuc, or the eastern part of the Cherry Mountain district, consisting of Mts. Mitten, Dartmouth, and Deception, with their northern slope to Israel's river. Mt. Mitten is composed of the same coarse feldspathic mica schist as Mts. Adams and Jefferson. It is the first of the east and west range branching from Mt. Jefferson. Mt. Dartmouth is composed of a granite, with small porphyritic crystals. Mt. Deception is built up of a coarse Concord granite. Between this ridge and Israel's river there is a long slope; and nothing is known of the ledges there. Along the river the rocks are concealed by thick piles of earth; and the poor prospect of finding much solid rock there has always debarred the most ambitious of our parties from making the attempt. The western part of the area is obviously the boundary between the Bethlehem and Montalban groups; and it is not likely that any of the granites extend very far in a northerly direction. Very near the north-west corner of Lowe & Burbank's Grant there is a corrugated mica schist, abounding in mica, dipping 85° S. 23° E.

Concerning another extensive area our information is also meagre. It is of the mountains south of Tuckerman's ravine, on the west side of Ellis river as far as Iron mountain in Bartlett. The rock is believed to belong to the same system of Montalban schists that we have been describing. It was through the heart of this region that the exploring party of Dr. Cutler made its way in 1784. We have, however, important facts to state concerning the district of Mt. Washington river. It has been explored three different times.

Mt. Washington river. This is the longer branch of the Saco above Bemis station, but it is reckoned as a tributary rather than the main stream. We have not visited its very source, close by the Lakes of the

Clouds, but passed down at the gap between Mts. Franklin and Pleasant. The rock is the usual mixture of andalusite mica schists and granitic gneisses at the starting-point, dipping N. 88° W., also 54° N. 48° W. near by. These two mountains send out spurs into the valley, the northern being longer, and the southern the steeper one of the two. About a mile and a half down the valley between them the dip is N. 63° W. Lower down the dip is small to the north. The rock contains fragments of an older schist in it. Beyond, there may be a south-westerly inclination, though this has not been satisfactorily observed. At a lower point the dip is distinctly 60° N. 83° W. On the east side of Mt. Clinton, high up, one can perceive from the valley a large, bare ledge. Where the tributary, down which we have come so far, joins the main Mt. Washington river the ledges dip 30° N. 73° W. Then, for half a mile, the schists generally dip in the same general north-westerly direction, but there are a few contorted dips in the opposite direction. The last ledge seen before reaching the labradorite outlier dips 85° N. 83° W.

The following represents the appearance of the ledges down the valley between Mts. Clinton and Jackson, before reaching Mt. Washington river. At the beginning of the slope the strata are about vertical, with a strike of N. 12° E. Beyond, the dip is 80° westerly, with irregularities in the direction, and there is andalusite present. Continuing down the mountain's side we come to a cascade twenty-five or thirty feet in height, at whose base enters the first important tributary from the north. The schists dip 70° S. 48° E. The rock below becomes more micaceous; and many ledges resemble the darker colored varieties seen at Nancy's brook. At the next fall, of over one hundred feet, the rock changes, and much resembles the porphyritic gneiss. Crystals of orthoclase are abundant, the dip being 70° N. 83° W. The finer-grained part of this rock presents a slightly talcose aspect; and our conclusion is, that if it requires removal from the Montalban group, it may represent the porphyritic member of the Bethlehem gneiss. The schists at the falls dip both east and west, the latter being lowest down, and contain quite large plates of mica, with a curved trap dyke. Below the falls the schists vary in mineral composition, and I have noted the presence of a very large trappean mass. Next, the strata are fine-grained and much jointed. The feldspar bunches recur again just before reaching the junction of this branch with the main river. Massive light-colored traps appear here. At the fork the strata of porphyritic aspect dip only 20° a little west of north; and fragments of other varieties of gneiss are imbedded in them. A few rods above the confluence of the two streams the dip is N. 67° E.

The occurrence of the labradorite rock is described elsewhere. The first rocks seen below it dip thirty or forty degrees northerly, and they are the dark-colored, twisted andalusite mica schists, with little feldspar. Below the outlet of the brook from Clinton the strata become flinty, are quartzites, with the characteristic White Mountain mica scattered through them, and are inclined 45° N. 43° W. A remarkable trappean conglomerate is next met with. For one hundred feet on the east branch there is an interesting trappean conglomerate, with pebbles of various Montalban schists, some of them three feet in length. Seams of an argillaceous cement interpenetrate them. At the lower end of the mass the quartzose rock reappears, dipping easterly. Across the river a similar ledge crops out, having a striped appearance, dipping 30° N. 38° W., or directly under the preceding. Where the valley curves sharply to the east, the hard quartzite has been cut deeply by the river, which has shrunk to less than half its former dimensions. At a great bend below, an enormous amount of drift is exposed high up on the southern bank. At this point the ledges of granite commence, though enormous boulders of them are strewn by the river's side for half a mile above. This granite is related to the "Conway" variety.

A matter of much interest may be seen below. After following a distinct granite floor for a considerable distance,—the whole gulf having this rock upon both walls a thousand feet high,—there appears an island of the flinty rock, which may be the remnant of the underlying material once covered by the pasty granite, and exposed at the present time on account of the long-continued agency of the water passing over it. The same rock crops out again at Bemis station, about three miles lower down. These and other facts lead us to believe that the base of the Saco valley lies very near the base of the whole series of Pemigewasset granites.

There is an interesting series of falls on this river, five or six miles above its junction with the Saco. Mr. Huntington says that the upper part consists of a fall of seven feet into an oval basin twenty-five feet long and twenty wide. Then the stream makes two leaps of ten feet each, one above the other, and finally terminates by a vertical plunge of twenty-three feet, the body of the stream here being only ten feet wide. Dr. Bemis narrates interesting expeditions to this locality, and found trout in abundance considerably above these falls. His companions,—among them the elder Crawford,—seemed to have great fears of the evil spirits that kept guard over the source of this mountain torrent.

Country East of the Peabody and Ellis Rivers.

BY J. H. HUNTINGTON.

Bean's Purchase, Chatham, etc. The great area of country stretching southward from the Androscoggin river in Shelburne is for miles a wilderness, uninhabited save by the denizens of the forests. It is broken by hills and valleys, rocky cliffs and deep gorges, mountain ridges and precipitous slopes; while on the west side of Bean's Purchase, and on the state line near Chatham, we have mountains that rise to the height of nearly four thousand feet. In Chatham and Jackson the country is hardly less broken. The gorge between Mts. Wildcat and Carter is quite as remarkable as any among the mountains, especially in its southern opening. The precipitous wall of rock on the west, the over-hanging cliffs on the east, the great mass of *débris* across the valley that confines the water of a small lake, are all of intense interest to the geologist. On the east the Bricket notch, just over the border in Maine, is remarkable, particularly in the way in which the streams divide as they come down from the side of the Notch. The stream from Mt. Royce, where it leaves the steep slope of the mountain, divides; a part runs north into the Androscoggin, and the rest flows south into the Saco. But what is most wonderful, from Speckled mountain, on the south-east side of the Notch, there is a stream the exact counterpart of the one from Mt. Royce;—so that the height of land in the Notch is an island by being surrounded by water from these two streams, or rather four streams, after the two have divided. At the head waters of the east branch of the Saco there is a low notch towards Wild river, and the slopes of the sides are regular, compared with most notches about the mountains.

The irregularity of ridges and mountain ranges in this section is due chiefly to the changes in the strike and dip of the strata. While in general the strike is not very far from north and south, there are many notable exceptions. The most marked is at the head of Cold river, where the strike is nearly east and west, and the dip is north, nearly vertical. A change in the strike causes the mountain ridge to sweep round in a curve towards Baldface mountain. Between Ellis river and Wildcat branch there is a sharp mountain ridge that runs nearly north and south, extending down from Wildcat mountain. This ridge has in places a height of two thousand feet. East of Wildcat branch there is a ridge, including Black mountain, that is somewhat higher than the last. The other well-marked heights in Jackson are either granitic gneiss or in part intrusive rocks.

The rocks of Bean's Purchase, Chatham, and Jackson are for the most part quite uniform. The entire range east of the Glen road, including Mts. Moriah, Imp, Carter, and Wildcat, is composed of the White Mountain gneisses. These rocks extend from this ridge eastward into Maine; and the mountain ridge including Mts. Royce and Baldface is the same. The rock in the area between Baldface mountain and the site of the Dearborn & Philbrook saw-mill is a feldspar-porphyry, with a limited outcrop of a dark-reddish, more compact feldspathic rock on the south-west side of Sable mountain. This last has sometimes the appearance of being a breccia, and resembles the feldspar-porphyries of Mote mountain. Though not seen in many places, it probably extends southward to Mountain pond. Both south-west and north-east from Mountain pond the rock is a reddish granite. Slope mountain is probably its limit northward. South of Chatham Centre we find a granite very similar to that of Conway, while in the north-east part of the town, north of the Centre, the rock is generally the gray micaceous gneiss of the Montalban group, though on the east side of Baldface a granite has been quarried that contains quite a large proportion of feldspar. The dip of the gneiss is quite variable. Half a mile north-west of Chatham Centre it is N. 3° E. 68°. Just above the school at the base of Slope mountain the dip is N. 37° E. and E. 56°. It has been affected here, no doubt, by a great granite mass on the west. On the south slope of Mt. Royce, where an observation was taken, the dip is N. 13° W. 20°; but, from the precipitous character of the mountain, the inclination of the strata must be much greater in many places. Passing over into Maine, the rocks of the Montalban group, where they were seen in Stoneham and Lowell, have a westerly dip, generally at a small angle.

West of Chatham in Jackson, Double Head is granitic gneiss, probably an extension of the Montalban southward from the Dearborn & Philbrook saw-mill, but it is limited southward by the intrusive rocks in the south part of Jackson and in the edge of Bartlett.

Valley of the Ellis river. From the height of land in the Pinkham notch southward to Jackson village, the White Mountain gneisses are the prevailing rocks. Though the inclination of the strata is everywhere westerly, yet the dip is quite variable. At Glen Ellis falls the dark gray gneiss dips N. 60° W. 45°, and N. 83° W. 60°. At the head of the falls there is a wide quartz vein that is metalliferous and somewhat decomposed. A fine view of these falls is given in Volume I, opposite page 632. The massive character of these White Mountain gneisses is nowhere better shown; and the jointed structure is in a measure brought out in the view. On the west of the road, as we begin to descend the hill going southward, the rock contains andalusite; and a few beryls have been found in the coarse granite veins that cut this rock. Going southward, we find the dark gray gneiss common to this mountain region; and at the distance of two miles from the falls the dip is N. 23° W. 60°. At the first house in Jackson,—N. M. Cook's,—the gneiss has in several localities an impure limestone interstratified with it. It can be seen east of the road, on a steep hillside about eighty rods south of the house, also in the river at a sharp turn below the house. The rock near the road dips N. 33° W. 45°; and the limestone with gneiss east of the road dips N. 20° W. 85° In the river where the limestone is found the dip is exceedingly variable. At H. Wentworth's the White Mountain gneiss dips N. 38° W. 25°; and on the west side of the road the strata dip N. 65° W. 30°. On Miles brook, at the falls, the rock does not look like the White Mountain rock elsewhere. It contains very little mica; the cleavage planes are very distinct, and the rock is broken by them so that the water falls over stair-like projections. In the vicinity of J. Rogers's there is an extensive outcrop of granite like that in Albany. The cliff west of Ellis river is made of this rock. The stratified rocks south of Rogers's seem to be more siliceous than the White Mountain rocks generally, though on the ridge east of the road they have their normal characteristics. West of Ellis river, and on the east slope of Iron mountain, we have a rock very similar to that on Miles brook, and it has here an easterly dip; while on the summit of Iron mountain the common White Mountain gneiss dips north. On Wildcat branch, at the most northern settlement, we have the characteristic White Mountain gneiss; but on the western slope of Black mountain, at J. Y. Perkins's, and south at J. R. Harriman's and J. Chesley's, there are many bands of fine-grained pyritiferous schist, and at Chesley's there is a dark siliceous schist free from iron. On the southern slope of Black mountain we have the andalusite schist. On Rocky Branch, above Abt. Emery's, the gneisses are everywhere pyritiferous.

The following additional dips show how exceedingly variable the strata are in this area.

Three and a half miles north of the Dearborn & Philbrook saw-mill, White Mountain gneiss dips	N. 85° E. 50°.
George Manson's, White Mountain gneiss dips	N. 73° W. 60°.
N. M. Cook's, limestone in the river dips	N. 78° W. 20°.
" " gneiss near the limestone dips	N. 30°.
Miles brook, at the falls, dip,	N. 34° W. 42°.
J. W. Brack's, White Mountain gneiss dips	N. 38° W. 64°.
A. Chesley's, pyritiferous schist dips	N. 33° W° 68°.
" half a mile north-east of house, siliceous schist dips,	S. 38° E. 66°.
Near the last, dip,	N. 43° W.
Summit of Iron mountain, White Mountain gneiss dips	N. 53° W. 25°.
Three miles west of Jackson, road to Rocky Branch, dip,	N. 13° W.

The variation is due in a great measure to the fact that the stratified rocks have been folded, and pressed against the harder, unyielding intrusive granitic rocks. We have already mentioned that a dark siliceous rock was found near A. Chesley's. A similar rock is found on Tin mountain, in the gap west and on the east side, and near the summit of Thorn mountain. It is also found near the village of Jackson, immediately north of the falls.

On Tin mountain, dark siliceous schist dips	N. 47° E. 80°.
Hill west of Tin mountain, siliceous schist dips	N. 7° E. 70°.
Thorn mountain, siliceous schist dips	N. 17° E. 68°.

These schists that come near or in contact with intrusive rocks are everywhere nearly vertical.

Intrusive rocks. In the south part of Jackson, and also running diagonally across the town, there are bands of intrusive rocks. On Wildcat branch, where the road from A. Chesley's crosses the stream, there is a granitic rock composed very largely of feldspar. The rock has the general appearance of the Albany granite, which outcrops on Ellis river, near J. Rogers's, and a large proportion of this rock is also feldspar. An outcrop of a similar rock was seen at C. Littlefield's, and it extends to Rocky Branch. At Jackson falls the Albany granite is found, with finer-grained varieties. It outcrops in several places on the ridge between Tin and Thorn mountains. It also forms the summit of the latter. On the east branch of the Saco, just below McMellin & Towle's saw-mill, the Albany granite comes in contact with the slates of Mt. Pequawket. Along the line of junction the slate forms a breccia, and the feldspathic material of the granite furnishes the cementing material. It is one of the most interesting localities in this section of the state. There is an area of the Conway granite that has its most northern and eastern outcrop on Copp's hill in Jackson. It extends south-west, and forms the southern part of Iron mountain, and it is in this rock that the iron ore is found, though it is immediately associated with a rock composed chiefly of feldspar, that reminds one of the Chocorua granite. If the granites that are composed so largely of feldspar are more recent than the Conway, as seems evident from their relations elsewhere, those that we find in the valley of Rocky Branch, between the high ridges of the Conway, must have been formed in a depression, or the intruding mass had not sufficient force to make its way through and overflow the preëxisting rocks.

J. H. H.

Areas of Montalban in Pemigewasset.

These areas are six in number:—First, the region about Bemis and Duck Pond mountain; second, a small patch between Deer mountain and Chocorua; third, a somewhat larger territory between Passaconnaway and Tripyramid, on the east branch of Sabba Day brook; fourth, a considerable tract along the Pemigewasset river in Lincoln, Woodstock, and Thornton, being a spur from a great development of this formation in the Merrimack district; lastly, inconsiderable areas in Albany and Bartlett.

A trip up Mt. Hope and the mountain opposite Nancy's brook in Hart's Location affords us a few observations concerning some of the rocks of the first-named area. Starting from the Saco river by the old Davis path, the common granite of the Notch is seen half-way up Mt. Hope. This is followed by a porphyritic rock (No. 430). Mt. Hope is a small eminence at the head of Glen Crawford, just south of Mt. Crawford. The Glen is shown in the heliotype of Mt. Crawford from Bemis. Mt. Hope and the southern part of Mt. Crawford are composed of fine-grained compact feldspathic mica schists, dipping 60° N. 3° W. This area is marked like Mt. Webster by the occurrence of enormous granite veins, with the direction N. 8° W., and some of them are at least thirty feet wide. These veins are supposed to have been connected with the eruption of the Conway granite. Some of the specimens from Mt. Hope are micaceous quartzites. On the south side of this eminence the granitic gneisses predominate, with only an occasional layer of the quartzite. Passing to the next mountain south, the schists dip 75° N. 52° E., also N. 23° W. Occasional masses of granite show themselves. On the very highest point of this mountain, and opposite to the mouth of Nancy's brook, the rock is like the common Mt. Washington schist, with a few spangles of fine mica among the abundant larger pieces. The specimen has a reddish color, from ferruginous stains. The dip is 70° N. 78° W. In passing down to Nancy's brook, rocks similar to those on the summit show themselves, with essentially the same position. Half-way down there is much of a hard, jointed granite. At the western base of the mountain the rock agrees with that on its highest part.

The rocks are well exposed on Nancy's brook. At its mouth the railroad passes through a large cutting, and the fragments thrown out may be taken as typical of an important variety of this formation. The color is mostly dark, nearly black, with a whitish sprinkling of feldspar or quartz. The substance is largely a compact silica, but the mica is well developed, and is not quite so conspicuous as the blotches on the presidential summits. The mica is often distributed in impalpable shining streaks instead of scales. At the saw-mill the dip is 45° N. 87° W. The brook has excavated a flume through the ledge, and the rock removed is a granitic aggregate, very siliceous, like the exposures in the Silver cascade and elsewhere in the White Mountain Notch. The flume exists because of the removal of this dyke, twenty-five feet in width. The vertical joints of the walls have the direction of N. 62° E. It is well known to tourists, and has been figured in Oakes's work on scenery. Half a mile up the stream the rock is micaceous quartzite. The specimens brought from various localities higher up, the last mile and a half east of Nancy's pond, are gneissic (Nos. 310, 311, 313). At Bemis station a dark rock appears, with the same general position as the strata at the saw-mill. A comparison of those already mentioned as coming from Mt. Hope, the ridge south, Nancy's brook, and Bemis station, with the rocks of Mt. Webster and the lower part of Mt. Washington river, proves them to be identical in appearance and composition.

Below Bemis this rock may extend nearly to Sawyer's river. At the most prominent bend in the Saco, about a mile and a quarter below Nancy's brook, some large ledges dip 75° N. 73° W., with many contortions. In the same neighborhood the railroad has uncovered a ledge dipping N. 80° W. Dr. Bemis says there is a slaty rock of this description on Half-way brook, higher up the mountain. Duck Pond mountain is supposed to be composed of the same materials, as I found ledges of a gneiss with much silica in it about a mile above Sawyer's river, on Duck pond, dipping 80° S. 60° W. Three fourths of a mile farther north-west the same rock occurs. Scarcely anything can be said respecting the areas west of Mts. Chocorua and Passaconnaway. Both show a high westerly dip. The first is clearly the ordinary schist of this series. The specimen from the other locality is a somewhat ferruginous micaceous quartzite.

In the report for 1871 it is stated that there is an outcrop of this formation upon the head waters of Little Deer brook in Albany. Our specimens from this locality very closely resemble the schist commonly characterizing this group. The outcrop is quite limited, lying between feldspathic porphyry and feldspathic breccia. Another small area has been discovered upon Rocky Branch in Bartlett.

Pemigewasset River area. The assemblage of gneisses and granites at the Georgianna falls in Lincoln may possibly belong to this series, though noticed under the Franconia breccia. It is probable that the Montalban schists extend about to the cascade, though none of our specimens came from a mile and a half beyond the neighborhood of the Lincoln post-office. At the post-office the dip is 50° N. 57° W. Section VIII shows a profusion of specimens belonging to this formation between the Pemigewasset river and the granite, a quarter of a mile east of T. C. Pollard's. The gneissic character is well shown in most of the specimens; and the dip near Pollard's is about eighty degrees north-westerly. At P. Russell's, in North Woodstock, the gneiss dips 70° S. 73° E. It is traversed by a trap dyke six feet wide, also by a thirty-feet band of granite. Near J. M. Rowe's a similar rock somewhat ferruginous dips 78° S. 38° E. Passing from the Pemigewasset to Russell pond we see first a variety of unclean gneisses and mica schists dipping 70° S. 63° E. A little south-west from the pond there are mammoth veins of coarse graphic granite carrying beryl, rough quartz crystals, and plumose mica. The strata somewhat to the south stand upon their edges, with a north-south strike. East of the pond a gneiss containing garnets dips 50° N. 42° W. Still farther east the rock is ferruginous on the west side; and there is a large vein of granite on top of a ridge, not the highest part of the water-shed. Just below Woodstock, P. O., an imperfect gneiss dips 80° S. 82° E., with many contortions. At Norton's falls there is an anticlinal in a granitic gneiss, possibly belonging to the porphyritic series, with the strike N. 13° E. This may be the northward continuation of the axis mentioned on page 102.

At E. Merrill's, in the north part of Thornton, there is a coarse granite with gneissic layers dipping 60° S. 18° W. Near Mrs. G. W. Grant's the rock is ferruginous. South-west from H. Fifield's, on the Woodstock line, the gneiss dips 65° N. 52° W. In the direction N. 8° E. from Fifield's there is an enormous vein of coarse granite east of the ridge running up to Russell pond. There is a low gap in the rim of the Pemigewasset which is 904 feet above the sea, and not more than fifty feet higher than Fifield's house. The ridge rises steeply to the north, and the schists there are not uniform in position. Hix and Wanosha mountains in Thornton are small eminences of the Montalban gneiss, and they are by no means the formidable summits they seem to be on the county map. Between them, near M. Sargent's, the rock is considerably ferruginous. At J. F. Morrill's, at the end of the road, the gneiss dips 70° N.

Fig. 10.
OLD MAN OF DIXVILLE.

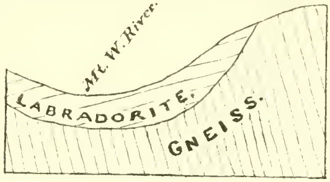


Fig. 20. Junction of Montalban Gneiss with Labrador System; Mount Washington River.

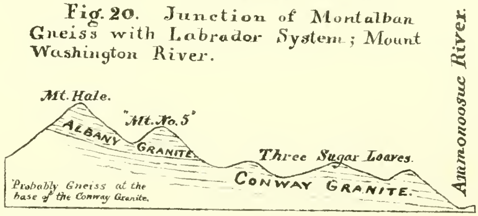


Fig. 13. Section from Lower Ammonoosuc River to Mt. Hale.

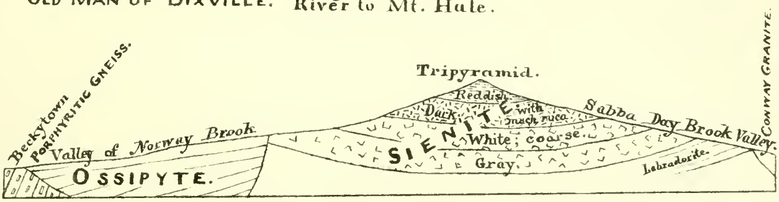


Fig. 19. Structure of Tripyramid Mountain.

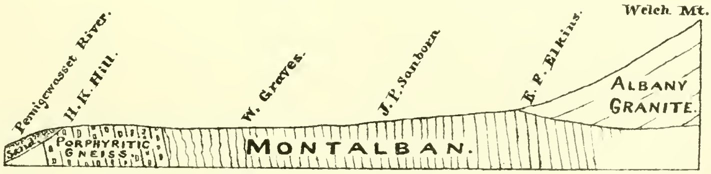


Fig. 12. Section from West Thornton to Welch Mountain.

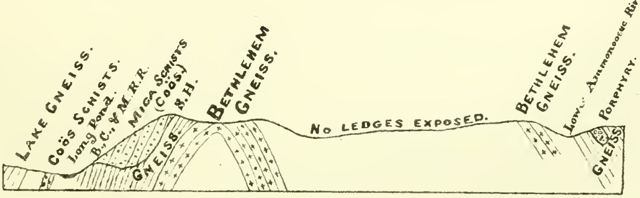


Fig. 11. Section from S. E. Dalton through Whitefield and Carroll.

72° W. At the saw-, shingle, and clapboard mill on the Woodstock line, gneiss dips 80° south-easterly. South of Hatch hill, on the road east, there are Montalban schists resembling those found farther north.

The immediate vicinity of the Pemigewasset is occupied by porphyritic gneiss noticed on page 102. There is an interesting section between Welch mountain and the river at West Thornton, represented in Fig. 12. At the westward is the Pemigewasset river, with its alluvium nearly to H. K. Hill's house. The underlying rock is the porphyritic gneiss, with a very high easterly dip, nearly vertical,—the other part of the anticlinal axis existing on the west bank of the river, and not represented. The strike is N. 38° E. The hill is the continuation southerly of the east water-shed of the river, and not a rock boundary. As soon as we come to Mill brook the rock changes to the Montalban schists. At W. Graves's they dip 85° south-easterly, and are much contorted. A similar position is noted all the way to Welch mountain, but especially at the school-house east of J. P. Sanborn's. Cone mountain is composed of the same rock. This designation is derived from the name of a person, and not from any resemblance to the well-known geometrical solid. At E. F. Elkins's the rocks are concealed; but we pass up the steep slope of Welch mountain, which is composed of Albany granite in broad plates dipping twenty degrees westerly, and supposed to overlie the Montalban group. The lower granite was not observed at this point.

This section illustrates, first, the mutual relations of the three rocks named. Supposing them to lie in their natural positions, one sees clearly that the porphyritic gneiss is the oldest formation, and possesses an anticlinal structure, while the same upper schists appear on both sides of the axis. The granite assumes the overlying, slightly inclined position argued for this rock almost universally in New Hampshire. Second, there is such a divergence in the strike of the porphyritic and Montalban groups in Thornton that one may be justified in inferring that there is an unconformity between them. The strike all through the central formation of the section is north-easterly. The course of the boundary between them is N. 10° W. The most common strike of the porphyritic gneiss is a little east of north, but at V. G. Durgin's the longer axes of the crystals run nearly east and west. Assuming the correctness of these statements, it may be inferred that the Montalban schists lie upon the upturned edges of the porphyritic gneiss over the whole area between the Sandwich and Pemigewasset River ranges; and, as the boundary line between them conforms to the strike of neither, it is likely that they are not divided by a fault, but the irregular edge is due to unequal erosion by atmospheric agents. Nevertheless, the line is straight enough to have been determined by a fracture; but even in that event the two formations must have been unconformable to each other. The very easterly directions of the strata at H. K. Hill's and V. G. Durgin's would seem to indicate the passage of the porphyritic rock directly underneath the Montalban gneisses along the line of strike. A similar course is probable for the very interesting outcrop of the older rock in the Pemigewasset river along the boundary between Thornton and Campton. Upon Section VII will be found a representation of the situation of this rocky blanket upon the porphyritic floor.

Little search has been made for the mineral andalusite in this range. There is, however, an outcrop near E. Cone's, at the crossing of the road by a tributary of Mad river, near a cemetery, showing either this mineral or kyanite sparsely scattered through the ledge. The dip is 60° S. 42° E. It is rare to find ledges in this part of Thornton, on account of the abundant loose materials spread everywhere over the surface. Passing southerly beyond the limits of the White Mountain district, this formation assumes a much greater importance, and covers an immense area.

Eruptive rocks. There is much to be learned from the study of the various eruptive rocks connected with this group. In the absence of a proper study of their lithological characters, little attention has yet been devoted to them. Hence they must be referred to again in another part of the report in the department of mineralogy.

One of the most important areas of eruptive granites intimately associated with this group lies between the Portland & Ogdensburg Railroad, north of the Notch, and the base of the presidential ranges, including Mt. Deception. The great contrast in the topographical features of this granitic region with those of the harder schists may be well appreciated by reference to the view of the Mt. Washington range from the Fabyan turnpike, Vol. I, p. 392. The whole of the foreground is granitic, and of two varieties, different from those in the Pemigewasset series. That from the Mt. Deception range resembles the Concord gneiss, save that it is coarser, and, so far as examined, seems to be a true granite. This variety prevails in the western part of the territory mentioned above, and may also be seen along the Ammonoosuc as far as Twin river. The other variety occurs extensively from Jefferson brook past Ammonoosuc station along the base of Monroe, Franklin, and Pleasant. It consists of a granitic aggregate much like the other variety, having two kinds of mica and especially long, slender feldspar crystals scattered throughout. In passing along the turnpike above Twin river one sees numerous boulders of this variety, in which the long, slender feldspar crystals are conspicuously brought to view through weathering. This rock does not extend above the junction of Franklin with Pleasant brook, with seams dipping 10° N. 47° E. Below it are great masses of feldspathic mica schists, and abundant evidence of its intrusion through strata. It is thought the schists do not extend very much below Franklin brook. Between the lowest schists and Twin river the outcrops are altogether of this variety of granite. Near the "White Springs" on the turnpike there are seams with a high westerly dip, and the rock is quite ferruginous.

On the west side of Mt. Webster, between the Notch and "Pleasant River bridge" over the Saco, there is developed a granitic aggregate of quartz and feldspar, the former predominating. Its eruptive character is inferred from the presence in it at various localities, particularly on the Silver stream, of large fragments of micaceous quartzite, and to its occurrence as a dyke at Bemis's saw-mill at the mouth of Nancy's brook. The occurrence of this granite is a marked feature in the geology of the Notch.

The enormous brecciated traps on the Mt. Washington carriage-road and at the Crystal cascade, the light-colored dykes in Tuckerman's ravine, Mt. Webster, the valley of Mt. Washington river, and elsewhere cannot be treated of satisfactorily at present. At a saw-mill rather more than a mile above the mouth of Rocky Branch in Bartlett, are large trappean dykes containing fragments of three kinds of granite. They may be related to the Mts. Pequawket and Mote porphyries.

The Franconia Breccia.

The most notable locality of this rock is just above the celebrated Basin in Lincoln. Innumerable pieces of porphyritic granite, dark gneiss, hornblende, and other siliceous rocks are cemented together by a light-colored feldspathic paste. The Conway granite lies upon it, the lower formation dipping south-westerly. The line of junction is uncommonly distinct, not being so much as a rod away from the Basin itself, which is so much visited by tourists. Hence it is a locality easily reached by all who are interested in determining the relations of the New Hampshire formations to one another. As the breccia is the material which furnishes information respecting the age of the formation, this will be a favorable place to commence our inquiry. Although mountains surround this valley upon every side, only a few of their ledges are represented in the recomposed rock. Neither the Conway nor Albany granite, the porphyries nor the labradorites of Mts. Lafayette and Profile, appear in the breccia. The Montalban group is not certainly known in the neighborhood, so that we should not expect to see its fragments abundant in the mixture, even if it had a prior existence. It is my impression, however, that I have seen genuine Montalban fragments in this rock, and for that reason I placed the Franconia group later in the chronological scale; but I can now find no specimens among our collections to justify this conclusion. The absence of the Pemigewasset series of granites and porphyries is of much significance, indicating their appearance upon the surface at a later period.

This formation ranges from Mt. Haystack in Franconia to Georgianna falls in Lincoln, a distance of over nine miles. Besides the fragmentary character already noticed, it is composed of an indurated schist very similar to the porphyritic gneiss of this neighborhood. Quartz, feldspar, and black mica are usually present, while every exposed ledge has a slightly rusty appearance from the oxidation of iron. Associated with these gneisses are finer-grained granitic layers, which are not of much importance. The ledges at Haystack pond and on the first eminence between Mts. Lafayette and Haystack, as we proceed northerly from the first-named peak, show the common gneissic variety of this formation. Nothing is known of their position in these two localities, but we suppose both are united together and to the Eagle Cliff range, which overlooks from the north-east the celebrated Profile of Franconia.

Travellers from Bethlehem and Littleton always notice the irregular ragged cliffs filling up the notch between Mts. Lafayette and Profile, as


EAGLE CLIFF
OVER ECHO LA

if they were a disturbing element in the scenery. These are the Eagle cliffs, which are entirely composed of this rock. At the Profile house they tower high up above the observer, shutting out from his observation a considerable portion of the sky. The finest view of them is presented in a heliotype in this volume, taken from a little rise of ground two and a half miles south of the Profile, near the site of the former Lafayette house, and the turning off to the east of a bridle-path up Mt. Lafayette, almost upon the south line of Franconia. The central part of the view is occupied by this range. The eastern wall is composed of the same rock. On the left the eastern precipice of Profile or Cannon mountain bounds the view in that direction. The other view of Eagle cliff upon the same plate was taken from Echo lake. The land falls in both directions from this central ridge of Eagle cliff.

The following observations will illustrate the nature of these rocks, and their disturbances between the Lake of the Clouds and Echo lake. At the upper lake porphyritic gneiss has been observed, as stated upon page 100. The steep hill-side east of Profile lake seems to be composed of the breccia. At the notch between Eagle cliff and this eastern mountain, where the new road up Lafayette passes, great sheets of granite dip 50° S. 48° E. On passing up the cliff to the west of the road we find ledges of hard gneiss dipping 50° N. 63° W. On top the layers are nearly horizontal. In this neighborhood I obtained a piece of a pebble of porphyritic gneiss in the breccia, which was twelve inches long, also an interesting oval concretion of mica. On top of the middle Eagle cliff the rock is entirely composed of the cementing material. The grain is fine, except a few crystals of mica and of feldspar of unusual size, suggesting very faintly the Concord rock, and when weathered it shows a tendency to crumble. There are many fragments in this paste. At the third cliff there are both the fine feldspathic and the common coarser gneissic rock. Here is also a large vein of very coarse granite like that on the "Nubble," described on page 111. Still farther on the dip is N. 33° W., and the rock is more like the porphyritic gneiss. On reaching the cliff, on the north side of Echo lake, the most conspicuous projection seen in the heliotype, we find it composed of porphyritic gneiss, underlaid by an igneous mass of the Franconia breccia, containing fragments of the former rock. It is likely that the breccia is not found any farther to the west, the succeeding ledges of Bald mountain being very porphyritic.

Although the positions are often obscure, it appears plain that, from the passage of the Eagle Cliff ridge by the Lafayette road, to Echo lake, there is a mixture of hard gneisses, with a feldspathic breccia dipping underneath the porphyritic gneiss. As the breccia is largely composed of porphyritic fragments, it must be of more recent origin than the other rocks, although occupying an inferior position. Our conclusion is, that there is an overturn along this ridge, and a fault at its eastern extremity. That will allow the existence of the anticlinal described heretofore and figured on Plate VI, Fig. 7, and will explain the position of a newer beneath the older formation.

At the base of Eagle cliff is a good place to procure specimens of the rocks that have fallen down from above. Opposite the Profile I saw fragments of porphyritic gneiss in the paste twenty inches long. Certain specimens ringing sharply under the hammer exhibit crystals of quartz in the feldspathic paste. A dyke of trap two feet wide, a little to the east, dips 75° S. 78° W. There are only a few outcrops of this formation between the Profile house and the Basin. At the latter locality there is a trappean-looking rock east of the road connected with the breccia.

This formation has not been seen beyond the Basin in connection with any other area, though there is an opportunity for further explorations on the east, above the porphyritic gneiss. Conway granite covers this rock on the west along the outlet of Tamarack pond. On the height of land between Mts. Profile and Kinsman the breccia is largely developed. Of the three peaks along this line the most northern is of granite; the others are composed of this breccia, whose component materials average coarser than at any other locality now known. The middle peak is gneissic; the third, and the valley preceding it, abound with fragments of porphyritic gneiss twenty inches square.

A trip to Kinsman pond, back of Mt. Pemigewasset, shows the same breccia, it being probably continuous from the peaks south of Mt. Profile. The rock did not appear in place; but the great size of the angular blocks indicates the character of the underlying material.

The last line of outcrops referable to this formation appears upon Harvard brook in Lincoln, above Georgianna falls. Mr. Upham visited the locality in 1870, and brought back an abundance of notes and specimens, which enabled me at that time to refer the assemblage to this period. Harvard brook is about three miles long, rising on the south-east side of Mt. Kinsman in Bog pond. Less than a mile from its source a small tributary enters from the north. Upon this and near the main stream there is a vein of quartz three feet thick, dipping 80° E., imbedded in the gneiss. Below the junction of the stream is the "Bog Eddy," an extensive marsh. Between the bog and the upper fall occurred the following: Gray granite, with two kinds of mica; irregular, very coarse granite, with masses of feldspar and quartz frequently eighteen inches long; the ordinary gneiss with black mica, much jointed; coarse granite eighteen inches wide, with the course N. N. E.; similar rocks for ten rods; a coarse granite bed one foot wide dipping, like all above it, 60° south-easterly; fine-grained granite eighteen inches wide, dipping sixty to seventy degrees north-westerly, in which particular the rocks below resemble it; coarse granitic rocks for ten feet. The gneiss at the upper Georgianna falls resembles somewhat the prevailing rock of Woodstock, which has been referred to the porphyritic gneiss. The main falls are situated upon the Franconia rock traversed by a two-feet dyke of coarse granite. [See Fig. 41, Vol. I.] The banks of the stream between the falls and its junction with the Pemigewasset have not been explored.

It is probable that the Franconia breccia is a local deposit, though it indicates a great disturbance among the more ancient formations. There must have been a violent action to break up the older ledges into such large pieces, and transport them to their present bed. If you believe in the transformation of the original sediments by metamorphism into the crystalline aggregates from which the pebbles were broken, it follows that the porphyritic and perhaps other gneisses underwent their changes prior to the Franconia period, since the fragments have experienced no modification in mineral character after leaving their original situation. It is hoped that some traces of this period will be found elsewhere in the state before our explorations are finally brought to a close. Perhaps it is represented upon Cascade brook above Beecher's falls.

PEMIGEWASSET SERIES.

In Chapters III and XV of the first volume I have set forth in a historical way the reasons which led me to describe the Pemigewasset series of rocks, chiefly eruptive, as the probable equivalents of the Labrador system of Logan and Hunt. I stated finally that the several rocks were arranged in the following order, beginning with the lowest: Conway granite, Albany granite, Chocorua granite, Ossipyte or labradorite rocks, and various compact and crystalline feldspars or porphyries. Owing to their particular geographical grouping, I believed all these members to constitute parts of one grand system. This conclusion was derived from the study of the specimens obtained from every part of the White Mountain district, and was not properly comprehended till the field-work had been essentially completed. There are difficulties in the way of accepting these views, and I desire to investigate the subject further before committing the report to the view already presented. I will not, however, depart from the established order in the description of localities and other important matters, only premising that there may be some modifications of our general conclusions hereafter. One is often staggered when attempting to realize the greatness of the task imposed upon us,—to delineate truthfully the geological sequence of all the formations in this unexplored territory. The difficulties in the way must bespeak the indulgence of the scientific public in our favor, should we fail to discover fully the true theory of the structure of the White Mountains.

The Conway and Albany Granites.

It will be convenient to describe both of these granites together, when speaking of their occurrence on the sides of the mountains, and thus avoid needless repetition.

The *Conway granite* was first described as the "common" variety in the report for 1871, page 6. Its type appears at the Basin, Pool, and Flume in Franconia, Goodrich's falls in Jackson, and throughout the town of Conway. The minerals composing it are the three normal constituents of granite,—quartz, feldspar, and mica,—each one being well developed, and so large as to be recognized without difficulty. The microscope is not needed to determine the particular mineral species present. The feldspar is mainly a flesh-colored orthoclase, but oligoclase is common in Franconia and Conway, and probably universally. I have also observed that the quartz is roughly crystalline, whenever carefully examined. The mica is thought to be an ordinary dark muscovite. There are many subordinate varieties connected with this mass, which will be noticed at the proper time; but the typical rock known as the "Conway" is the best example of a real granite found in the state.

The *Albany granite* was first brought to notice at the same time with the other, in 1871, but received the designation of "trachytic," in allusion to a slight resemblance to the volcanic product known as trachyte. It is porphyritic in structure, having crystals of orthoclase imbedded in a fine granitic paste. Two prominent varieties should be noticed,—the one carrying bits of quartz, the other entirely devoid of it; and in this latter case containing the mica disseminated through it, looking as if the rock had been sprinkled over with pepper. The latter variety is the more abundant of the two. A small per cent. of manganese is often present. The porphyritic crystals from Albany gave to Prof. Seely, of silica, 61.6; of alumina, 22.2; of lime, .8. The other percentages were not determined.

In regard to the distribution of these granites, it may be said in general that they occupy the area bounded northerly by the Ammonoosuc as far as the Crawford house, then easterly by Mt. Webster, from whence the northerly boundary passes easterly to Chatham. From Chatham the line passes east of Mt. Pequawket, and takes in the Green hills of Conway. The line then curves westerly from the south part of Conway to Waterville, whence it passes north-westerly and northerly to the Basin in Franconia, and above the Lake of the Clouds on Mt. Lafayette. From thence the boundary is somewhat east of north till the Ammonoosuc river is reached near the Twin Mountain house. In proceeding to a detailed description of the occurrence of these rocks, I will follow the order just indicated.

Passing southerly from the Twin Mountain house, by way of the three "Sugar Loaves," we find, first, the ordinary coarse Conway granite. On top of the first two peaks the rock holds more than the ordinary quantity of black mica. Between them there is an unusual proportion of quartz present. In the saddle between the second and third peaks the planes dip ten degrees northerly. The fourth mountain (No. 5 of Fig. 32, Vol. I) is distinctly composed of the Albany variety, the crystals of feldspar being very numerous. I think the jointed planes dip in the same direction with those farther north. The high mountain to the south of Mt. Hale is composed of the same material, and we do not know that it extends farther in that direction. The line connecting these several peaks makes the arc of a circle, and the supposed position of the granites along this curve appears in Fig. 13.

In travelling from the third Sugar Loaf transversely across to Mt. Tom, the rock is chiefly the Albany granite. The ledges are at the east side of this third peak, on a west branch of New Zealand river as well as at the stream itself. The granite range north of Mt. Tom shows a precipitous cliff on the west side. This has six summits north of Mt. Tom, of which the first and second are nearly porphyritic, being compact, with scattered crystals of orthoclase in it. On the third summit the rock is easily referable to the Conway. That from the fourth contains much quartz. In the fifth the feldspar has very much of a crystalline arrangement. From the Sugar Loaves the Conway granite is continuous, by way of the lower falls on the Ammonoosuc and the several peaks just mentioned, to the Notch. On the east slope of Tom it descends quite low, and finally crops out on Cascade brook. The precise connection between this point and the same kind of granite on the Saco, deep down below Mt. Willard, will be spoken of presently. Both the lower granites are made out clearly on the east side of Mt. Tom.

A second visit to the first part of this granite ridge north of Mt. Tom showed that there was a long, low summit composed of the Albany granite, with jointed planes dipping about five degrees north-easterly. On descending the mountain on the east side, this spotted rock was found to be about three hundred feet thick, succeeded by the Conway variety, which was followed down nearly the whole of the slope. On another occasion we found the Albany granite occupying the saddle between Mts. Tom and Field, as well as nearly all the space northerly to the summit of the first named. Between this point, near the summit of Tom, and the mountain north the country is composed of andalusite slates, perhaps of the Coös group. Evidently there have been great dislocations here.

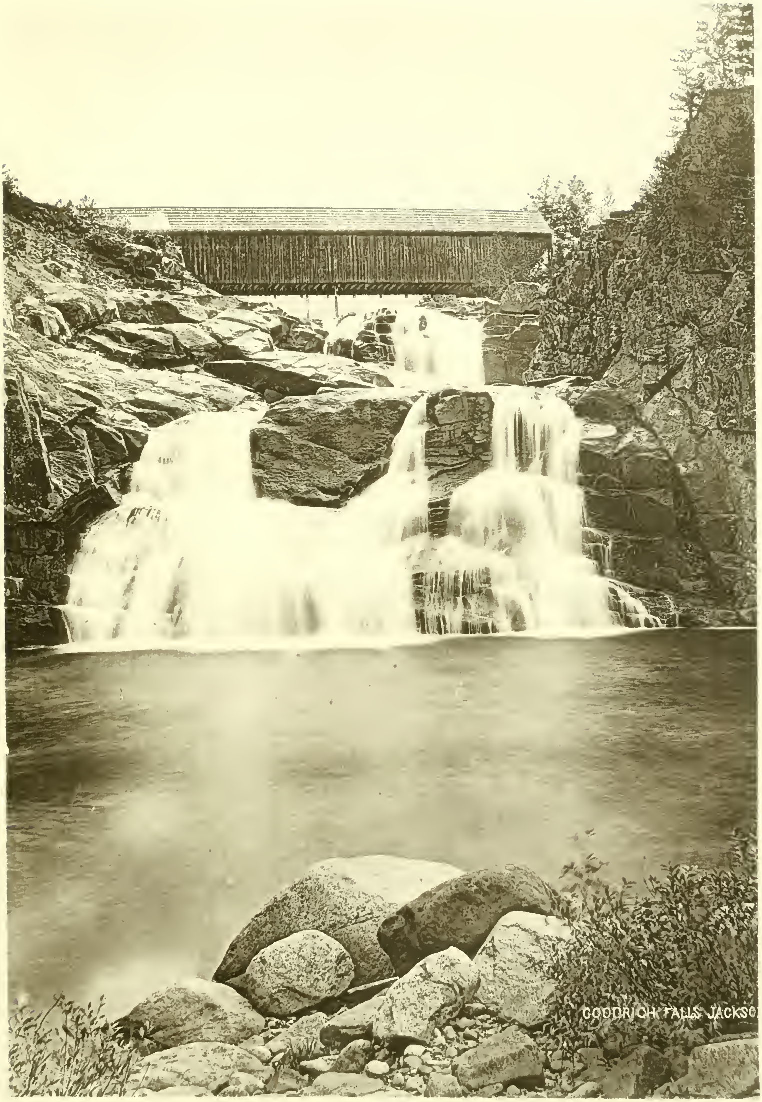
Between the Field-Tom saddle and New Zealand pond the Conway granite prevails. After reaching the base of the upper portion of Mt. Willey the slates are succeeded by one of the granites, and the Conway variety seems to prevail in going to the Willey house. In passing westerly, on the steep south-west side of Mt. Willey, the Conway rock constitutes the *débris* visible, with the ingredients rather finer than usual. Following the south side of the low ridges between Mt. Willey and New Zealand pond, the rock is altogether the ordinary Conway variety. The high ridge east of the pond is somewhat precipitous, with no trees for half a mile up its western side, on account of the abundance of enormous blocks. About one hundred and fifty rods east of New Zealand pond there is a small pool of water among the fragments, which is probably persistent through the year. The pond is very near the divide between the waters flowing northerly into the Ammonoosuc through the New Zealand river, and those discharging themselves into the east branch of the Pemigewasset. Though the pond has the name of New Zealand, it has no connection with the stream of that designation. As the map shows, it discharges itself through a small outlet into a considerable stream flowing easterly from the south Twin mountain, and immediately after their union its course changes to southerly. The notch receiving the name of the pond and stream is broad and deep, about 2123 feet above the sea, which is lower than any part of the divide between the east branch and the Saco. The interesting character of the notch is well shown in Mr. Morse's sketch of the mountains northerly from Mt. Carrigain. [See the plate in the Atlas.]

West of the pond, in following up the stream, we soon come to a wall of granite fifty feet high, over which the water falls uninterruptedly. For the distance of half a mile the descent of the stream is about 220 feet. The granite is not very coarsely grained, and is succeeded on the ridge between the New Zealand and Little rivers by a porphyritic rock described further on.

North of Mt. Carrigain and from a short distance above the "Forks,"—the union of the Hancock and principal northern branch,—the whole of the valley of the east branch of the Pemigewasset is occupied by the Conway granite. This is verified by a few observations. At the falls, less than a mile above the mouth of the stream from New Zealand pond, and near the north line of Elkins's Grant, the usual variety of this formation is present. Two miles above these falls, on the stream two miles south, on a tributary, and on another branch in going from Mt. Carrigain to Willey, the granite is made of finer materials than ordinary, and there is much quartz present. The same is true of the rock at Nancy pond.

The mountains between Mts. Willey and Nancy are comparatively low, falling off more than a thousand feet. This is probably due to a line of subsidence, since the finer-grained granites and sienites occurring there are among those usually capping the more elevated summits. We have on hand a number of facts concerning the granites on both sides of the Saco river, which will be presented further along, as some of them will be amplified or otherwise modified by a special reëxamination of the valley, made in 1875.

Section from Tin to Hancock mountain. The figures for the altitudes of this route are mentioned in the chapter on Altitudes, page 290 of Volume I. Upon Tin mountain the schists belong to the Montalban series, with a high inclination somewhat west of north. Between the tin mine and the village of Jackson there is a development of Albany granite. On reaching the lowest point on the section, at Jackson falls, the rock has changed to the Conway granite. In the bed of Ellis river there are joints dipping at an angle of seventy or eighty degrees to the west, which are so well marked as to resemble bedding. Others are present, also, as appears from an inspection of the heliotype in Volume I, opposite page 256. A mile or so lower down are Goodrich falls, represented in the heliotype very finely. Mr. Vose remarks of the rock here: "The jointing and quasi-bedding of the granite is very well seen from above the bridge to below the falls. One set of joints runs east and west, and dips steep to the north. The other set runs S. 33° W. The granite at this place decomposes in a remarkable and instructive manner, showing the original structure of the rock better by the decay than by the solid ledge." [See Fig. 14.] Returning to the precise line of section, we find the same rock extending far up the flanks of Cobb's hill. The summit of this low elevation is composed of the Albany granite. On the west side the Conway rock returns again, and extends to the valley of Rocky branch in Bartlett, where there is an outcrop of the Montalban schists overlooked by us in our enumeration of the several areas occu-


GOODRICH FALLS JACKSO

pied by that formation. We have no observations respecting the dip of the strata here. The occurrence of a remnant of the floor beneath the granite in the valley reminds us of what has been said previously (p. 126) concerning a similar state of things in the lower part of the valley of Mt. Washington river.

The high ridge between Rocky branch and Razor brook shows the Conway granite throughout, both on the surface and on the precipitous southern slope facing Saco river. The section passes next up the east side of Hart's mountain, and no exploration has been made there to determine the precise boundary between the granite and the highly-inclined White Mountain schists. The section now crosses one of the larger areas of the White Mountain group, concerning which ample details have been presented upon a previous page.

The next rock over the southerly flank of Mt. Lowell and the top of Mt. Carrigain consists of porphyry. No outcrops show themselves for two miles west of Duck Pond brook on the section line; and this is the proper horizon for the recurrence of either the Conway or Albany granites, before coming to the porphyritic series. These latter rocks are of a reddish cast, the crystals being of a deeper shade than the homogeneous base. Jointed planes dip towards Mt. Carrigain. The porphyries upon the east slope of Carrigain are finer grained, more slate-like in color, and dip at first towards Mt. Lowell. Higher up they begin to dip into the mountain. Whether these planes are to be regarded as those of deposition, remains to be seen. On the summit of Carrigain the rock is a peculiar speckled porphyry, requiring further examination for specific description. On the west side the descent is quite steep, and the planes constantly vary in position, as if representing numerous small folds in the stratification. The talus is more abundant here than on the east side, though not equal to that on the south side of Mt. Lowell.

Our delineation of this section (Fig. 15) brings in the porphyritic gneiss at the south base of Mt. Carrigain, in the deep valley of Sawyer's river, so as to show the mutual relations of all these formations. Mt. Hancock on the west is composed of the ordinary Conway granite. Next we will introduce a sketch of the rocks south of the Saco river, chiefly in the town of Albany, as these come next in order. As a matter of convenience the porphyries and breccias in that area are described. There are also a few remarks about the eruptive rocks of Jackson and vicinity upon a previous page.

Rocks South of the Saco River.

BY J. H. HUNTINGTON.

Feldspar-porphyry and breccia. If a person were to study the rocks of the mountain region of New Hampshire only along the travelled roads, he would not only get an imperfect, but also a very erroneous idea in regard to the geology of this section of the state; and there is no one point where a person would seem to have better data from which to draw conclusions than from the examination of the rocks along the Saco in Bartlett, and Swift river in Albany. At a point on the Saco we have a granite composed largely of feldspar; and at a place on Swift river, directly opposite, we find the same kind of rock,—so it would seem reasonable to conclude that this is the rock between these two points; but a person who came to such a conclusion would be very much mistaken. Finding the granite in Bartlett, opposite the mouth of Stony brook, we follow up that stream. Three fourths of a mile from the road, the first outcrop of rock we find is a feldspar-porphyry, which is composed in part at least of a triclinic feldspar. This extends probably a mile; and the jointed structure of the rock gives to it the appearance of stratification. This rock is followed by a breccia and porphyry; in the latter frequently there are small crystals of a flesh-colored feldspar. The feldspar crystals continue to become more abundant, until the rock is hardly distinguishable from a reddish gneiss, yet a careful examination shows that mica is wanting. Near the height of land the rock changes, and is composed apparently of a compact feldspar, with a little quartz. Descending from the height of land towards Swift river, perhaps a fourth of a mile from the summit, and on the main branch of Little Deer brook, the rock is a distinct breccia, which is of a dark color, having a feldspathic paste, and pebbles of labradorite, porphyrite, quartz, and fragments of schist or gneiss. About half-way from the height of land to Swift river the rock is of much brighter colors, and contains mica, probably from fragments of gneiss. Below, there is a narrow band of a schistose rock, that has itself somewhat the character of a sandstone, but so jointed is it that it is difficult to determine the dip. This is succeeded by a breccia; this in places passes into a homogeneous red porphyry, the composition of which is silica, 64.20, alumina, 8.80, iron oxide, 12.60, magnesia, 2.37, lime, 3.50, soda, 4.24, potash, 6.25. On Swift river, near the mouth of Little Deer brook, the rock is the Albany granite.

On a ridge west of Little Deer brook, perhaps two miles north of Swift river, there is a schistose rock similar to the narrow band found on the brook; and then west we find the Albany granite, and the outcrops are numerous on the west branch of Little Deer brook. East from Little Deer brook, nearly to the Saco, except for two or three miles along Swift river, the rock is everywhere a breccia and feldspar-porphyry. The whole of Mote Mountain range presents a fine field for the study of these rocks, both from the numerous outcrops that present it in so many different phases, and also from the fact that the forests along the whole range have been recently almost entirely destroyed by fire. The most southerly outcrop of this rock is in Albany, on Dry brook, near the house of B. Farnum. Although here it is a breccia, yet there are distinct crystals of feldspar and particles of vitreous quartz, making the rock more a feldspar-porphyry than a breccia. From near Farnum's there is a footpath to the summit of the south peak of Mote mountain. On this path, perhaps a mile from Swift river, the rock is composed principally of distinct fragments of schist, compact feldspar, and quartz. Half a mile above this outcrop there are places where the rock is so entirely changed that the marks of the rock as a breccia are almost obliterated, and we have a rock, the base of which is feldspar, and in this there are orthoclase and triclinic feldspars and quartz. Above this the rock is quite uniform, consisting of a feldspathic base, in which there are fragments of schist, and always crystalline particles of feldspar and quartz. This is the rock of the south peak of Mote mountain and the ridge north until we come to the steep ascent half a mile south of the north peak. Here the fragments of schist become more frequent and more distinct. On the north peak of Mote mountain the fragments of schist are larger and more numerous than we have found them elsewhere, some of the largest fragments being a foot across, and in general immediately on the summit the fragments are less firmly cemented together than they are on the ridge either north or south. The largest fragments are andalusite schist; besides, there are a few fragments of quartz and feldspar. The rock seems to be made almost altogether of the andalusite schist of the White Mountains. The dip of the rock on the summit of the north peak is N. 5° E. 10°. On the ridge extending north-east from the summit the rock is of the same character as on the ridge south, except that there is a band a mile and a half from the summit where the fragments are more rounded than they are elsewhere, and they are smaller than they are generally on the mountain. The breccia extends south to within a mile and a half of Diana's Bath.

Albany granite. From the Saco in Conway, extending west along Swift river, perhaps two miles above where the road crosses this stream, there is a granitic rock everywhere porphyritic; but, about a mile south of Swift river, we find a rock of an entirely different character. This rock, though it is not always uniform, yet in its numerous outcrops it has the same general characteristics. It consists for the most part of a greenish feldspar, almost black vitreous quartz, and there is sometimes a little hornblende irregularly distributed through it. It weathers whitish, and to so great a depth that no one would suspect the character of the rock from its exterior, and it is with the greatest difficulty that unweathered specimens can be obtained with an ordinary geological hammer. At Champney falls, which are the most picturesque of all the many falls and cascades about the mountains, numerous walls of this rock can be seen. Here the rock is so cut by joints that they give to it the appearance of being bedded, and near where the falls begin some of the blocks have been moved and tilted up. The space between the blocks being filled up, the water stills runs over them, so often the effect is very fine. At Pitcher's falls,—called also Champney falls,—the water descends nearly perpendicularly, except that there are three projections on which it strikes. There is another outcrop of this rock four miles east, at Ellen's falls, on a small stream that flows into Swift river nearly opposite Eagle ledge. The water falls twenty feet, and it has worn an oblong cavity in the rock twenty-five feet in length, from five to six feet in width, and fifteen feet or more in depth, which is filled with water. This rock is found on the east side of Chocorua, and it is also probably the rock of the north peak of that mountain, but the rock is so weathered it cannot be determined with certainty whether it is exactly the same or not. The same is also the case with the rock of the summit of Passaconnaway


BEAVER FALLS

and the high ridge south. It is true, however, in regard to both these mountains, that the rock of their summits is composed chiefly of feldspar, with which there is associated a little hornblende. A similar rock forms a part of the ridge extending from Passaconnaway to Chocorua. North of Swift river, Silver Spring mountain, and also a mountain north and one west of it, are composed of this rock. On Swift river, just below the falls, there is a rock very similar, except that it contains some quartz. There is an outcrop also on this stream four and a half miles above Albany interval.

Conway granite. The area of Conway granite in Albany is not large. In the south-east part of the town it can be seen in several places. Near the house of S. Littlefield it seems to be undergoing rapid decomposition, yet there are some places where it is not much changed. At Littlefield's house the granite is cut by a trap dyke, that is not far from a hundred feet in width. Three miles south of Swift river, towards Birch interval, there is a typical granite, rather coarse, but the feldspar, which is of a light color, is not stained by iron or coated by manganese. The first outcrop of granite south of the house of N. Shackford is somewhat porphyritic, and the crystals of feldspar are often very large. This is suggestive of the ancient porphyritic gneiss. The rock of Green's cliff and its ridges has all the constituents of common granite, but they are so distinctly crystallized that it very readily crumbles and falls in pieces. Up Downs brook for two miles and a half granite is the only rock, except a trap dyke that cuts it. In Waterville, on Sabba Day brook, there is common granite at the falls and a mile above. J. H. H.

The Granites in Conway and the Southern Border of the District.

There are many outcrops of the lower granite along the edge of Conway and Bartlett, in the neighborhood of Kiarsarge village. They are well shown in the Artist's Falls stream, up towards Pequawket and the Green hills. We find both these granites under Mt. Pequawket on every side. On the east, west, and south there are specimens illustrating them on Section VIII, and they have also been found on the north. The Albany granite is not more than two or three hundred feet thick, but it seems to form a sheet extending horizontally through the mountain beneath 2000 feet of later rocks. The relations of the underlying Conway granite, the narrow Albany variety, the slate breccias, and other rocks composing the upper part of the mountain, are well shown by colors upon our heliotype of Mt. Pequawket taken from the south.

The whole of the Green hills are of the Conway granite. On the summit the rock is fine-grained, with jointed planes dipping north-westerly twenty degrees. At the west base the inclination is less. The highest of these mountains, though 2390 feet above tide-water, seems to be composed of the same granite with that constituting the base of Pequawket. The top of the Conway granite on the road up Pequawket is about 900 feet, so that the slope between these two points is about four degrees. To the south of North Conway, in the valley, ledges are not abundant; but the south-westerly limit of the lower granite is probably near J. Tuttle's house, where a ledge of it crops out. Pine hill may also show a ledge of it. There are no ledges between Conway Corner and Conway Centre, nor for a considerable distance towards Walker's pond and Eaton. These latter ledges, when reached, are of the underlying Montalban series.

Concerning the granites in this neighborhood, Mr. Vose, in his report of 1869, writes as follows. He did not distinguish between the three kinds of granite occurring here.

At Chocorua, in the Swift River Valley and all along through Conway and North Conway, we find the principal rock to be a coarse granite with little or no mica. The same rock, or one very much like it, occurs at the southern base of Pequawket; but does not appear to extend higher up than four or five hundred feet above the base of the mountain. The "Ledges" opposite North Conway, are chiefly, if not entirely, of granite of various degrees of fineness. The vertical striped appearance of these ledges is due to the water which runs down over them, as far as I could judge, and does not show structure. The granitic rocks through the whole of this region are much cut by joints, but whether any true bedding can be made out is doubtful. The five summits east of North Conway village, called the Green Hills, as also the "Ledges," and, in fact, all exposures of rock in this region, show what might perhaps be called horizontal or nearly horizontal stratification; but this bedding, if it is such, must not be confounded with an apparent bedding caused by a scaling off of the rock in concentric layers, from five to ten feet thick, an example of which may be seen in the upper part of the large or south ledge (White Horse). Over the whole region from Jackson to Tamworth, and far over into Maine, there is seen a well marked orographic feature which *may give* a clue to the arrangement of the rocks in this district. I refer to the general outline of the hills, which present almost universally a long gentle slope to the


Mt. Chocorua

N. and an abrupt face to the S. The dip of the rocks, too, where this can be made out, is almost always from 20° to 80° to the North, the N. W., or the N. E.

The same granite which appears at Chocorua, in the Green Hills, and all along through Conway, is found at Kiarsarge village, and in the lower part of the mountain itself.

On the road from Conway Corner to Knowles pond in Albany, skirting the base of the mountains, we find only the Albany granite. There is quartz in this rock on the ridge near D. Allard's. If we take the road along the outlet of Knowles pond, we see in the south-east corner of the town, south of the other road, a precipice of the Albany granite perhaps 400 feet high. The hill south of J. C. Kenniston's and Knowles pond is composed of the Conway granite. This region has one peculiar topographical feature: there are several hills scattered over it, usually having a southerly precipitous slope. This structure may be due to rock composition, or to the peculiar way in which granite is eroded; but there is scarcely any difference between those composed of the Conway, Albany, or Concord granites. It is necessary, therefore, to visit each one to determine its specific character. The next hill, nearly south from Kenniston's, on the line between Albany and Madison, and north from J. White's, is composed of Concord granite, and is outside the limits of the Pemigewasset series. We have no evidence of the existence of the eruptive granites east of the railroad in Madison.

Mt. Chocorua. One will observe an interesting order of rocks in ascending Mt. Chocorua. Starting with the Concord variety near Whitton pond, we next find as thoroughly characteristic Conway granite as is ever seen among the mountains on the hill between Whitton and Knowles ponds, by J. C. Kenniston's. Between this and J. Piper's, whence we commence the ascent of Chocorua, the rocks are concealed. There are two ways of ascending from Piper's. The more usual course consists in following the ravine a little west of north in a direct course for the peak. On this route no rocks show themselves for a long way. The other course is to pass due west from Piper's up the long southerly spur. This route meets the path from J. Tasker's, north of Chocorua pond. Six hundred feet higher than Piper's house there is a fine-grained granite, slightly gneissic in appearance. Two hundred feet higher is the unmistakable Conway granite. On reaching the south end of the spur, we find a rock different from anything that has been mentioned. In its several varieties it occupies the whole of the Chocorua group of elevations. That first seen is much weathered, of a reddish cast, sometimes manganesian. The feldspar predominates in crystalline bunches; the quartz is not abundant; and the black scaly mineral is apt to be hornblende. In other samples from this spur the quartz is abundant, and the mica or hornblende is scanty. Similar rocks extend to the very summit. Scarcely anywhere else is it so difficult to appreciate the normal appearance of the rock, on account of extensive and complete weathering. In favored localities the granite assumes a greenish color, the feldspar at first sight resembling labradorite. A typical variety consists only of this greenish feldspar, apparently orthoclase and amorphous smoky quartz, very like that noticed heretofore from Lightning mountain in Strafford. (No. 443 of Mr. Huntington's catalogue.) At the east base of the peak there is a similar rock of greenish color, very fine-grained, prevailing to the exclusion of everything else. These two types of rock represent our *Chocorua granite*. I have called them labradorite, perhaps erroneously, in our first volume. As they will require further study before receiving their proper designations, I need only to speak of the behavior of the mass in relation to the other rocks. The specimens from the north-east base of Chocorua peak and the summits to the east are labelled as Albany granite, though they somewhat resemble the other. This variety has not yet been discovered on the route between Piper's and the summit of the peak, while on the north-east it seems to take its proper place between the Conway and Chocorua varieties. Hence our order of succession from the starting-point seems to be, first, the Concord, second, Conway, third, Chocorua granite. In Fig. 61, Vol. I, one sees how the Chocorua mass is separated topographically from everything else.

Mr. Morse's panorama from Chocorua in the Atlas shows incidentally the slightly inclined—25° N. W.—jointed planes in his foreground. Others nearly at right angles to this appear upon the summits, one in particular of immense extent. They are prominent along the ridge for half a mile.

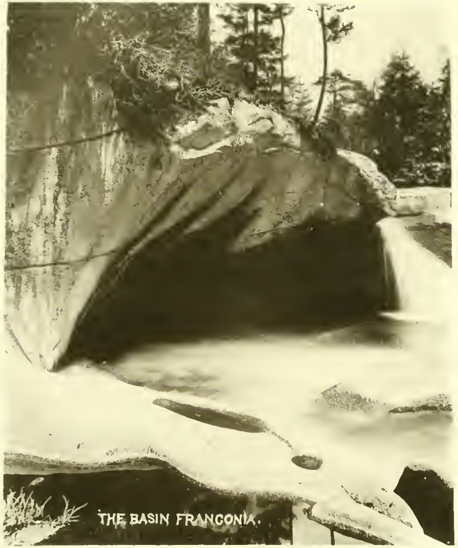
This peculiar granite occupies a larger area in this neighborhood than is elsewhere known. It occurs all the way to Ellen's falls on the north, at three and one fourth miles west, and perhaps farther; to the south it occupies all of the principal spur perhaps as far as Chocorua pond. I have not examined the area between the spur and pond as yet, and cannot affirm from observation that these two outcrops are joined together continuously. Specimens of it have come also from Great Hill pond, and one mile from Berry's saw-mill in the north-west part of Tamworth. Toad mountain, about two miles north, is composed of Albany granite. Most likely the upper rock of Mt. Whiteface corresponds with this (p. 104), though it is sienitic. Other localities of it are the north peak of Mt. Passaconnaway, the ridge between Sabba Day and Downs brooks and Champney falls in Albany. The principal part of Mt. Passaconnaway is Conway granite. None of the Pemigewasset series of granites have yet been recognized in Sandwich.

Waterville, etc. Fortunately for our ease in making explorations, there are settlements along Mad river in Waterville. This clearing reaches the interior of the White Mountains, and thus we get glimpses of its structure afforded by no other settlement. As one looks at the amphitheatre of mountains from Greeley's hotel, he should understand that a considerable portion of these lofty eminences is composed of the Pemigewasset granites. On the south-west, west, and north nothing else can be seen. Welch, Tecumseh, and Fisher are supposed to be entirely composed of Albany granite. Osceola, at first thought to be the same, seems to be more nearly allied to the Conway. In an extract following, by J. P. Lesley, mention is made of the interesting apparent bedding in this mountain. North-easterly, the former variety appears at the lower end of the great slide. But on the east, Snow's mountain, and the enormous Sandwich Dome on the south, so far as known, belong to the porphyritic gneiss. I find in the collection specimens of Albany granite from the Mad River notch, or about the Greeley ponds, the east ridge of Osceola, and the ridge between Mad and Swift rivers. The Conway granite occurs at several places on Mad river below Greeley's, at the north end of the north-east ridge of Sandwich Dome, on the east side of Snow's mountain, at and above the cascades, on Flume brook a fine-grained variety, on the ridge between Mad and Swift rivers, about a mile above the falls on Sabba Day brook, the falls, and on Downs brook, a mile from Shackford's house in Albany. The greater part of Mt. Passaconnaway has the same composition.

The rock of Mt. Osceola is to be referred to the lower division, except the eastern spur, which is Albany granite. At the first crossing of the west branch of Mad river by the mountain path, I have noted the presence of large blocks of porphyritic gneiss. These will probably be found in place there, and will explain partially why the lower granites should exist at so great an altitude as the summit of this mountain.

A reëxamination of the specimens from the lower part of the Tripyramid slide, or what has been noted upon pages 38 and 39 of Volume I, satisfies me that the rock should be referred to the porphyritic gneiss instead of the "trachytic" or Albany granite. Hence we may accept our first impressions of its gneissic character, and believe it to be simply an extension of the rock on Cascade brook, perhaps including the cascades. It may appear, also, that these ledges will connect with the loose blocks beneath Osceola. I hope to reëxamine the locality, and to present the results of the visit in the sequel.

On the ridge between Mad and Swift rivers, up Flume brook, the granite uniformly has a fine grain. According to our present information, the great range from Osceola to the east branch of the Pemigewasset, including the Black mountain, south of the mouth of Hancock Branch, is of the Albany variety. From Waterville across the notch between Mts. Osceola and Tecumseh into the north part of Thornton, and from thence to Pollard's house in Lincoln, along the west edge of the granites, the Conway granite is developed, capped at Loon pond by higher groups. These two varieties continue beyond the East Branch in the same order, the western range passing into Franconia, and the eastern continuing uninterruptedly beneath Mts. Flume, Liberty, Lincoln, and Lafayette, then passing east of the range, as the continuity is interrupted by underlying gneisses, capping Haystack, till we are brought to the base of the Twin mountains, or our starting-place in this description. There will be some further details concerning the central part of the Pemigewasset district, over a very important line, in Section VIII. The actual junction between the Conway granite and Montalban group is apparent near T. C. Pollard's. The schists dip at a very high angle westerly; the granite appears to underlie them, and there is a large vein of it in the strata, evidently injected subsequently to their deposition and elevation. Mr. Huntington has recently found the same granite


THE BASIN FRANCONIA.


BOULDER.

extending all the way from Pollard's to the top of the south spur of Twin mountain. The difference in height between the two points being 2300 feet, it is supposed the granite mass is not less than this figure in thickness.

Franconia region. The discovery of the proper succession of the granites and porphyry was made in Lincoln, in a section from the top of Mt. Liberty through the Flume to Mt. Flume. [See p. 42, vol. i.] In this section the typical character of all the members is well developed. The Conway granite is exposed for 600 feet in thickness, the Albany about 1000, and the porphyry at least 600 more. The lower granite has planes dipping 30° S. 38° E. Near its upper boundary they dip in the opposite direction. The Albany granite is of that variety which shows very rounded feldspar masses, looking like pebbles at a distance. At the Flume, a few rods west, in the Pemigewasset river on the way to the Flume house, and at the Pool, are excellent outcrops of the lower granite. The Flume is one of the most attractive objects in the neighborhood. It is a chasm excavated out of the Conway granite, three or four hundred feet long, twelve to twenty feet wide, and over fifty feet high. Its course is east and west. Our heliotype gives a fair idea of its character. On the right hand are the natural walls or joints which cut vertically across these rocks all over the mountains. On the left are fainter lines nearly horizontal, which illustrate the common position of another set of joints possibly corresponding with the layers of accumulation. In the distance may be seen a boulder of the Franconia breccia, caught between the walls, suspended overhead, and apparently needing but a slight push to cause it to drop. An enlarged view of it appears upon another plate, whereon the slight attachment of the stone to the walls is more distinctly exhibited. It is estimated to be fifteen feet in the longer diameter, eight feet wide, or across the chasm, and twelve feet long, east and west. The lower part may be twelve or fifteen feet above the head of the visitor looking up from the platform. The stone probably came from Eagle Cliff, four miles away, in the glacial period. It was transferred by ice, and most likely arrived before the formation of the Flume.

On following up the stream one comes to a trap dyke consisting of two sorts of material, the outer, the ordinary dark rock common to this neighborhood, the inner, a gray, friable mass, both perhaps twenty-four to thirty inches wide. The occurrence of this dyke at once explains the origin of the chasm. The running water wears away the light-colored trap. Then water, percolating the vertical joints back of the eroded space, freezes in the cold weather, and, by the consequent expansion, pushes a mass of rock inwardly till it falls into the stream. During the warmer months the water is busily engaged in pulverizing the boulders, assisted by chemical reagents, or the removal of the potash of the feldspar by solution. As soon as there is space for the further action of freezing in the joints, other masses of granite are overthrown and worn away, till Nature has succeeded in manufacturing the completed flume. In the heliotype one sees on the right the remnants of some of the vertical sheets not entirely broken down. It is likely that the regularity or parallelism of the walls has been perfected by the action of the dyke upon the rock when in the formative condition.

The Pool is a circular excavation in the same granite, about one hundred and fifty feet in diameter, and forty deep. It is supposed that it has been excavated by the action of the Pemigewasset river, just as is the case with the Basin,—a pot-hole about twenty-five feet in diameter, situated midway between the Flume and Profile houses, by the side of the carriage-road. It is figured on the same plate with the Flume boulders. The rock is the same as in the Flume; but the Franconia breccia underlies it just above the junction appearing in the view.

Very large exposures of the Conway granite show themselves in connection with cascades on the stream from the west just below the Basin. This granite shows orthoclase and oligoclase. It extends southerly, capping Mt. Pemigewasset, this being its farthest development in that direction. At Tamarack pond and over Profile mountain the same feldspar, with quartz and mica, are present; but the materials will not average more than the tenth part of their lengths in the coarser rock. The north-west spur of Profile mountain, towards Franconia, is clearly a granitic cone, probably like that of the principal part of the mass. The Profile is made of similar materials, in a decomposed state. These ledges often approximate to the porphyritic structure. The planes dip west of north near the Profile house. Trap and porphyry dykes occur on the same side. On the eastern summit of Profile the planes dip S. 35° E. The highest part of the mountain, to the west of the location usually


LUME FRANCONIA

visited, exhibits planes dipping 10° westerly. Though the rock is firmer than ordinary, we have mapped all this region as connected with the Conway division.

If one takes the short cut to Tamarack pond, from where the old bridle-path leaves the main road for Mt. Lafayette, on the town line between Franconia and Lincoln, on the west side of the valley where he begins to climb, he will find an excellent granite for building purposes, having a lively color, and not liable to crumble. It contains chlorite and the two usual feldspars. A similar rock, but coarser, crops out near the Fish house. At another location on the road-side, a mile or two below the Profile house, there may be seen a crumbling ledge of Conway granite, with both vertical and horizontal joints, and it shows a tendency to decompose along the seams, presenting slightly the aspect of a mass of spherical bodies closely packed together. On the west side of the valley one sees a precipice where the jointed planes are spheroidal, and rudely parallel to the vertical wall of the cliff. At the base of the precipice are large piles of *débris*. This is on the east wall of Profile mountain, and the southern continuation of the famous Profile. A view of it appears on the same page with the heliotype of Eagle Cliff range from the south.

Walker's stair-case or falls exhibits finely the jointed planes slightly inclined westerly. [See vol. i, p. 305.] Both the Conway and Albany granites appear on this stream; but the texture is finer than ordinary, so that it is difficult to draw the line plainly between them. As ledges of porphyritic gneiss occur considerably higher up, it would appear that there existed here a deep valley, into which the granites flowed, not filling up the depression to the brim, unless there have been extensive erosions since.

We find quite near the top of the Lafayette range, close to the porphyries, a considerable area of the Albany granite, resting upon porphyritic gneiss or the Franconia breccia. This sheet seems to connect with that already spoken of as underlying Mts. Liberty and Flume. We have not yet found the Conway granite in contact with the Albany north of Mt. Liberty, at the higher level, though there are immense tracts on the western slope of such difficult interpenetration that their exploration has been neglected. The resting of a hornblendic variety of granite upon the porphyritic gneiss, disposed in nearly horizontal plates, near Walker's falls, has been noted upon page 101. We have got glimpses, besides, of Montalban schists, the Franconia breccia, and labradorite rocks along this same range or uplift of older rocks, between the valley granites and those high up the flank of the Lafayette range. The finer Conway granite, like that of Mt. Profile, crops out on the bridle-path up Lafayette, midway between the south Franconia line and the Lakes of the Clouds.

Between Mts. Lafayette and Haystack there are three elevations, whose character may be conveniently mentioned here. Lafayette itself is composed of porphyry at the very summit. The long north-westerly spur from it has the same character. The first eminence towards Haystack is composed of gneiss connected with the Franconia breccia. Specimens of granular quartz illustrate the second. The third is composed of Bethlehem gneiss. Haystack itself seems to belong to the Albany granite layer. Specimens from these summits were collected for us by Messrs. Smith, Hoitt, and Conant, of the Dartmouth party of 1871; and the trips taken to find them were very laborious. It is supposed that the Albany granite is continuous from Haystack to the north slope of Twin mountains, but this theory has not been verified by actual perambulation.

Mr. Huntington having climbed Mt. Lafayette since the above was put in type, communicates his impressions of what he saw, in the following letter:

The first outcrop of rock on the bridle-path above Eagle Cliff is perhaps three fourths of the distance from the Cliff to the summit of the ridge west of the Lake of the Clouds. It is a narrow band of the spotted (Albany?) granite. On the summit of the ridge the rock is porphyritic gneiss, the dip of which is probably south 60°. Whether it is the same as the gneiss in the central part of the state is a question, since you will remember that portions of the rock that makes up the breccia are also porphyritic. Just above the Lake of the Clouds there are a very few crystals of feldspar; and the rock resembles that of a portion of the breccia. Above the rock is a breccia, or, if it is a gneiss, there are concretions in it. There is little doubt that it is a breccia, however. The rock succeeding this looks more like a gneiss, and dips almost directly east. We then have a fine- and coarse-grained granite, then the spotted (Albany?) granite, and, last, the porphyrite, that forms the summit of the mountain. On the lowest part of the ridge, towards the south peak, the spotted granite outcrops; but on all the higher points, including south peak, the rock is porphyrite. I did not see any rock that I could call labradorite, though even in the spotted granite some of the crystals of feldspar appear to be labradorite.

It would be properly in order next to take up the labradorite rocks, and the porphyries occupying the area inclosed by the granites just described. Inasmuch as a little more investigation is required for their satisfactory description, I will depart from the established order, and present next a full account of the rocks recently displayed by cuttings along the Portland & Ogdensburg Railroad, in the White Mountain Notch, followed by abundant citations from the best authors who have written anything concerning the geology of the White Mountains.

The Rocks in the White Mountain Notch.

I propose now to describe carefully the outcrops of all the formations, mostly not alluded to before, cropping out along the route of the new railroad between Fabyan's and Bemis station, with any new information I may happen to have about the adjacent mountains. The slates of this region have not yet been described, and I shall therefore anticipate that part of the chapter. The following sketch is mostly the result of observations made in July, 1875, undertaken for the purpose of testing the value of theories suggested in the earlier part of this report. There is a somewhat triangular area occupying the Ammonoosuc valley first requiring attention. It is bounded east and south-east by the range of presidential summits, which are all of the Montalban series; west, by the Field-Tom line of elevations, extending to the Ammonoosuc river, and north by the Cherry-Deception-Dartmouth group. The land is everywhere comparatively flat, as compared with the mountainous border. The difference is excellently set forth in the heliotype showing the Mt. Washington range from the Fabyan turnpike, Volume I, p. 392. Two sorts of granite occupy the whole of this low country. The first is much like that of Concord, well seen along Section IX. It is tender, friable, with a nearly uniform texture. The second shows crystals of feldspar, porphyritic and extensively elongated. Its most conspicuous localities lie along the east border of the valley from Mt. Dartmouth across to the base of Pleasant. It protrudes through beds of the Montalban schists at the base of Mt. Pleasant, as well as constituting an extensive area by itself. This fact, however, shows its age. This area is probably continuous westerly across to the Portland & Ogdensburg Railroad, a mile north of the Crawford house, where it crops out in a small stream. Between the

Crawford and Fabyan houses, along the railroad, there are numerous exposures of one or the other of these two granites. They do not extend far up the side of the range to the west, where they join the Conway granite, for the whole way. Other facts concerning this area are stated upon page 137.

Concerning the streams flowing westerly from the main range of presidential summits, it may be proper to mention, that, as very few of them are distinguished by any appellation, I have designated them by the name of the mountain they spring from, both upon the map and in our descriptions. The well-established name is Ammonoosuc, which starts from the Lakes of the Clouds. Then we have Monroe, Franklin, and Pleasant brooks. The Ammonoosuc passes the station, giving it a name. Monroe crosses the turnpike a short distance west of the station. Franklin and Pleasant unite quite far up. We have also used the name of Jefferson brook for the second stream north of the mountain railway.

Mt. Tom and Cascade brook. Passing up Cascade brook for about three fourths of a mile, there is a foot-path designed for observing Beecher's cascade; and at the upper end a fine view may be obtained of Mts. Pleasant, Monroe, and Washington. For this distance we conceive the rocks belong to the Montalban series. It is very granitic, penetrated by several systems of joints. Silica is abundant, seemingly finely diffused through the mass. The rock partakes somewhat of the character of that excavated for the railroad at the Notch, but more of that in the Ammonoosuc plain, just noticed. Of the nearly vertical seams we find low down the courses east and west, north and south, north-west and south-east, as well as north-east and south-west. These predominate in the lower series of falls. The main fall, figured in Volume I, page 305, exhibits the north-easterly course, the stream having worn a deep, flume-like passage for itself out of the granite. A more remarkable set of joints begin to display themselves above the principal cascade, dipping easterly from five to twelve degrees. They seem to exist in greater perfection the further we ascend from the Crawford house. The first ledges seen have been excavated irregularly; and numerous narrow branching granite veins ramify in various directions, though notably in the same direction with the stream. There is also a dyke of trap two or three feet wide, with a course east of north. The upper seat marks nearly the western limit of the Montalban group, and it may be from three fourths to seven eighths of a mile west from the Crawford house, by estimate, and perhaps several hundred feet of elevation.

Nearly a quarter of a mile beyond, a granite allied to the Conway shows itself, with the prevailing numerous joints dipping a few degrees easterly. The constituent minerals resemble those of the rock just passed over, but are considerably larger. All the outcrops for at least three fourths of a mile are of this character. At the lower end of an unusually broad opening it is very ferruginous; the joints are inclined less than five degrees, and the grain is more like that of the first rock. It is just above this that the north side is bare of trees; and in the valley there is a great abundance of a vermilion vegetable coating spread over the boulders and ledges. The lower exposures are of great importance, because the granite contains many fragments of the hard Montalban schists, sometimes from twelve to fourteen feet long. Several of them seem to carry andalusite quite abundantly. It is not clear whether these fragments are distinctly Montalban, or whether they agree with the dark slates found higher up the mountain, and also back of Mt. Willard. They would be clearly ranked with the first, unless the metamorphic influences of the granitic paste have altered the character of the upper slate. This is the only example yet discovered which seems to intimate the possible origin of the Conway granite as later than the deposition of the dark andalusite slates. In a similar brecciated mass by the side of the railroad, under Mt. Willard, the fragments are entirely of the lower schists; and the imbedding granite more nearly resembles the Albany, while the Conway is adjacent. Upon Cascade brook the cementing granite is more abundant than in the latter locality. In both cases, one can recognize near each other fragments of the same mass.

Higher up this stream there is a great abundance of the Conway granite, with its usual features. At about two and a quarter miles, by estimate, there seems to be a limited outcrop of a spotted granite, porphyritic by numerous crystals of orthoclase, in contact with slate. A similar contact will be described upon the south side of Mt. Willard, further on. As no ledges show themselves for a considerable distance below the line of junction, we have no data for determining the width of the spotted granite. Both to the north and south of the stream, it forms a comparatively broad belt. The slates first seen are somewhat indurated, and dip 55° N. 62° W. A little higher they stand on their edges, and presently the dip is 55° N. 80° W. Here we left the valley and climbed up a steep slope, bare of vegetation, because removed by powerful currents of water in the time of freshets. Ledges of slate, having about the same position with those just described, occur frequently at the steeper part of this ascent. More particularly, about one hundred and eighty feet up, the rock is an argillaceous quartzite, dipping 75° W. It is well exposed for several hundred feet vertically with the same position. Above that it is less siliceous and more argillaceous, and slightly wrinkled. The dip is often 70° or more, and again 60° N. 82° W. At various places below and above we found slates rusty from an external ferruginous coating, with the interior whitish. The top of Mt. Tom is broad; and you may travel a considerable distance over a slightly inclined surface, where the trees are a foot or more in diameter, even to the very summit. At the saddle, between Tom and Field, the spotted granite is in place, but at the highest point the rock is a feldspathic indurated slate.

I have descended the mountain easterly three times, by somewhat different routes. The rusty, felsitic slates, first seen in going down, become white when broken. Passing northerly we meet with large blocks of spotted granite, not certainly in place, but it has little thickness, and then we find ordinary argillo-mica slates ; and, under them, others charged with andalusite. The dip is very high in the direction N. 82° W.

A matter of interest may be seen on top of a north-easterly spur of the mountain which lies upon the east side of a stream flowing northerly at first, and joining the south branch of the Ammonoosuc about two miles below the Fabyan house. The rock is a black slate, crowded with pencils of white andalusite, being the same layer with that yielding the numerous boulders of this nature so conspicuous in the streams. The dip is 60° N. 72° W. If this knob deserves a name, it should be called *Mt. Andalusite*, after the beautiful crystals first found here by Messrs. Abbott and Bacheler, lost sight of for some time, and then rediscovered in 1873. The position all over it is essentially as just indicated. We found the same rock to the south-east, trending towards Cascade brook.

It does not appear there, because so completely covered by drift. Below this slate we found an interesting slate breccia, like that on Mt. Willard, with a westerly dip. Under this and the slates, in proceeding easterly, we found a great thickness of the spotted granite in ledges. Beneath this is upwards of a mile breadth of the Conway granite. But I suppose the first small eminence north of Cascade brook, at the very foot of Mt. Tom, and adjacent to the Crawford house, is made up of the harder Montalban granites. On another line of descent, not more than a mile north of that just mentioned, the same order of granites was observed below the slates.

A trip was taken to the north of Mt. Andalusite to determine more carefully the relations of the slates and granites, as well as to search for a compact variety of the spotted or Albany rock, so nearly resembling labradorite as to have been originally mistaken for it. The first rock north of the slate proved to be the Albany, which we followed for a mile or so, with planes dipping north-easterly four or five degrees. This continued for about three hundred feet down the easterly slope, where the Conway granite was encountered, and may be one thousand feet thick. The peaks to the north of this, as far as the lower falls of the Ammonoosuc, near the White Mountain house, are entirely composed of the Conway granite.

Mt. Willard. Mt. Willard is a small mountain situated directly in the water-shed between the Saco and Ammonoosuc basins, to the west of the Notch. In the heliotype opposite page 79, Volume I, the view from the Crawford house, it may be seen rising up from the Notch on the right. It is 926 feet above the Crawford house, by a recent aneroid measurement. The northern slope is not steep, and has over it a great thickness of glacial drift, upon which large trees grow abundantly. On the south side is a bare precipice of a thousand feet depth, one of the largest seen about the mountains. A carriage-road winds to the summit; and the view of the Notch below is exquisite, though poorly represented opposite page 625, Volume I. Since that drawing was prepared, a very conspicuous line has been cut out around the west side of the valley, high up, marking the position of the Portland & Ogdensburg Railroad. The excavations on the steep side of Mt. Willard and farther south, for the benefit of this railroad, enable us to speak of the rocks along the

Saco valley with more precision than usual. At the end of the road on the summit the rock is the Conway granite, with joints running in various directions. To the east, the line of junction between the granite and hard gneisses may be observed about five or six hundred feet distant, at the south-east angle of the cliff. On passing to the base of the first cliff, one can readily distinguish this line of junction, with a north-west course, and vertical. On looking down the steep, impassable slope, the schists seem to come to a point in the granite one or two hundred feet distant. In the granite above there are joints parallel with the line of union, seen especially where the cliff overhangs about twenty feet. The most northern point where I have seen the granite must be about six hundred feet north from the summit, near the line cut from the carriage-road to the new flume. To the west, perhaps two or three hundred feet of surface is occupied by the Conway variety. The principal part of the cliff is composed of this rock, and it may be followed down across the railroad to the upper bridge over the Saco, in the carriage-road down the Notch. The railroad runs over this rock about seventy rods. The vertical thickness, from the Saco to the top of Mt. Willard, is at least 1800 feet, which represents the vertical dimensions of the granite. It is supposed to be continuous southward along the west base of Mt. Webster. Along the railroad it disappears, passing beneath the spotted granite and the slates, coming up about a quarter of a mile south of Willey brook, as if it constituted a synclinal axis.

Along the Railroad. Starting from the Crawford House station, we proceed 1900 feet before coming to the first cut in the rock, 200 feet long. This interval represents an extensive accumulation of detritus brought down from the adjacent mountains by the Ammonoosuc branch, Cascade brook, Gibbs brook, and others of smaller size. The ledges we suppose fall off to the north very much as they do towards the Willey house, and would therefore be more than one hundred feet below the Crawford house. On the north side of Elephant's Head is a ledge of gneiss resembling the Concord granite, with jointed planes, possibly strata, dipping N. 87° W. The stone has been quarried somewhat for piers and abutments. The rock in the first cut lies beyond this granite, and is a hard gneiss, breaking with difficulty into angular pieces, with the dip of S. 63° W. 75°. It is cut by several large and coarse granitic veins, holding black tourmaline, small garnets, a greenish mineral not yet determined, apparently a hydrous-mica, occurring in thick lamellæ, albite, and others. Some of these veins are three feet thick. A few layers concentrate a bronze-colored mica; others consist of what seems at first a hard granite, lacking mica, which is the most characteristic rock throughout the Notch, and is called a granite on p. 123. It so intermingles with what is surely stratified that it cannot be separated from gneiss. So compact are its constituents that they seem as if cemented by an infiltrated silica. Other layers, partly decomposed, show a reddish color from the oxidation of iron and white spots of feldspar.

The second is a much larger cut than the first, being 450 feet in length and three times as deep as the first. The rocks are the same with those just described, but the veins are larger, more numerous, and somewhat diversified. They contain all the minerals first named, also fluorite, galenite, smoky and transparent quartz crystals, pyrite, pyrrhotite, calcite, siderite or ankerite, and an unknown green mineral. The fluorite is both pink and green. The iron-carbonate has completely oxidized, and the crystals crumble to powder upon exposure, leaving behind abundant bunches of "paint." In other parts of the cut a little copper pyrites and green tourmalines occur. Among the fragments in the pile to the south, I find bunches of chlorite. There is no regularity in the strata or joints in this cut. The vein holding fluorite and quartz crystals runs north and south. The most marked planes that have any resemblance to strata dip S. 78° W. Other veins cross the supposed strata irregularly. So numerous are these veins that Professor Dana, who examined the rocks of this neighborhood with me, suggested they might indicate the presence of an anticlinal axis at this point. Possibly the dip corresponding to this, so as to make the arch, may be the one to N. 57° E. 76°, above Silver cascade, p. 123, though opposing inclinations are not needed to prove the axis in a region full of inverted folds.

After passing the trestle-work, there is a third excavation known as the "James cut," 250 feet long. This is through the more granitic variety of the hard schist common at the two other cuts. Near its southern termination there is an apparent dip of 70° S. 70° W. A possible dip of 75° N. 38° E. is spoken of here. These planes may perhaps be connected with the course of an interesting trap dyke, having the same strike, or N. 52° W., and dip. This dyke may be five or six feet wide, and is supposed to cut both the hard schists and the Breccia granite just below, towards Dismal Pool. As seen from the carriage-road at its western curve, this James ledge is full of reticulating granite veins, some two or three feet wide. The strongest run north-westerly, but at three places one can see them cut and shifted by smaller veins crossing nearly at right angles and otherwise. With the sun shining upon their blanched surfaces, they are very conspicuous. They also occur upon the hard ledges inside of the westerly projection of the road.

Immediately below the cutting there is developed an extraordinary vein or mass of granite, whose presence has led to the discovery of additional interesting features in the geology of the Notch. The junction is now concealed by the abutments just below the James cut, where it was displayed to the best advantage in fresh excavations. The phenomenon is, briefly, a vein of slightly porphyritic (allied to the Albany) granite, 450 feet thick, dipping under the hard Montalban schists somewhat east of north, the latter supposed to have a strike either N. 20° W., or N. 52° W. As seen from below, the mass of schist has a slope of perhaps 15° from the top of Mt. Willard to the James cut, underlaid by this bed of granite. Both masses are quite conspicuous, and the line of junction, having the direction N. 18° E., may be followed up past the flume, where the common strike of the schist is N. 27° W., the dip being vertical. Near the southern point of the schist the position is very nearly the same, the strike being N. 22° W. At the head of the south or Butterwort flume, the strike is N. 32° W. Hence the evidence is clear that this mass of granite fills a chasm, passing squarely across the Montalban strata. Were the granite a stratified formation, the relations of the two to each other would be described as unconformable. The granite itself when fresh shows a predominance of orthoclase in large crystals of half an inch or so in length, and smaller rounded (sometimes crystalline) masses of quartz scattered through a fine-grained granitic aggregate. The mica may often be in black patches, large enough to be conspicuous, though usually in very small bits. A finer grained variety of this rock occurs near its junction, but is not abundant. As usually seen, this granite has a reddish aspect from weathering; and it has a close resemblance to many ledges referred to the Albany series elsewhere among the mountains. The lower junction of this granite with the Montalban is concealed by drift, but the strata of the latter are distinct, standing vertical, with the strike N. 42° W. They are better characterized than those above, though they do not extend more than 1200 feet before a change ensues.

The fact of greatest importance in regard to the granite remains to be mentioned. Following the railroad to where it would naturally be intersected by the Butterwort dyke, or 4700 feet from the Crawford station, we come to a breccia of enormous pieces, five or six feet long, and less, the fragments consisting entirely of the hard Montalban schists, while the cement is of the variety of granite just mentioned. One can see that it has found its way between large pieces that naturally fit together. This breccia extends for 1200 feet along the railway, but it does not appear much higher on the mountain. Between it and the exposure of schists at the summit only granites appear. Something of a breccia character in the Montalban schists has already been mentioned in the description of the upper part of Mt. Washington river; and at the Notch cuttings, imbedded pieces of the schist in the granitic portions are not rare. It forcibly reminds us, however, of the Franconia breccia, thought to mark the close of the Montalban period; and we have recently described also masses of the same rocks imbedded in the Conway granite above Beecher's cascades. As a matter of convenience, I propose to call this cementing material the *Breccia granite*, to distinguish it from the many other varieties of this rock in the White Mountains.

The next rock seen along the railway is the well-known Conway granite, already mentioned as constituting the summit of Mt. Willard, and following up the valley of the Saco to about the 1500 feet contour line. It occurs along the railroad for 1300 feet, and makes up the greater part of the south precipitous exposure of the mountain. Its features are precisely the same as if it occurred in Conway or Franconia. On one large ledge the crystals of quartz seemed uncommonly abundant. Its union with the spotted granite, as well as the boundaries of the slaty breccia and slate along the railroad, are obscured by drift.

Along the Carriage-road in the Notch, etc. The beginning of the original Notch, before railroad excavations cut into it, appears in the heliotype opposite p. 79, Vol. I. The rock is the same with that described in the first and second cuttings. The dips cannot be discerned so easily as in the cuttings, on account of weathering. In the original Notch there is only just room enough for the small Saco river and the carriage-road. The most prominent joints have the courses N. 58° E. and N. 32° W., being vertical, and dipping 70° easterly. Another runs north-easterly. By their intersection the rock is cut into quadrangular blocks of large size, sometimes isolated by the denudation of the surrounding mass. Such is the "Pulpit." On the east side of the road one sees also small valleys, made by the enlargement of the jointed planes through erosion of softer seams, sometimes veins or dykes. Other irregularities are fancied by tourists to be the profiles of the "Young Man," "Old Maid," "Baby," etc.,—which resemblances are not striking. Over against the lower part of the second railroad cut is a great mass of the schist cut into blocks by N. E. and N. 36° W. joints. There is also a south-west flume-like excavation, six or eight feet wide, separating another smaller mass of schists from the first, through which the Saco may run at times, there being another course nearer the road. The northern side is fifty and the southern thirty feet above the stream. Following it around nearly to the south end of the railroad cut, one will find a cave in the hard rock, produced by the enlargement of one of the jointed seams. Very soon the road overlooks the Dismal pool, an expansion of the Saco, rendered larger of late by the fragments of rock thrown down by blasting. This is 225 feet lower than the track at the James cut, and not quite so far beneath the road. A little farther south, where the road makes its greatest amount of westing, the hard schists may dip north-easterly. This curve in the road is occasioned by the occurrence of a spur of hard rock on the east. At some distance below we pass in succession the Flume and Silver cascades.

Next, our attention may be directed to the distribution of the Breccia granite. It was said to dip somewhat east of north along the railroad. Coming down to the mouth of Dismal pool, the high cliff seen to the east, connected with the most western angle of the road, is composed of the usual hard schists, traversed by numerous veins of coarse granite. The Breccia granite dips under it in the direction N. 58° E., only the upper part of it showing. From thence it may be traced south-easterly to the Silver cascade, crossing the road about by the Flume cascade, or a

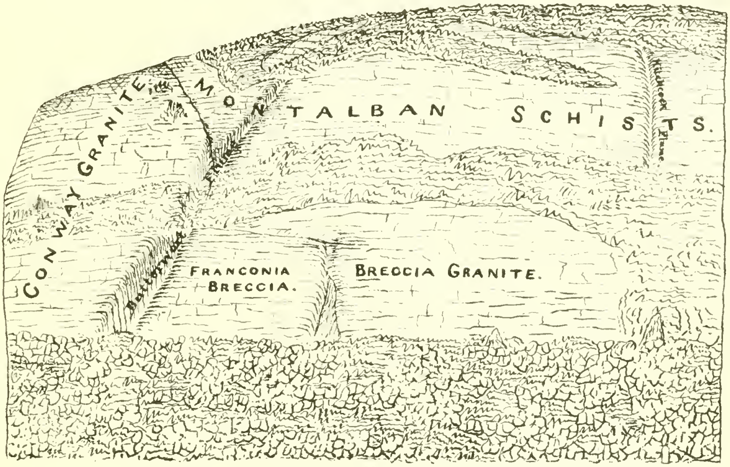


Fig. 16. View of Mt. Willard from Silver Cascade.

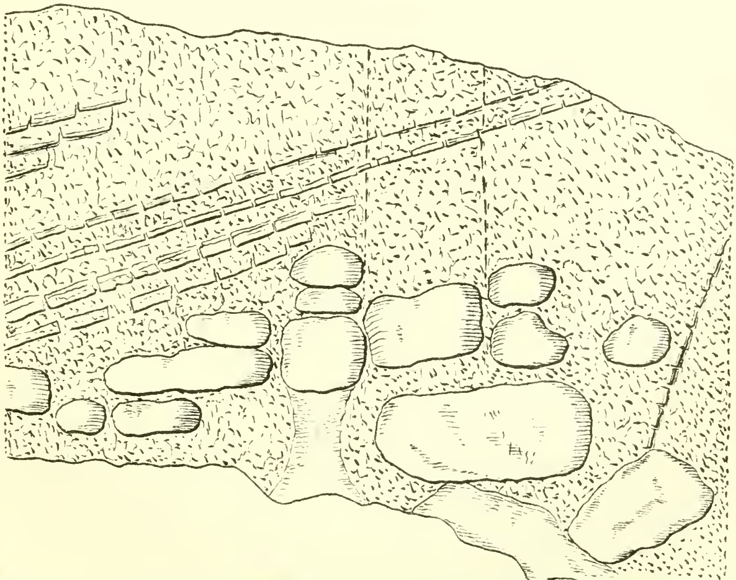


Fig. 14. Remains of Structure in Granite at Goodrich Falls.

little lower. On ascending the Silver cascade, the first thirty or forty yards from the road consist of the hard granitic schists. Next follows perhaps 300 feet thickness of Breccia granite rather more siliceous than common, reaching to the top of the falls as shown in the heliotype, while the same Montalban gneisses appear behind where the water has worn through them. The color of the foreground represents the hard Montalban schist; the upper is the new variety of rock. The under slope of the Breccia granite at the falls dips 60° S. 48° W. The gently dipping planes, 15° S. 17° W., are in this rock. The harder variety does not seem so well adapted to be permeated by them. The rocks above are noticed on p. 123. From this point I have traced this granite along the hill-side to the middle and upper parts of Mt. Webster. Between the cascade and first outcrop of Conway granite the Montalban schists prevail, perhaps a distance of sixty or eighty rods.

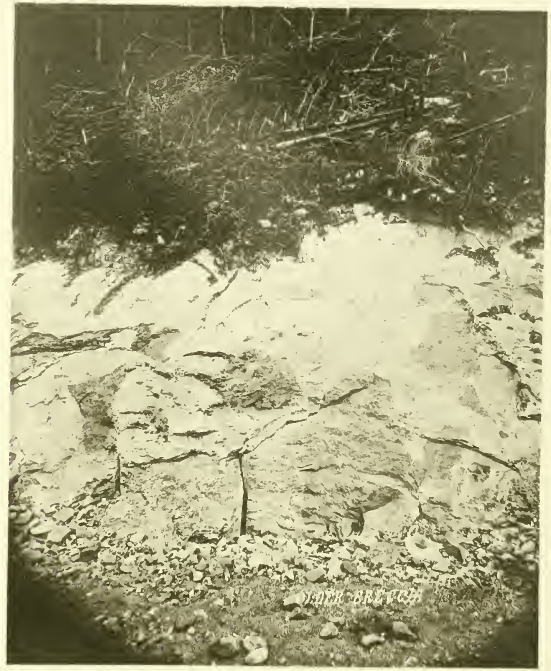
I desire to present here a rough sketch of the appearance of the several kinds of rocks on the east side of Mt. Willard, as seen from a short distance above the road at the falls on Silver cascade. It is given in Fig. 16. The view extends from the south cliff of Mt. Willard, a little above the north flume. On the left the limits of the Conway granite are defined. The Montalban schists extend thence past both flumes down to the James cut, beyond the limits of the figure. The cliff under the Butterwort flume is thought to be the brecciated part of the Montalban schists, which attain here their highest elevation. To the left is a smooth face of the Breccia granite, dipping gently northerly. Below, the bushes and débris conceal the exposures as far down as the railroad. From a point farther south on Mt. Webster the whole length of the Butterwort flume is finely displayed. From the last point of the hard schists on the carriage-road to the southern termination of the same schist on top of Mt. Willard, the course is about N. 75° W.

Flumes. During our examination of the upper part of Mt. Willard two interesting flumes were discovered. Starting from the top and following round the edge of the cliff, we soon pass the junction of the Conway granite with the hard Montalban gneisses. The first flume is only a short distance beyond. It is not perceptible from the top of the cliff. Its course is determined by a trap dyke dipping 65° S. 10° W., about five feet wide. For about 200 feet the excavation into the mountain may average a depth of twenty feet, and the inclination of the floor is too steep to allow one to descend or ascend in it. The schists on the south stand on their edges, with the strike N. 20° W. The dyke has caused the formation of joints parallel to itself in the schists, almost to be confounded with strata. In this flume I found, growing rather sparingly, a beautiful flower, the *Pinguicula vulgaris*, or Butterwort. It is said to range from "western New York to Lake Superior and northward." None of the botanists who have explored the White Mountains for plants speak of it; so it must have escaped their notice. In memory of this plant, therefore, I will call the chasm the "Butterwort flume," to distinguish it from the one farther north. As one stands on the slope of Mt. Webster, or even at the bottom of the steep hill in the Notch, and looks up Mt. Willard, he can see this flume extending downwards for perhaps 500 feet of vertical descent, or pointing directly towards a blacksmith shop on the railroad, about 3000 feet north of the Willey brook.

North of the Butterwort flume the hard schists have the strike N. 30° W., and a disposition to dip S. 60° W., scarcely less than vertical. Presently we come to another and larger flume, estimated to be 1000 or 1200 feet from the top of Mt. Willard. The rock has the strike N. 27° W., with vertical strata. Looking east one sees a narrow chasm with the course N. 68° E., curving presently a little more northerly, and seeming to point to the Silver cascade on the east side of the valley. After travelling through the flume, I made the following estimates of its size. It is 350 feet long, seven feet wide at the top, varying to six, ten, five, and finally eight feet. It is everywhere widest at the top. The walls are generally vertical, the south wall occasionally hanging slightly over a perpendicular. I judge that portions of this wall rise 100 feet above the floor; usually they will not exceed half this amount. The top rises 220 feet above the lower opening, the latter being 580 feet above the railroad beneath. The place is evidently one of interest to tourists, and the proprietors of the Crawford house have already cut a path to it, and propose to add a rustic bridge, so that its beauties may be better appreciated. Doubtless many persons have noticed a cleft in the upper edge of the mountain, when looking in that direction from the bridge at the base of the Silver cascade: that is this new flume.

It may be proper here to state that this dyke may once have been con-


HITCHCOCK FLUME



tinuous from Mt. Willard across the valley to Mt. Webster, through the flume and cascade, at the level of the higher land. At the time of the ejection of the trap, the liquid would have flowed out at the bottom of the valley and not have reached the summits of the mountains, unless the whole space between were filled up to the brim; therefore the ledge must have been continuous from summit to summit. It would seem to follow in like manner, from the occurrence of numerous dykes in Mt. Webster, that the whole of the Notch valley was once filled with solid rock. The immense depth of this remarkable gorge, from the Gate to Sawyer's rock, has all been excavated out of solid material by aqueous and glacial agencies, acting constantly since the beginning of Paleozoic time. Possibly its course may have been determined by fractures induced during the folding of the strata. Essentially this view of the origin of the Notch, especially the use of trap dykes to prove an immense erosion, was suggested by Prof. O. P. Hubbard, in a memoir from which extracts will be presented shortly.

Below this northern flume there are about 120 feet of hard schists, and then for the rest of the way to the railroad the Breccia granite is exposed in a smooth precipitous slope, almost impassable. Paths could easily be made along this eastern wall of the mountain, that would be very attractive to tourists. If they are slightly dangerous the course will be the more eagerly traversed.

North-west side of Mt. Webster. A further examination of the north-west side of Mt. Webster has enabled us to profit by our knowledge of the exposures along the railroad. It will be remembered that the Breccia granite starts near the Butterwort flume, and gradually descends the wall of Mt. Willard to the James cut, thence to the outlet of Dismal pool, whence it changes its course and begins to pass up the east side of the valley, crossing Silver cascade a hundred feet east of the road. It continues from thence to the most considerable cliff on the west side of Mt. Webster, figured in our heliotype, p. 79, Vol. I. At this point it has about the altitude of Mt. Willard, and is estimated to be 300 feet thick. As near as I can judge, its course is not in a right line, on account of various shiftings of the rock not fully understood. The general course is from near the top of the Willard cliff to Dismal pool, thence up the west side of Webster to the greatest precipice, and perhaps farther.

Were the valley full of rock, as has been supposed to account for the trap dykes, this vein would have a northerly inclination of ten or twelve degrees. In fact, it proves denudation just as well as the dykes.

A trip up this ragged edge of Webster starts from the Conway granite in the valley. Thence, over an interminably long slope of débris, we come to the base of the large cliff more than a hundred feet high. Upon examination it proves to be composed of several kinds of rock. At the north end of its summit the Montalban schists occur with the strike N. 16° E. These are traversed by segregated veins of granite twenty or thirty feet wide, analogous to those in the first cuttings in the Notch. Next to this is two hundred feet width of Breccia granite, the line of junction being N. 68° E., at right angles to the edge of the cliff, and the rocks meet with vertical faces towards each other, pointing into the mountain. At the southern edge of this precipice are more of the hard schists, followed by Conway granite, supposed to extend southerly from this point for miles uninterruptedly. Lower down the precipice are towers or quadrangular pinnacles of the hard schists, precisely like the Pulpit in the Notch. The Conway granite is supposed to extend also from the road to the base of the cliff. The top has about the same elevation as Mt. Willard. The course to the north edge of the Conway granite on Willard is N. 57° W. Supposing these rocks to conform to their course on the railroad, we should suppose the south part of the schists corresponds to the Breccia adjoining the Conway granite.

Passing up the ragged edge seen in the heliotype, we find the Conway granite again, directly over this cliff, as far to the upper precipice as indicated upon p. 123. At the middle one the rock is very characteristic, with prominent joints running N. 63° E., vertical. A small flume ten feet wide has been excavated out of them, carrying a thin, light-colored trap dyke. Other joints dip 50° N. 38° E., agreeing with the position of Montalban schists half a mile to the north. The edges of the schists are traversed at their lower edges (the upper cliff) by very large granite veins,—some of them corresponding in lithological features with the coarser varieties traversing the Notch cuts, and twenty or thirty feet wide. Others possess a very fine grain, and are somewhat like the finer Breccia cement, lacking the porphyritic aspect. All the rocks are terribly decayed through weathering. The schists are much like those at the Notch at the junction. Half a mile to the north they hold essentially the same position, all of them dipping 50° N. 38° E., but are very evenly bedded with the mica in layers, and are not permeated with the intense hardness that prevails below.

The character of the rocks upon the top and west side of Mt. Webster may be seen to good advantage from the summit of Mt. Willey, across the valley, because they are of different colors. The upper part is a reddish-brown color, corresponding to the ferruginous Montalban schists. These extend plainly from above the large cliff just described to a point opposite the Willey house, where the gray color, indicating the occurrence of the Conway granite, takes its place. The upper rock is traversed by thirteen large granite veins, broadest at the lower edge of the reddish rock, and ramifying into numerous branches above. Some of them are tortuous, with an average direction parallel to the junction between the red and gray ledges. I have not been able to traverse extensively the granitic slope beneath, but have thus far seen there only the coarser Conway granite, occupying fully seven eighths of the surface. In several places patches of the reddish color flow down into the gray, sometimes irregularly. This is the result of aqueous action, and there is no reason to believe the rocks have been much dislocated by faulting. There are fourteen slides on the west side of Mt. Webster. From Willey one sees also the pyramidal shape of Mt. Webster, as expressed on our contour map. Visitors travelling along the valley beneath are led to believe that the top is nearly horizontal. The highest point is at its northern extremity.

We conclude that the line of union between the Montalban schists and Conway granite is in general straight, but when minutely investigated, jagged like a comb wanting occasional teeth. From this frayed edge innumerable large segregated granite veins spread off into the schists like a long row of immense branches of trees, mostly in their natural vertical position.

Mt. Willey range of Slate. Our researches lead us to believe that this rock has its southern termination near the summit of Mt. Willey, being as wide as the peak at the depth of a thousand feet, say a mile and a half. The dip on the summit is 80° W., and perhaps on the south side, near their base, the slates may dip easterly at a somewhat smaller angle. On the ridge the slate runs back on to the south slope of Mt. Field. There is a gradual slope north-easterly from the base of the formation at the south of Mt. Willey to a point on the railroad 2000 feet south of Willey brook. From Mt. Webster this dividing line between the granite and slates is very conspicuous, the former rock being bare and white, and the latter black and obscured by bushes. The general course of this formation from the Willey summit to its extreme northern development, a little north of Willey brook, is about N. 10° E.

The sudden falling off of the mountain south of Willey has been noticed. It is due apparently to the disappearance of the slate, the broad terrace-like hills beyond being composed of the underlying granite. The slates stop suddenly, cut off as abruptly as the end of a plank. They do not seem to have been altered into anything else, but have been removed bodily. In character they are identical with the rock at Willey brook, and in the valley running north-westerly from that point. I observed no andalusite in it, but cannot doubt it exists as abundantly on Mt. Willey as farther north.

A very interesting feature is displayed at the lower limit of this formation, on the head waters of Kedron. The Conway granite there approaches it, but between them is a harder variety of granite, accompanied with fragments of slate imbedded in it. The Conway rock is surely the cementing material of the harder bunches with the slates. This agrees with what has been described on the stream above Beecher's cascades: in that, pieces of this newer slate have been cemented into a brecciated mass by the Conway granite.

On the Portland & Ogdensburg Railroad these slates are exposed for a width of 2700 feet, 700 north of Willey brook. Their usual inclination both south and north of the brook is 67° N. 82° E., with a reversed dip a few rods north along the railroad. On top of Mt. Willard the dip is north-westerly; and on the way down the mountain I have noticed the presence of an anticlinal of small extent near the line of junction. The deep cut just south of the iron bridge over Willey brook has a smooth westerly wall. As the same seam is perceptible down to the bed of the brook, it is likely that a fault is indicated by it, though not one of sufficiently great importance to complicate the structure. The ledges here are beautifully filled with long crystals of andalusite.

In illustration of a change in the direction of the slate range near the railroad, I will first call attention to the small heliotype of Mt. Willard, colored to represent the several formations. It was taken from the Willey slide. The house in the foreground very nearly obscures from view the original edifice occupied by the unfortunate family at the time of their engulfment by the sliding granite débris. Its front barely appears under the eaves of the addition. The blue color represents the area occupied by the slate just described, bounded by the Conway granite on the south, with an intervening belt of the spotted variety on the north. This last will be seen to extend to the top of Mt. Willard, and also to apparently cap the slate nearly over the house. That distant mountain, however, is the north spur of Mt. Field, a remarkably conspicuous eminence, as seen from the Crawford house. The spotted rock is continuous from near the railroad. While it may not exceed a score of feet at the base of the precipice, it is two hundred feet wide on top of Willard, and as much as a mile on the spur of Field. Its course is the same with that of the slate area, or N. 77° W. The principal part of the steep south side of Mt. Willard is the Conway granite, of which nearly 1200 feet altitude are visible. It constitutes only the south face of the mountain, whose principal mass is composed of Montalban schists, which are shown by color on the extreme right. The schists support the granite behind, the line of junction being vertical and transversely across the strata. The granite is supposed to follow the other variety north-westerly, to where it is extensively developed on Cascade brook and the east flank of Mt. Tom. The strike of the slate does not agree entirely with that of the area occupied by it. Very near the junction on top of Willard we have the strike N. 22° W., and N. 12° W., a little beyond, while the course of the area is N. 77° W. Following down the junction to the railroad from the top, I found quite near the top the strike N. 8° E., and a westerly dip. Lower down is an anticlinal, very near the border, but it is only a few rods wide. About one or two feet thickness of the slaty mass next the junction consists of a breccia not unlike that on Mt. Pequawket, usually more compact. The granite close by the junction has its orthoclase and quartz in distinct crystals, whose faces show distinctly when the rock is broken, making beautiful specimens for the museum shelves. A few feet away they lose their perfect character. About half way down a high cliff presents a smoothed aspect, as if there had been a sliding of one rock over the other at their line of union. Near this place, also, the breccia is better developed, attaining a thickness of twenty feet. The lower two hundred feet above the railroad are obscured by a large pile of débris.

On reaching the lower part of the small saddle back of the Mt. Field spur the slates dip 50° S. 8° W. On the very ridge they seem to stand about 85° N. 82° W. All about this tract of several acres extent the strata are much contorted in small corrugations, and I also observed masses of the breccia. South-westerly, in climbing up through the more recent growth of trees, there is a light-colored quartzite. Farther north I found no slates, but came to loose pieces of Conway granite, which may possibly have come from neighboring ledges. I suspect the white, moist rocks, of precipitous character, seen north of Willey brook at about the same elevation with Mt. Willard, may be of this character. Higher up, a bare ledge proves to be of the spotted or Albany variety, with numerous joints a few inches apart, dipping 75° S. 8° W. On top of the north shoulder of Mt. Field are ledges of greenish porphyry, not very extensive. The small cone constituting the very highest point of Mt. Field is composed of this same spotted rock, with joints dipping about four degrees easterly, besides others nearly vertical. Combining these observations with those mentioned on page 144, it appears plain that this Albany granite is continuous from the south side of Mt. Field along the ridge nearly to the top of Mt. Tom ; and it probably occurs beneath the slates on the west side of Mt. Tom continuously to the smaller mountains north.

A word as to the top of the north-east spur of Mt. Field. In the ascent direct from the uppermost Beecher cascade, no rocks appear save the spotted variety. The summit is double, and very prominent joints dip 75° westerly, nearly parallel with the slate on its west side, which we have traced to this saddle from Mt. Willard. It is also clear that the slates pass from this saddle down to Cascade brook above Beecher's cascades, and thence northerly to Mt. Andalusite, where they cease as abruptly as they started on Mt. Willey. I have previously noted the character and position of these slates on the Mt. Tom region.

The conclusion to be derived from these statements is obvious. This andalusite slate starts from Mt. Willey, pursues a course N. 10° E. to the railroad, thence climbs Mt. Willard about N. 75° W., and back of the Field spur changes to N. 10° E. again, crosses Cascade brook, and after reaching a very great altitude suddenly terminates. It is flanked on both sides for a considerable part of its course by the Albany granite. If this was a stratified rock, we should say that the structure of the slates was that of an inverted synclinal, underlaid regularly by this constant inferior member. In the present state of our knowledge of altered and eruptive rocks, it cannot be said that these underlying granites are certainly *not* sediments, so thoroughly metamorphosed as to have lost their lines of original bedding. The evidence in favor of their eruption, since the deposition of the andalusite slate, is increasing.

In the preceding description of the slates, I may have stated too strongly their apparent distinctiveness as a formation from the neighboring rocks. This is the impression one gets from their examination in the field, uninfluenced by theoretical considerations. If we carry the theory of metamorphism to an extreme, it might be said that the slates could be altered into a granite by hydrothermal influences. If both rocks contain essentially the same elements, it is conceivable that the fusion of the dark slate might produce the spotted or the Conway granite. The slate is penetrated largely by andalusite, a mineral devoid of alkali. If either of the granites has resulted from the fusion of the slate, it is plain the latter must contain considerable potash, else feldspar could not be readily formed in the great abundance which is everywhere apparent. Some analyses will be made of the slates in order to ascertain whether an alteration of this andalusite slate into granite be possible.*

Two considerations may be stated which incline to the belief that the slates constitute an independent formation, and have not undergone metamorphosis. First, in comparing together the courses of the strata back of Mt. Willard, and the spur of Mt. Field, it would seem as if the slates had been violently bent into their present trend by the subsequent eruption of the spotted granite crowding into their eastern flank. The slates are twisted and broken in many places, the fragments being cemented

* The results of one analysis show a deficiency of silica in the slate instead of alkali. This agrees with the results of numerous recent analyses of the Cornwall killas by J. Arthur Phillips—*Quar. Jour. Geol. Soc.*, Aug., 1875. He also insists that the granites are not derived from the metamorphosis of the slates.

together by a granitic paste; and oftentimes in the midst of the north-westerly trend there are ledges and smaller masses retaining the northerly course. It is easy to say that some portions of the original strike were retained, even after the exertion of the disturbing agency, altering the position of the principal portion of the areas in order to explain these phenomena. Second, cases have been cited showing that fragments of the slates occur imbedded in the underlying granites. This is most easily explained by saying that pieces of the slates were broken off during the disturbances connected with the eruption of the granite, and caught in the fluid mass. If so, of necessity the granite came into being later than the slate.

In a part of my labor in the Notch I had the pleasure of the company of Professor Dana, who made many valuable suggestions and queries. After communicating to him some facts observed after his departure, he writes: "There can now be no reasonable doubt, I think, with regard to that Notch valley being the course of an anticlinal, the veins and the broken line of rock being so extensive. [See p. 167.] The stopping short of the andalusite slate [on Mts. Willey and Tom] is strange. The point of special importance in connection with it is, what rock appears to be its continuation? Is it the porphyritic [spotted] granite that lies to the west of it? Is it a stop-off through a fault, or through a change in the material of the stratum, leading to the development of a different crystalline rock by metamorphism?"

The distribution of the slates will be alluded to again further on, after describing the other areas of this formation among the mountains.

The Notch valley between Willey brook and Bemis. Our observations in the valley between the andalusite slates on Willey brook and the reäppearance of the Montalban gneisses at Bemis, are fewer than their importance demands. The first ledge of the Conway granite, 2000 feet below the Willey brook, is mentioned on page 175. It is finer grained than usual, and useful for building purposes. None of the spotted variety of granite shows itself adjacent to the slates on their south side, as in the case farther north. This Conway granite seems to conform to the position of the slates underlying them. Opposite the Willey house this rock is coarser, and closely agrees with its most common type of mineral structure. Passing up Willey mountain it is displayed in many high precipices, well situated for quarrying. In Kedron there is an interesting narrow dyke, from six to ten inches wide, of a light-colored soft material, readily fashioned with a knife. Along the railroad one sees other very pretty dykes of trap crossing the valley, and probably connecting with similar exposures upon Mt. Webster. The Conway granite may be traced to Cow brook, along the railway. It is followed by the Albany variety, containing several trap dykes of great interest. In the numerous cuttings below it is interesting to observe the change of color from greenish or grayish to red, in proximity to each trap dyke, occasioned by the oxidation of the iron present.

Frankenstein cliff is the name of the north-eastern extremity of the Mts. Lowell-Anderson-Nancy range, where it is cut by the railroad. It is known further by the very high iron trestle-work adjacent on the south. This cliff is chiefly sienite for about half a mile along the railroad, north of the iron trestle. It resembles the rock of Mt. Whiteface, north part of Passaconnaway, and much of what is called the "Chocorua granite." At the north end of the ledge the hornblende is replaced by mica for a few rods. Small cavities, lined with quartz crystals and containing a little chlorite, are common in this ledge.

This sienite seems to occupy the position of the Chocorua rock, as indicated heretofore, for in coming south from the Willey house we found the usual succession of granites,—the Conway first, then the Albany, and lastly the sienite. Near their several junctions there is an intermingling of the adjacent varieties. Likewise in going south we find the reverse order of succession beyond the iron trestle, though there are other varieties which make the order of distribution somewhat perplexing. The overlying place of the sienite is very clear. Where a reddish hard rock appears, south of the trestle, one can see the sienite ledge above descending to the cliff from the south-west; and immense blocks of the upper rock have been detached by frost and fallen down to the level of the railroad. The appearance of the sienite belt rising to the south reminds us of the similar position of the Breccia granite on the south-east face of Mt. Willard (page 168). At the lowest accessible point in the valley, at the crossing of the Saco river by the carriage-road, not very far below Frankenstein, there is an unmistakable extensive development of red Conway granite. The upper and lower members of our granite series therefore occupy their proper places. Furthermore, we have as yet found no indication of the uppermost rock in the southern development of Mt. Webster across to Mt. Washington river. There are large boulders of Chocorua granite in the last named valley whose source is unknown. The granite cropping out at the angle between the Saco and Mt. Washington rivers is classed by us in our note-book with the Conway variety. Up Sleeper's brook there is a ledge of schist, indicated in our collection, a quarter of a mile above the Saco, but granite higher up; and Giant's Stairs is composed apparently of a fine grained variety of the Conway rock. At the base of the stairs the rock is very fine grained and white. Specimens from Mt. Resolution, and on the Davis bridle-path at two and three fourths and three and a half miles north of the mouth of Mt. Washington river, are doubtfully referred to the Albany. Other specimens of the same are put down between Mt. Crawford and Mt. Hope, and opposite Nancy brook. The granite from the top of Mt. Crawford is like that from Frankenstein cliff, but its western base belongs clearly to the lower group. It here contains veins carrying fluorite, as on Mt. Webster.

There are several varieties of rock in passing up Bemis brook. From near the railroad I obtained a very interesting boulder of schist for the museum, showing curves in the strata, and small dislocations. Its source has not yet been ascertained, but the rock is like the andalusite slate. The accompanying plate will make a description of the curves and faults quite plain. The stone is forty-five inches long and thirty-six wide. The view on the left represents the top, and that on the right the side of the specimen. On the top we recognize four small anticlinal axes, and a wedge-shaped segment driven into the stone a distance of five inches; but the longer fault shows a displacement of only about two inches. The shorter fault has cut transversely through the first anticlinal, and the longer one passes across the next anticlinal. The third and fourth are unaffected by shoving. Turning to the side of the stone, these four axes are observable, and one of the faults, which develops a new ridge. On the left is a smaller fault, not connected with those on top. Of the anticlinals, the first is the farthest to the left; the second disappears; the third is almost lost, broadening very much; while the fourth is much more prominent, appearing on the extreme right. The amount of shoving along the fault is two inches. The width of this side of the fragment is two feet.


MT. CRAWFORD


LAKE OF THE CLOUDS

Above the railroad, and the same rock occurs both north and south along the track for a considerable distance, is a red compact granite, apparently one of the varieties of the Conway series. With slight modifications this rock occurs all the way up to Tuckerman's falls, eight hundred feet above the road. It is usually much permeated with joints. At the "Stair falls," some of these joints dip ten degrees easterly. Higher up the dip is from twelve to fifteen degrees S. 32° E. A specimen from one and a half miles up is like the Frankenstein granite. Two kinds of dykes up this brook are peculiar; the first, two miles up, of compact feldspar; the second, half a mile beyond, of trap containing fluorite and calcite. Still higher, at the falls forty or fifty feet high, there is a trap dyke from four to ten feet wide, dipping 80° N. 87° E. Tuckerman's falls are one hundred and twenty feet high. Mr. Huntington says the rock all the way up Bemis brook, and thence over the mountain to Ripley's falls, and down Cow brook to the road again, is of the Conway variety. This journey was taken in July, 1875. Mr. Galbraith went up Davis brook to a peak opposite Mt. Crawford, thence north-west to another mountain, thence south-west to Nancy mountain, and reports all the ledges as composed of granite. The specimens from Nancy pond are a fine-grained variety of the Conway series, containing much quartz. This variety prevails in the neighborhood (see p. 146). At a mile east of Nancy pond the granite is reddish and coarse grained. It is continuous with that which is typical of the series at Bemis pond, and so on to Green's cliff and the Swift river interval in Albany.

Still another variety of granite, related to the Albany, is developed adjacent to the gneiss, an eighth of a mile north of Bemis station. It is composed of crystals of orthoclase and quartz, usually an eighth or a sixteenth of an inch in diameter, with a yellowish tint, verging to light gray. It is necessary to cleave this and the spotted granite in a particular way, in order to exhibit the crystalline faces perfectly. When broken otherwise, the presence of perfect crystals in the mass is not evident. These granites holding crystals will be described fully in the mineralogical part of this report; and they will be noticed also in the discussions likely to be presented subsequently respecting their origin.

History of Opinions Respecting the Age and Elevation of the White Mountains.

These mountains have afforded scientific writers abundant opportunity for the display of theories respecting the geological equivalency and elevation of the strata. A citation of the most important among them will illustrate the progress of scientific thought, and give credit to divers original suggestions. The older writers generally believed in an igneous ejection of granite, bursting through horizontal strata, pouring over them, and throwing great masses upward with steep inclinations. These views came not from original application to these mountains, but were a transference of the ideas of European authors to our ranges.

A very early publication was that by President Dwight, in his *Travels in New England,* volume 2, 1821. He writes thus concerning the Notch (p. 147):

> The Notch of the White Mountains is a phrase, appropriated to a very narrow defile, extending two miles in length between two huge cliffs, apparently rent asunder by some vast convulsion of nature. This convulsion was, in my own view, unquestionably that of the deluge. There are here and throughout New England, no eminent proofs of volcanic violence; nor any strong exhibitions of the power of earthquakes. Nor has history recorded any earthquake, or volcano, in other countries, of sufficient efficacy to produce the phenomena of this place. The objects rent asunder are too great: the ruin is too vast, and too complete, to have been accomplished by these agents. The change appears to have been effectuated, when the surface of the earth extensively subsided; when countries, and continents, assumed a new face; and a general commotion of the elements produced the disruption of some mountains, and merged others beneath the common level of desolation. Nothing, less than this, will account for the sundering of a long range of great rocks; or rather, of vast mountains; or for the existing evidences of the immense force, by which the rupture was effected.

James Pierce presents a notice of a trip to Mt. Washington in 1823, from Fryeburg, Me., to the Notch, and thence over the several peaks to the summit, which hardly differs from what one would write at the present day of the same route. He speaks of "Mt. Prospect" as the name for the eminence now known as Pleasant.*

Prof. C. U. Shepard, in 1830, speaks of the granite and other rocks in the Notch. It "here offers the aspect of immense beds frequently

* *Amer. Jour. Sci.*, I, vol. 8, p. 175.

PLATE X.

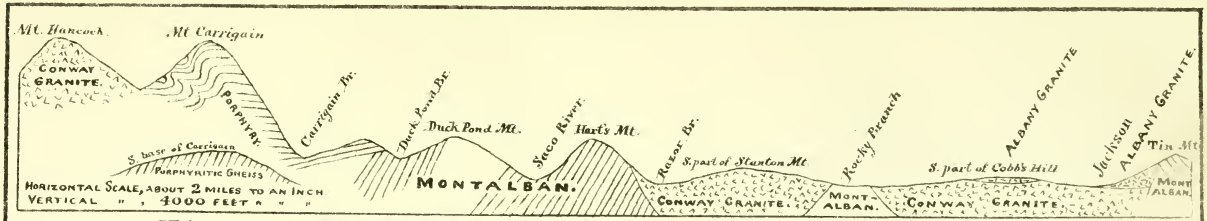


Fig. 15. SECTION FROM TIN MT. TO HANCOCK MT.

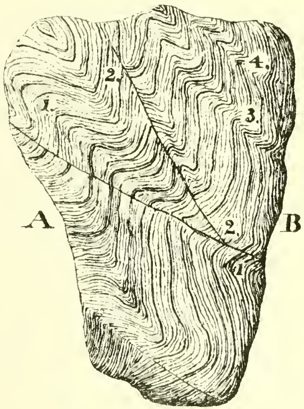


Fig. 22. Top View.

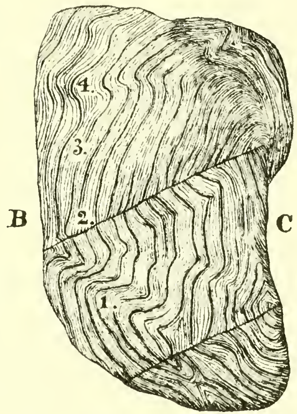


Fig. 23. Side View.

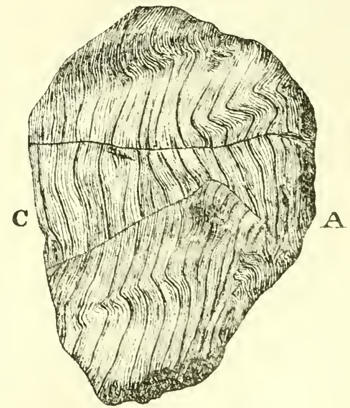


Fig. 24. Bottom View.

BOULDER FROM BEMIS BROOK.

HELIOTYPE.

divided by fissures in two opposite directions, one of which is vertical, while the other is parallel to the plane of the horizon, the cuboidal or prismatic masses being piled upon each other after the manner of rude masonry." After speaking of the macle noticed in the fragments below what is now Mt. Willard, he says: †

The notices we had received concerning the geology of these mountains made the appearance of any other rock than granite, quite unexpected; and our surprise was not a little heightened on being presented by Mr. Cook of Fryeburg, Me., with specimens of a decidedly brecciated, or recomposed argillaceous slate, which he assured us, covered, to a considerable height, the flanks of the Kearsarge mountain. * * * I am disposed to believe, that whenever these mountains shall be more closely studied than they hitherto appear to have been, a much less degree of uniformity will be found to exist in their composition than has generally been supposed; though I am far from supposing that granite is not the principal rock, and that it does not constitute the summits of their most considerable elevations.

Views of Prof. O. P. Hubbard respecting the geology of the White Mountains, from *American Journal of Science*, I, vol. 34, 1838, p. 120:

The only particular to which I wish at present to invite attention, is the nature of the rock crowning the summit of Mount Washington. The peak he sees capped with a rocky covering, destitute of vegetation, broken up into huge masses, which, as he passes from rock to rock, seem as *disjecta membra* in the wildest confusion; but when he has once surmounted the peak, and recovered from the mingled emotions of surprise, pleasure, and sublimity which fill his mind, and given his attention to nearer and minuter objects, his satisfaction, if he be a geologist, will hardly be less than when viewing the more distant and imposing scene.

The foundation or mass of the mountain, as it is seen in the deep gorges cut by the slides in the western side, is granite; and the top has been stated, by those who have and by others who have not ascended it, to be granite; and Alpine travellers, who have visited Mont Blanc, have thought they saw in the vast ruins surrounding the summit, the remains of lofty aiguilles that towered above the present peak; but let the observer stand at the most elevated point, near the rude artificial monument, as in the centre of a decapitated summit, and let him critically examine the rocks in the whole circle about him, and he will soon discover the incorrectness of these opinions. He will find the rocks stratified, layer upon layer, and symmetrically arranged around the centre he occupies. The rock is *mica slate*, consisting of coarse mica and fine quartz, occasionally with fine-grained veins of the two minerals, with a little feldspar, and some considerable veins of white quartz. The uniformity of this surface, in level

† *Amer. Jour. Sci.*, I, vol. 18, p. 291.

and appearance, is such that a passage to the top is marked out by no ravines and eminences, but the path leads directly over the ruins, and the *guide* himself is directed by masses of white quartz, or collections of stones raised at proper distances. Near the top are small black tourmalines, and above a small spring of water.

The case is clear. The mountain of granite was raised from the deep, bearing up on its Atlantean shoulders this huge covering of mica slate that extends a quarter of a mile below the summit, and by disruptive agencies has been fissured in every direction, and reduced to ruins. The granite, instead of upturning the mica slate, and protruding at the centre of elevation, itself forming the peak, has broken it at some distance from the centre, and we ought to find the long line of disruption of the mica slate, if the rocks remain and are uncovered, very far down the mountain; if not, in the low grounds of the valleys.

Dr. Jackson's views, p. 77, *Final Report Geology of New Hampshire.*

Dr. Jackson ascended the mountain by the Crawford bridle-path, the same now travelled direct from the Crawford house. I quote only the geological statements:

On Mt. Franklin all traces of vegetation, excepting plants of an alpine character, disappear. The rocks consist entirely of granite and gneiss, with occasional veins of quartz. The geological features of Mt. Washington possess but little interest, the rocks in place consisting of a coarse variety of mica slate, passing into gneiss, which contains a few crystals of black tourmaline and quartz. The cone of the mountain and its summit are covered with myriads of angular and flat blocks and slabs of mica slate, piled in confusion, one upon the other. They are identical in nature with the rocks in place, and bear no marks of transportation or abrasion by the action of water. On the declivity of the cone occurs a vein of milky and rose-colored quartz, but it is not sufficiently high colored to form elegant specimens. The geologist will be fully rewarded for his toil in ascending this mountain, by the magnificent and comprehensive view which may be obtained of the surrounding country. He will remark that the mountains are not grouped at random, but form regular ranges, running in definite directions coinciding with the axis of elevation. To the south-eastward three ranges of mountains are seen, and appear to run N. N. E., while to the south-west the mountains run in a nearly north and south direction. The valleys are observed to be regularly continuous between the mountains. The whole country, so far as the eye can reach, is thickly clad with the primeval forest trees. [1840.]

After mentioning the observations of Messrs. Channing and Hale upon Mt. Jefferson, noticed above (p. 115), Dr. Jackson remarks:

The results of this exploration were important; since the observations made in the bed of Israel's river prove the nucleus of the White Mountain range to be granite rock, and the mica slate seen on the summit of the mountain, is but a superficial crust or superimposed layer. [Page 160.]

In Volume I, page 10, I have reproduced Dr. Jackson's ideal view of the stratigraphical structure of the White and Green Mountains, in their relations to the formations of the adjacent states, with his figure. A few critical remarks will be found there, expressive of what is correct and what is erroneous in these views, according to the latest interpretation.

E. Hitchcock's views. In 1841 my father ascended Mt. Washington from the old Notch house, and, in a paper upon *Glacio-aqueous action in North America*, makes the following statements respecting the rocks:*

The principal part of the White Mountains, I will not say all, appears to me to consist of steep parallel ridges of granite and mica slate, running about north-northeast and south-southwest, with occasional spurs. The Notch is a passage through the highest of these ridges. * * * This ridge [Clinton to Washington] is composed essentially of a peculiar kind of mica slate, occasionally containing feldspar, and sometimes traversed by veins of granite. It also abounds, as does the same rock at Monadnock, with a mineral which has been called fibrolite, but which demands further examination. It often constitutes a large proportion of the rock. All the peaks, except Clinton, which I ascended, (Jefferson and Adams I did not ascend,) are made up of broken fragments of this slate, which have been entirely removed from their original position by frost, and form sometimes a coating of loose angular blocks several feet thick. This is particularly the case upon the summit of Washington, and downward about one thousand feet. But in all the valleys between these peaks, more or less of the rock in place appears.

Views of H. D. and W. B. Rogers. Of all the papers published upon the geology of the White Mountains previous to 1869, that by the Professors Rogers in 1846 † is the most valuable, and therefore it is copied here entirely, save a few paragraphs relating to some supposed fossils, which they themselves subsequently discovered to be simply singular mineral aggregations. ‡

The White Mountains, the most elevated of the mountain masses of the Atlantic side of North America, have been hitherto regarded as consisting exclusively of the granitic and gneissoid rocks under their several modifications, and as having originated in the so-called primary periods of geological time. This common notion of their

* *Trans. Assoc. Amer. Geologists and Naturalists*, pp. 183, 184.

† *Amer. Jour. Sci.*, II, Vol. I, p. 411.

‡ *Id.*, II, Vol. V, p. 116.

great antiquity is to be ascribed to the highly crystalline texture of many of their more conspicuous rocky masses, which, until closely scrutinized, do certainly bear a near resemblance to the typical forms of the most ancient gneiss, mica slate and granite. But it involves we conceive two errors, first, that of assigning to all the strata of the gneissoid class, merely in virtue of their crystalline aspect, a date remoter than that of the protozoic or earliest fossiliferous deposits; and secondly, the error of supposing that the strata of these mountains contain no organic remains. So long as their fossiliferous character was undiscovered, the metamorphic condition of these rocks might naturally enough deceive the observer, and lead him to false inferences in relation to their age.

Having in the month of July last, enjoyed the opportunity of studying with some care the structure and composition of that part of the chain which is exposed to view in the picturesque and deep defile of the Saco, we had the good fortune to detect in the vicinity of the Notch, the fossiliferous character of a portion of the strata, and to see through the metamorphic disguises in which intense igneous action has obscured these originally sedimentary palæozoic masses. We succeeded in determining some of the organic remains sufficiently to identify thereby some of the formations, much altered as they are from the purely sedimentary aspect, and from these data we have attempted to deduce some inferences respecting the *limit of antiquity* of these mountains, and the date of their elevation. By detecting in many of the pseudo-granitic rocks a genuine sedimentary stratification, we were able to follow in sundry places the true direction of the almost obliterated bedding, and to discover the course of the anticlinal axes. These once clearly recognized, led us finally to conclusions which have much interested us in regard to the structure of the whole chain and the nature of the forces of elevation. In the present short paper we propose to submit a concise abstract of these observations, and the results to which they have brought us.

By inspecting the accompanying little map, the reader will notice that the general direction of the Gorge of the Saco, neglecting the local windings in its course, is nearly from north to south. In one place, about half-way between Crawford's and the Willey house, the contracted valley as we trace it south bends abruptly to the westward, and in the distance of perhaps a furlong sweeps back again into its former southerly direction, making a double or sigmoid curve. This feature is especially favorable to the exhibition of the range and dip of the rocks, which are here exposed endwise in the transverse section. In the mountain on the north and west of the Gorge, the end of which is full in front of the traveller as he ascends the valley from the Willey house, the stratified structure of the rocks throughout this gigantic ridge, is plainly to be seen in the differently colored perpendicular belts which outcrop edgewise along its naked and nearly mural face.

At the Notch (represented in the sketch at *a*) the rocks on both sides of the narrow chasm are traversed by two sets of nearly vertical planes or joints, the one running nearly N. E. and S. W., the other nearly N. W. and S. E. Though in this place the stratification is but obscurely indicated, we succeeded in making out the planes of bedding; and in some cases with such satisfactory clearness as to prove the true strike of the beds to be N. E. and S. W., and the dip to be for the most part vertical, but with some local arching. Observations made both at this locality and elsewhere, induced us to regard the rocks of the Gorge generally as a group of highly metamorphic sandstones and slates, traversed by enormous beds and veins of syenitic granite, by the heating agency of which they had for the most part been rendered semi-crystalline, and in some cases had even been transformed into apparent gneiss and granite. At certain points in these altered strata, the original sedimentary structure is still distinctly retained; and at one locality we were so successful as to discover well characterized impressions and fragments of fossils, from which we have been able, safely as we think, to approximate to the geological age of the strata, as well as to the epoch of the earliest movement of elevation.

At the curve in the valley, where the anticlinal axis xy crosses the Gorge obliquely, entering the end of the ridge already alluded to, and from that point down to the Willey house, the rocky fragments dislodged from the naked and steep slopes on either side, consist chiefly of a finely laminated hard sandy slate of a bluish color, and a coarse very compact rock of similar composition; and mingled with these are occasionally found masses of the same composition, but wearing a more altered aspect, some of them containing crystalline spots and white amygdaloidal kernels, the obvious indications of an advanced stage of igneous metamorphosis. These fragments are extremely instructive; for they exhibit nearly all the later stages of alteration, from the ordinary sedimentary texture to the diffusedly crystalline one. In some cases we see the planes or lines of sedimentary deposition coexisting with a general but not fully perfected crystallization, in which however may be distinctly discovered genuine *feldspar*, *augite* and *mica*. Such specimens are to be viewed as an incipient hornblendic gneiss, in which through the sedimentary granular structure, typical of the secondary strata, may be seen everywhere and intimately dispersed, the crystallized definite mineral aggregates equally typical of the so-called primary rocks. Many of these specimens seen facewise, would pass for genuine ancient gneiss; but looked at edgewise, they betray equally unequivocal marks of their sandstone nature and origin. Among the more argillaceous altered rocks, are some which have evidently once been sandy shales, but which now consist of a purplish gray semi-crystalline base, imbedding several obscurely developed minerals. These rocks likewise contain serpentine, talc, and other silico-magnesian species, as well as some clearly insulated grains of crystalline quartz.

About one third of a mile below the northern entrance of the Notch, on the west side of the Gorge and therefore not far from the extremely wild and picturesque cascade called the Flume, there occurs especially in the craggy summit of the mountain, a thick-bedded white semi-crystalline altered sandstone, which is intersected by injections of feldspathic granite, and is itself in many parts concreted into a near approximation to a binary granite composed of distinctly developed quartz and white feldspar, with a few sparsely scattered specks of mica. In its weathered surfaces this rock wears a close resemblance to some fine grained quartzo-feldspathic granites, but upon inspecting a fresh fracture with a magnifier, we instantly perceive many rounded grains of quartzose sand: we perceive moreover much of the feldspar to be only imperfectly formed, as if congealed when *in transitu*, though the mica has more nearly reached the standard condition which it has in granite. In some of the coarser varieties of this white rock, small distinctly rounded pebbles of quartz are to be seen, giving unequivocal evidence, even to the naked eye, of its being an altered sandstone. Upon inspecting many varieties of this rock, we felt no hesitation in deciding it to have been a coarse silico-argillaceous white sandstone, now almost granitized by extensive metamorphic action. The slope of the steep mountain side is in many places strewed even to its base, with long trains of the angular blocks of this seeming granite fallen from the high crowning cliffs above. Seen in places near the summit of the mountain, the rock presents two or more systems of extensive and very regular joints or planes of cleavage, by which the whole mass is cut into cubical and trapezoidal blocks. This jointed condition, itself so significant of an extensive internal structural change, is a principal cause of the magnitude of the piles of fragments which clothe the slopes of the mountain. It is beheld even more conspicuously in the shattered crests which bound the valley above and below the Willey house, where an almost continuous thick sheet of angular *débris* conceals the stratification except in the craggy precipices near the summits. Those sublimely terrific and desolating *slides* which have occurred here at different times, are therefore primarily attributable to this jointed structure. This has permitted the elements to dislodge the fragments and heap an unusually abundant and heavy *talus* high upon the slopes of the steep hills, where its unstable equilibrium, weakened by saturation from copious rains, has caused great bodies of the rubbish to give way and rush down with destructive impetuosity into and across the bed of the narrow valley beneath.

Generalizing the position and dip of these clearly mechanical but altered strata, on both sides of the Gorge of the Saco, we think that there are ample data for inferring the existence of a great anticlinal fold or axis, crossing the valley in a direction nearly N. W. and S. E., as represented by the line $x\,y$. This axis is plainly indicated on each side of the Gorge by a deep depression in the summit line of the mountain, especially in the crest which overlooks the valley on the western side. At this latter place the situation and bend of the axis line is easily discernible, even from the valley below, in consequence of the contrast of certain dark-colored argillaceous strata, in color and bedding, to the other rocks.

In the flank of the mountain, capped by the highly altered white granitized sandstones already mentioned, we discover on the west side of the Gorge, about one third of a mile below the Notch and within one hundred feet of the road, a thick bed of a light brownish altered shale, imbedded with a nearly vertical dip between strata of the metamorphic sandstone before referred to, as so nearly granitic in its aspect. This shale is replete with fossils of recognizable genera and species, but in the state of casts and mere impressions. * * * * * *

This stratum, so remarkably fossiliferous, is only a few yards in width where it is exposed at the locality we have designated, and it there lies with a nearly vertical dip, between masses of highly altered sandstone, possessing, until carefully inspected, a close resemblance to granite. The white feldspathic or granitized sandstone, already described as crowning the top of the hill, belongs probably to one of these including masses; but from the perpendicularity of the dip it is obviously impossible to infer which was originally the superior formation. Near the summit of the ridge, however, the sandstone seems to overlie the shale; but an inversion of the dip here might very naturally exist, and it is necessary therefore to appeal to some other evidence than that of position merely to determine the stratigraphical order of these rocks. As the altered white sandstone in the portions examined, is apparently destitute of organic remains, we have no feature to guide us but its composition and aspect. These are well marked and strongly indicate its identity with the *Levant white sandstone*, (or Shawangunk grit.) To no other formation in the whole Appalachian series, except perhaps the *primal sandstone*, (Potsdam sandstone,) does it bear any near resemblance, and its affinity even to the primal sandstone is rather remote. The shales belonging to the primal rocks contain moreover scarcely any fossils and certainly none of the species here enumerated, and since there is no visible hiatus in the strata indicated by an unconforming dip, this argument may be held to be conclusive. We are therefore disposed to regard the two formations, the white sandstone and the fossiliferous shale, as the equivalents respectively of the *Levant white sandstone* and one of the higher *Levant shales* near the horizon of the fossiliferous iron ore. Upon this view some of the intermediate shales are absent, and when we advert to the distance between the White Mountains and the nearest outcrop of the *Levant series* in New York, this ought not to surprise us. Upon the less probable conjecture that the fossiliferous bed is a portion of the *Matinal shales*, no assumption of a deficiency in the series is required, for the *Levant white sandstone* comes naturally next in the ascending order. The general conclusions to which we are brought by this unexpected discovery of a fossiliferous formation, related evidently to one of the earlier Appalachian periods, are not however in the slightest degree affected by this trivial amount of uncertainty respecting the age of either bed. We proceed therefore to state the inferences deducible from the foregoing facts.

One of the most interesting conclusions to be drawn from the evidence afforded by the above described fossiliferous strata, relates to the geological age of the chain of the White Mountains. These strata present convincing proofs that the region, now occupied by this mountain chain, was overspread by the waters of the ancient Appalachian ocean at an era as late in the Palæozoic ages, as the Matinal, or more probably the Levant periods. Placed as the district is, immediately between the nearly contemporaneous formations of the states of Maine and New Brunswick on the one hand, and Vermont and New York on the other, it fills up an interval in the area of the Appalachian rocks, which hitherto seemed vacant, and suggests strongly that the waters of the *Matinal* or *Levant* eras, extended continuously across at least all northern New

England. As it is known that the Appalachian strata abound as far to the N. E. as Nova Scotia, and perhaps Newfoundland, and spread to a great distance north and north-westward in the continent, the prodigious magnitude of the Appalachian sea, at least in its earlier periods, is made apparent. But while these fossiliferous beds of the White Mountains make it probable that the continuity of this sea was unbroken by any land in the position of New Hampshire before the Levant period, they indicate as plainly that some land did emerge after this period had commenced. How long subsequent to the deposition of the earlier Levant strata that portion of the bed of the ocean was uplifted into land, it is not practicable very positively to ascertain, until we are certain of the latest age in which any of the fossiliferous rocks of the White Mountains were produced. That the elevation was before the *Carboniferous period*, which witnessed the final draining of the Appalachian sea, seems manifest enough from two considerations.

It is almost certain, in the first place, that none of the Appalachian strata of the middle or latter ages were deposited within this region; for no traces of the coal rocks nor of the fossiliferous *Postmedial shales*, (Marcellus shales, &c.,) nor any of the red shales referable either to the later *Levant* or the *Ponent* (Catskill group) *periods* have yet been met with: and since these newer palæozoic formations abound both to the S. W and N. E. we must infer that their absence in this locality is due to a lifting out from the bed of the sea previous to their deposition. Had they been deposited within this area, some remnants of these strata would almost certainly have been preserved from denudation in the close folds or synclinal bends of this contorted district. In the second place, there is abundant evidence in the region of the Hudson valley, where the Levant rocks rest almost horizontally on the upturned edges of the Matinal, that the bed of the Appalachian waters underwent a local disturbance at the close of the Matinal period, and it is equally obvious that the direction of this disturbance, as seen in the course of the axes of elevation and depression, was different from that of the subsequent movement by which all the deposits *at the end* of the Appalachian ages were contorted and upraised. So in like manner we may perceive, in the structure of the White Mountains, the proofs of two distinct intersecting systems of dip, the components of two separate sets of axes or contortions of the crust, indicating two different epochs of elevation. One of these, and apparently the latest, is a N. N. E. and S. S. W. set of anticlinal and synclinal folds; and is therefore probably a part of the general movement which lifted the whole Appalachian or Alleghany chain, and drained away the palæozoic waters; but whether the other accords as nearly in direction and date with the earlier system of the Hudson valley, the epoch of which was either at the close of the Matinal or early in the Levant times, is an important and interesting question which only future research can answer. The most natural inference from all the facts would seem to be, that in the somewhat disturbed period last referred to, when, as geologists are already aware, all the more ancient Appalachian rocks, from the earliest to perhaps the Levant sandstones, suffered a contortion and general outlift in the region which is now the northern part of the Hudson valley, the same disturbance and elevation of the earth's crust extended to the district which is now the White Mountain chain. If we conceive indeed the whole of the wide tract of undulating and in some places mountainous surface, from the upper Hudson and Lake Ontario, eastward to Maine inclusive, and possibly a large territory north of the St. Lawrence, to have emerged from the waters into permanent land, during the close of the Matinal period and the first ages of the Levant, while the still wider spaces to the S. W. and N. E. remained undisturbed, for the reception of later strata, we shall be able to interpret many important facts in the geological structure not only of this ancient district but in that of the neighboring regions.

The hypothesis which supposes that the bed of the Appalachian ocean was violently and extensively agitated by a succession of earthquake movements, at the end of the Matinal and early in the Levant periods, resulting in the conversion of all northern New York and New England, and probably the whole south-eastern border of that sea into permanent dry land, supplies us in the first place with an explanation of the unconformable superposition of the Levant upon the Matinal rocks, discovered by one of us in 1837 near the city of Hudson, and visible at a number of other points E. and N. E. of the Catskills. It furnishes moreover a cause for the extremely wide diffusion, and the coarse conglomeritic composition of the early Levant sandstones, amid the pebbles and sand-grains of which, are many fragments obviously derived from the uplifted and broken Matinal and Primal strata. It provides furthermore a physical reason for the marked transition observable in the species, when we ascend from the organic remains of the Matinal to those of the Levant formations. An era of paroxysmal action would be naturally the period of a modification in the conditions and forms of life, for extensive and permanent changes would arise in the bed of the sea, the waters would grow shallow in many places, would deepen in others, their temperature and their currents would alter, and even the proportions of the elements held in chemical solution, which are the very pabulum of the aquatic races, would sustain some change. But perhaps the most interesting application of the hypothesis here referred to, is the explanation it affords of the excessively crystalline or metamorphic condition of the Appalachian deposits in the district supposed to have undergone this ancient elevation. Upon this supposition these districts, embracing nearly all New England and the Atlantic slope of the Middle and Southern states, were the areas of chief movement, while the other portions of the Appalachian sea were but slightly affected. Here therefore the crust underwent the maximum degree of dislocation and of heating, and the newly precipitated surface sediments were rent, brought into contact with the intensely heated veins and dykes of internal molten matter, and baked and probably partially crystallized, while those of the remoter and still submersed tracts were but slightly acted on. As these districts, the south-eastern and north-eastern parts of the Appalachian basin, were the first to be invaded by igneous action, so they continued, as it would seem, to be the quarter where this action was oftenest repeated, and where at each epoch of disturbance, especially that which witnessed the final drainage of the Appalachian sea, it was greatly the most energetic. The whole structure of the

Appalachian chain supports this conclusion; the truth of which is confirmed by the excessively folded and dislocated condition of the strata along this whole belt of country, and the gradation to features of less and less disturbance as we cross the strata westward still further, by the progressive flattening of the anticlinal arches, by the decreasing amount of crystallization in the rocks, and even the increasing quantity of the volatile bitumen in the coal. When we advert to this repetition of igneous action along this chief belt of volcanic force, upon the early elevated Primal and Matinal deposits, we can no longer wonder at their highly metamorphic condition, nor hesitate to impute to such cause any extent of lithological alteration exhibited by portions of the strata, even to the aping of true granite and gneiss.

The suggestion we have here made, that the Primal and Matinal rocks of the White Mountains emerged from the waters in the Levant period, and were elevated into anticlinal and synclinal flexures with a different strike from those of the more extensive crust undulations of the late carboniferous date, offers a natural cause, we think, for the superior elevation of their outcrops in this mountain chain, compared with their height in the Green Mountains and other districts where only one system of axes, upon a large scale, is discernible. As the level of the water is highest at the intersection of two crossing billows, we can understand why in a region of two interfering sets of dips or archings in the strata, such as we see indicated in the great defile of the Saco, there should coexist a series of loftier peaks than are anywhere else presented in the general mountain chain. The same intersection of axes of different geological dates has probably produced in like manner the very elevated and pyramidal group of mountains between Lake Champlain and Lake Ontario, to which the general name of the Adirondack range is given. The prodigious elevation and insulation of the peaks of the Alps have likewise manifestly originated in the want of coincidence in the great folds or axes, during the successive movements of elevation.

Views of J. P. Lesley. The fullest statement of the views of Mr. Lesley, which I have seen, is contained in the *Proceedings of the Academy of Natural Sciences of Philadelphia*, for 1860, page 363.

Mr. Lesley stated briefly the results of some observations he made in the White Mountains of New Hampshire during the summer. His visits to this region in 1849, and subsequent years, had laid the foundation for a growing conviction that the range of the White Mountains would prove to be *synclinal* instead of anticlinal, and therefore of probably Devonian age. A section which he made in 1857, along the Grand Trunk R. R., showed him the synclinal structure, with comparatively low dips, and at least two main anticlinal divisions. The profile in the Franconia notch is evidently a cliff outcrop of a horizontal plate. The newly opened Greeley Mountain House in Waterville, in a cul-de-sac valley at the head of Mad River, and six or eight miles in an east line through the woods from the Flume House, is surrounded by bold outcrops of nearly horizontal massive plates of granite. Ascending Mad River from Campton, the traveller has the White-face range on his right, with apparent gentle dips to the north-west. But on his left he has the Welch mountain range and Mount Osceola, with an unmistakable and universal dip, never over 15°, and much of it under 10°, to the south-east, which can be studied for at least seven miles, north-east and south-east. Turning to the left and ascending Mount Osceola (which Mr. Lesley found by barometer to be over 2600 [feet] above the Greeley House, and therefore not much lower than Mount Lafayette), the bridle path mounts over successive outcrop edges of perfectly horizontal plates of granite, as evidently and regularly bedded as any of the sandstone masses of the Alleghanies, the bed planes not being at all disguised by the cleavage planes. Between these plates of granite lie plates of unchanged dark blue sandstones; a rock which at the cascades (two miles from the house in another direction) has been mistaken for greenstone trap. The successive terraces and cliffs of the mountain are evidently the consequences of this horizontal and alternate structure. As in other horizontal mountain plateaus the terraces here are projected between the ravines in the form of noses, with straight crests, and terraced or stepped at their ends. In fact, to a practiced topographical eye, the aspect of the whole White Mountain range is that of synclinal erosion.

Other considerations reinforce this opinion. The continuation and broadening of the range north-eastward through Maine and Lower Canada, where supersilurian rocks abound,—the termination of the range south-eastward before reaching Massachusetts and Vermont, as the Alleghany synclinal stops at Catskill before crossing the Hudson,—the presence of horizontal rocks at Worcester and more generally than would be supposed through middle New England,—the fact that the Connecticut Valley runs everywhere under the western escarpment of the White Mountains, separating it from the silurian range of the Green Mountains,—and the presence of Potsdam and other low formations in eastern Massachusetts—all these facts would find their explanation in a synclinal terminal eroded structure of the White Mountain mass.

The granite of Mount Osceola and the surrounding heights consists of large crystals of feldspar, smaller crystals of quartz and smaller flakes of mica. Here and there hornblende appears. The rock bears no resemblance to the subsilurian Highland and Blue Ridge range, and Adirondacks. It is friable under the weather, shedding its crystals upon the ground under every overhanging ledge. The boulders are rounded by the weather action apparently more than by movement; for they have only travelled down the slopes beneath the cliffs from which they have fallen, and where those that remain are sharp-angled. The peculiar gravel and sand of the Mad River Valley is a local drift of similar origin. The metamorphism of these granites is considered by Logan, Hunt, and others, as no longer disputable. They could easily originate in the clayey sandstones of Formations VIII, IX, and X, of the Appalachians.

Considering the whole White Mountain mass a synclinal plateau, then the summit of Mount Washington, which is such an acknowledged anomaly, becomes regularly the single residual fragment of the highest formation which escaped erosion. Its rock is so different in texture and structure from the rest of the mountains that no other explanation seems possible; and if this hypothesis be adopted, there is no longer any need of that which supposes the submergence of New England *up to the base* of the head of Mt. Washington *and no higher*, leaving the head in the air to escape the general rounding and polishing action. It becomes easy to consider the external difference due rather to the difference of the rock formations above and below that horizon.

It is to be hoped that a systematic explanation will be made of this interesting region and the structure made out and mapped, so that we may arrive at conclusions, instead of venturing conjectures.

Views of T. Sterry Hunt. At the Cambridge, Mass., meeting of the American Association for the Advancement of Science, 1849, Mr. Hunt made an oral communication upon the results of the geological explorations of Canada, and the conclusions to be derived therefrom respecting the age of the New England rocks. The substance of these remarks was printed in the official record of the meeting, also in *American Journal of Science*, II, vol. ix, p. 12. Reference is made to the section from Lake Memphremagog across to Canaan, Vt., by W. E. Logan, in the report on the geology of Canada for 1847–'48, which afforded the data from which the conclusions were drawn. The fossiliferous rocks of the St. Francis valley are referred to the Niagara group, which are continuous with the "calcareo-micaceous formation of Prof. Adams," in Vermont. Resting upon this Niagara group in Gaspé is a body of arenaceous rocks, 7000 feet thick, corresponding to the Chemung and Portage groups in New York. "To this," he says, "may perhaps be referred in part the rocks of the White Mountains."

Similar views are met with in a paper on the *Crystalline Limestones of North America*, in the *American Journal of Science*, II, vol. xviii, p. 199, 1854.

When we consider the geographical position of the Upper Silurian rocks in the Connecticut Valley on the one hand, and the coal field of south-eastern Massachusetts on the other, we can scarcely doubt that the intermediate gneissoid and hornblendic rocks, with their accompanying limestones, are the Devonian strata in an altered condition.

In 1870 Dr. Hunt wrote a letter to Prof. Dana upon the geology of eastern New England, in which he proposed the name of Terranovan series for the rocks to which the White Mountains were supposed to belong; and conjectured that their age was "between the Laurentian and the Quebec group." To this publication I have already made abundant references in Volume I, page 522.

In 1871, in the presidential address before the American Association for the Advancement of Science, Dr. Hunt thus defines the White Mountain series:

This series is characterized by the predominance of well defined mica-schists interstratified with micaceous gneisses. These latter are ordinarily light colored from the presence of white feldspar, and, though generally fine in texture, are sometimes coarse-grained and porphyritic. They are less strong and coherent than the gneisses of the Laurentian, and pass, through the predominance of mica, into mica-schists, which are themselves more or less tender and friable, and present every variety, from a coarse gneiss-like aggregate down to a fine-grained schist, which passes into argillite. The micaceous schists of this series are generally much richer in mica than those of the preceding series, and often contain a large proportion of well defined crystalline tables belonging to the species muscovite. The cleavage of these micaceous schists is generally, if not always, coincident with the bedding, but the plates of mica in the coarser-grained varieties are often arranged at various angles to the cleavage and bedding-plane, showing that they were developed after sedimentation, by crystallization in the mass; a circumstance which distinguishes them from rocks derived from the ruins of these, which are met with in more recent series. The White Mountain rocks also include beds of micaceous quartzite. The basic silicates in this series are represented chiefly by dark colored gneisses and schists, in which hornblende takes the place of mica. These pass occasionally into beds of dark hornblende-rock, sometimes holding garnets. Beds of crystalline limestone occasionally occur in the schists of the White Mountain series, and are sometimes accompanied by pyroxene, garnet, idocrase, sphene, and graphite, as in the corresponding rocks of the Laurentian, which this series, in its more gneissic portions, closely resembles, though apparently distinct geognostically. The limestones are intimately associated with the highly micaceous schists containing staurolite, andalusite, cyanite, and garnet. These schists are sometimes highly plumbaginous, as seen in the graphitic mica-schist holding garnets in Nelson, New Hampshire, and that associated with cyanite in Cornwall, Conn. To this third series of crystalline schists belong the concretionary granitic veins abounding in beryl, tourmaline and lepidolite, and occasionally containing tinstone and columbite. Granitic veins in the Laurentian gneisses frequently contain tourmaline, but have not, so far as yet known, yielded the other mineral species just mentioned.*

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Although I have in common with most other American geologists, maintained that the crystalline rocks of the Green Mountain and White Mountain series are altered paleozoic sediments, I find, on a careful examination of the evidence, no satisfactory

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* Hunt, Notes on Granitic Rocks; *Amer. Jour. Sci.*, III, i, 182.

proof of such an age and origin, but an array of facts which appear to me incompatible with the hitherto received view, and lead me to conclude that the whole of our crystalline schists of eastern North America are not only pre-Silurian but pre-Cambrian in age.

Views of G. L. Vose. In a paper before the American Association for the Advancement of Science, at Burlington, Vt., 1867, Mr. Vose remarked as follows:

Regarding the arrangement of the great central mass of rocks forming the main chain of the White Mountains, it was stated that this portion of the group appeared to have neither the anticlinal build of the older geologists, nor yet the regular synclinal build more recently suggested; but that the top of Mt. Adams, of Mt. Jefferson, of Mt. Clay, and the section from Tuckerman's Ravine through the Lakes of the Clouds, all seemed to show a prevalent steep dip to the north and north-west; and it was suggested that the main chain of the White Mountains was formed by a fragment of the western slope of an immense anticlinal wave, of which the crest would have been over the Peabody valley, and of which perhaps a fragment of the eastern slope may be found in the opposite and parallel range of the Carter Mountains; in which case the Peabody valley would be a valley of denudation.

In 1869 Mr. Vose prepared a report upon special details of the geology of Jackson, Conway, Mt. Pequawket, the Ossipee mountains, etc., which was printed in the annual report for 1871. As he indicated no generalizations concerning the structure of the mountains, it will be unnecessary to reprint any portion of it here.

After the presentation of the few remaining facts relating to the distribution of the White Mountain formations, I will offer a few general considerations concerning their structure and probable age.

Sketch of the Geology along the Grand Trunk Railway, from Island Pond, Vt., to Gilead, Me.

BY J. H. HUNTINGTON.

As the rocks are more accessible along the lines of our railways, we give here a summary of the facts relating to the geology on the line of the Grand Trunk Railway.

As a view of the crystalline rocks, the geology along this line is intensely interesting; and so varied are the rocks that at every turn, almost, the scenery changes.

The artist is not often satisfied to place upon his canvas a view as seen from a single point. Here he traces the bold outline of a mountain;

near by, the foot-hills, and elsewhere the trees and the swelling hills that form the foreground of his picture; but here, as we ride along, the changes are so rapid that we have these combinations in a single picture.

The swelling undulations of the gneiss; the pyramidal hills of porphyrite, broken by dizzy precipices; the rolling hills of the siliceous and chloritic schists, the vertical strata of which have been worn and torn and ground by the glaciers of the great ice age; the mountains of granite, that have been crumbling by slow degrees through the ages; and, finally, the mica schist and gneiss of the White Mountains, that have the strata crumpled and contorted by a thousand foldings, and here form bold, projecting points and sudden recesses, that break the mass into such picturesque wildness,—all form not so much a single picture, perhaps, as a general panorama, each view of which has some point of beauty which seems to excel all the others.

Bluff mountain, directly north of Island Pond, is mica schist. The rocks, left bare by the fires that have swept the vegetation from its summit, show a reddish tinge, and point to the fact that they are ferruginous. These rocks are cut by the railway north-west of the village, where they have an easterly dip.

At the village near the station there are huge moraines, made up for the most part of very coarse material derived chiefly from granitic rocks, probably those in Morgan and Norton. East of the village we come to an outcrop of a peculiar granite, probably intrusive. The quartz which very largely predominates is gray and vitreous. The mica is a rusty brown or black; the feldspar, when found, is dark and triclinic. This rock extends ten miles east of Island Pond. Near its eastern limit, at Nulhegan station, there is in this rock a bed of very fine-grained granite. It is quarried to some extent, and is used along the line of the railway.

After crossing the Nulhegan river, going east, we find a kind of sandstone schist, often thick bedded, but elsewhere foliated and micaceous, passing into mica schist. This rock is not cut by the railway, but is found to the north along the carriage-road; while to the south of the railway we find the White Mountain gneisses. Along the Connecticut, in the vicinity of North Stratford, we find mica schists with strata nearly vertical, but with varying strike. In this rock, west of the river, there is a variety of andalusite somewhat rare. It occurs in crystals of a reddish-brown color, not far from an eighth of an inch in diameter. The mica schist is continuous south below Stratford Hollow, but varying considerably in texture. Some of the last outcrops of this rock on the south, where it approaches a hydro-mica schist, have the strike E. and W., but the strata are nearly vertical. The inclination at J. Merriam's is 80° southerly. The railway keeps on the drift and terraces of the valley, and nowhere cuts this rock. We have described these rocks as Huronian, except the schists at Island Pond, which probably belong to the Atlantic series. Rocks similar to those near North Stratford, and containing the same kind of andalusite, are found in Franklin county, Me., adjacent to porphyritic gneiss.

As we enter Northumberland we come to an entirely different class of rocks, that extend along the railway nearly to the town of Stark. They consist chiefly of chloritic feldspathic gneisses, and chloritic siliceous schists; but on the eastern border the rock is more an argillaceous sandstone schist. Southward, hornblende and epidote are frequent constituents of this rock. At Groveton there are many outcrops that show some of its different phases, and here, included in them, there is an iron ore, which, with the rock, forms a breccia. The strata in the vicinity of the notch have a north and south strike, are nearly vertical, and are arranged in a series of folds. At Groveton we see the pointed summits of the porphyrite mountains. The most marked of these is Mt. Lyon. Although the railway nowhere cuts it, yet the high ridge immediately south of the railway in Stark is composed of this rock. It has a dark, compact feldspathic base, with crystals of feldspar, probably triclinic. Northward the Percy peaks are peculiar in their dome-shaped summit, not so flat as ordinary granite, neither are they as sharp as the mountains of porphyrite. The explanation is found in the constituents of the rocks. Crystalline feldspar very largely predominates; there is some black mica, and a very small proportion of hornblende. The feldspar does not so readily decompose as that of the coarse granite to the north, but resembles that of Mill mountain. In the west part of Stark, on a hill between the railway and the river, we have a granite unlike that found elsewhere. It resembles the Conway granite and the coarse varieties found in Columbia, but it differs in being more compact, of finer texture, and having a feldspar more decidedly flesh-colored. Its proximity to the railway, and the scarcity of building-stone in this part of the state, make it worthy of attention for local, if not for more extended use. This granite, at least along the railway, is limited to this hill, for the next outcrop of rock is at Devil's Slide, just west of Stark station. Here we have a variety of rocks. At the west side the rock is a beautiful sienite, but unfortunately it is not easily wrought. Going up the steep ascent, the quartz disappears, and in places, also, the hornblende, so that we have only a crystalline aggregation of feldspar. Half-way up the rock is colored by manganese and other substances, so that it is a dingy mass, mostly feldspar, with a very little hornblende; and we have included the whole under the general term of porphyrite. The east end of the slide is a dark siliceous schist, that stands vertically by the side of the intrusive porphyrite, but there are places where it is penetrated by it; and boulders forming a breccia can be seen at the boarding-house near Hickey's mill.

The mountain opposite, that rises a thousand feet above the station, is composed of essentially the same rocks as the slide; but on the west side of this mountain, from the base far up its slope, there are boulders of labradorite, though diligent search has not revealed a single outcrop. The marvellous beauty of the finely-striated crystals of the feldspar is shown by polarized light in the microscopic sections. The vertical walls of the slide, shown in the heliotype opposite page 69, and Mill mountain, rising so high and shutting by the slide, give to the place a picturesque beauty, especially when the setting sun throws a deep shadow over the face of the slide, and casts across the vast amphitheatre the sombre hue of evening while as yet the mountain is in the bright sunlight. Leaving the station, we pass the limit of the porphyrite, and at Stark water-station we strike a dark siliceous schist. Going east, the rock resembles somewhat a hydromica schist, but still it is a gray siliceous schist, and numerous outcrops can be seen. The railway cuts it in the east part of Stark, in the corner of Dummer, and several places for a mile east of West Milan. It has both easterly and westerly dips, but the easterly dips prevail on the west, and the westerly dips on the east, so, as a whole, it seems to be a synclinal axis, with minor folds near the middle of the area. These rocks, except the hard siliceous schists on the west, we have placed in the Lyman group, which is the upper member of the Huronian. On the railway, not far from the one hundred and fifth mile-post, we have a hornblendic gneiss, with nodules of epidote and veins of calcite. The dip is a few degrees west of north, generally at 50° or more, so that it evidently rests unconformably on the gneiss that follows, extensive outcrops of which are found near Milan station. The dip of this is usually north, or a few degrees west of north, near its western limit, but on its eastern limit, where it varies from north, it is easterly.*

On the steep, precipitous slope that overlooks Dead River pond, in a rock itself apparently intrusive, there are dykes of a compact, jaspery-looking rock, which is a compact feldspar; and in this there is a cave of some little note.

Going down the line of the railway, we find that it cuts a coarse granite that has plates of black mica three or four inches across, and this immense mass has disturbed the hornblende gneiss in its immediate vicinity; but the position, general dip, and lithological character of this gneiss are such that it is evidently a repetition of that in Milan, and it is on the opposite side of the common gneiss. South of the station, at Berlin falls, we have gneiss in several nearly vertical folds, and this is traversed by immense "trap" dykes. It is difficult to determine as to the stratigraphical position of this area. It seems to belong rather to the remnant of an older formation, than to the rocks in either of the areas we have described.

At Gorham we have the rocks of the Montalban or White Mountain series, dark gray gneisses with large plates of mica, having interstratified with it the granitic gneiss so common in this series. The rocks here, as well as elsewhere along their western border, have a westerly dip. The interstratification of the hard gneisses that form so large a part of this series is better shown here, probably, than anywhere in the whole area they occupy in New Hampshire and Maine. A short distance above Shelburne station is the only point where the railway cuts these rocks,

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* The facts, stated by Mr. Huntington upon pages 67 and 68, indicate the presence of an anticlinal axis in this area of Lake gneiss. The Montalban rocks occupy a considerable tract in Dummer and Odell (p. 66), on the north side of their axis, and the same rocks are spoken of further on along the Grand Trunk Railway. The Lake gneiss area terminates a few miles north-east from Milan, the farthest exposures of it dipping northerly. These observations are of importance in determining the relative positions of the Lake and Montalban divisions of the Atlantic system. It will be noticed that these conclusions do not agree with the statement of J. P. Lesley (p. 194), to the effect that the fundamental structure is synclinal. As Lesley does not give details, it may be that his synclinal lies entirely to the south-east of Milan, where the structure is of that character. The range of this older gneiss lies several miles to the north-west of the line of principal White Mountain elevation. Section XI, Plate VI, Fig. 5, illustrates a part of this route along the railway. C. H. H.

and here they are not the most characteristic, but on either side of the railway there are many outcrops where it can be seen. J. H. H.

Additional Facts.

Mr. Huntington communicates to me in a letter a few additional facts concerning the rocks along the Grand Trunk Railway in Maine, which are worthy of preservation in this connection, and are herewith presented. It appears that the Montalban series prevails over most of the region. At my request he also states a few facts additional to what we have known concerning the geology of this region, which he observed in the summer of 1875, when not employed in the service of the geological survey.

At Gilead we first find the White Mountain gneiss, where the prevailing dip is easterly. The gneiss here has been evidently much disturbed. At Bethel we find granitic gneiss, and the stratification is very indistinct. At Bryant's pond the gneiss is much coarser than the common granitic gneiss of the Montalban group. At West Paris there are immense veins of coarse granite in the gneiss. Half a mile south-west of South Paris the White Mountain gneiss dips S. 52° E. 18°; a few rods south-west of this outcrop there is an impure limestone interstratified with the gneiss, and there are veins of coarse granite.

At Mechanic falls the dip of the White Mountain gneiss is S. 80° E. 18°. Half a mile east of the village the dip is E. 20°. It has here, as at the falls, numerous large veins of granite that contain tourmaline; and the feldspar is often of a bluish color. At Danville Junction the dip of the gneiss is quite variable; sometimes it is N. 10° E., but generally more to the east. The inclination is generally not far from 15°. Here there are veins of both granite and trap. (See Hunt on *Granite Veins*.*) At Pownal station the White Mountain gneiss dips N. 10° E. 68°, and variable. Half a mile N. E. of the station the dip is S. 40° E. 25°; elsewhere the dip is E. 18°.

Mt. Pleasant (Me.) is composed of a granite *very similar* to that found in the upper part of the Waterville Slide. The summit at the hotel is composed of a feldspathic rock, the physical character of which is unlike that of any rock I have seen in New Hampshire.

In climbing up to King's ravine from Randolph, the rock for the first mile of the way consists of a peculiar granite, unlike anything described in the report as belonging either to the Montalban or Lake Winnipiseogee series. It should be referred to the latter rather than to the former.

There are no ledges at the head of Cutler's river, to the south of Tuckerman's ravine.

Waterville and Sandwich. Israel's mountain is a gneiss. In texture it differs from both the common and the White Mountain, and it has a northerly dip. Sandwich

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* *Chemical and Geological Essays.* By T. S. Hunt, p. 196.

Dome is the White Mountain gneiss, and the dip is N. 15° E. 40°. The ridge north, beginning at Bald Knob and ending at Noon Peak, is granite. Mt. Waternoo, the highest point in the Campton mountains, is White Mountain gneiss, and dips N. 20° W. 35°. On Kimball hill in Whitefield, north-east of Howland's observatory, there is a band of intrusive granite that contains fragments of schist often a foot or more in length.

In Granby, Vt., east of Moose river and a mile north of the road to Victory, there is also intrusive granite containing fragments of schist with staurolite.

Extension of the White Mountain Rocks into Maine.

In 1873 Mr. Huntington and myself presented to the American Association for the Advancement of Science a joint paper upon the geology of the north-west part of Maine, which was printed in the proceedings of the Portland meeting. Its object was to show the relation of the New Hampshire rocks, in their north-easterly extension, to the fossiliferous formations approaching as far as the low regions of the Gulf St. Lawrence. I will state the most important of the facts published by us, and the conclusions drawn from them at that time. The facts are embodied in our map showing the relations of the geology of New Hampshire to that of the adjoining territory. [Plate I.]

The country alluded to is bounded on the east by Moosehead lake, on the north by the west branch of the Penobscot river, on the west by the water-shed between the Kennebec and Chaudière rivers, including the neighborhood of Lake Megantic, on the south and south-west by the mountain range of which Mt. Bigelow is the culminating peak.

The fossiliferous rocks of this section were first pointed out by Dr. Jackson, who studied them particularly in the vicinity of Parlin pond.* He mentions a locality, half a mile north of Parlin pond, where he discovered a great number and variety of impressions in a bed of graywacke. He speaks of them as the most perfect casts of marine fossils that he had ever seen. He seems to have been led to the discovery by the numerous boulders that have been scattered from this formation as far south as the outer island of Penobscot bay in the mouth of the Kennebec. Dr. Jackson passed over Moosehead lake; then he followed Moose river up to the Canada road, which is some thirty miles from the lake; thence he went southward, after he had explored the country northward to the Canada line. In passing up Moose river he crossed the fossiliferous strata diagonally. He noticed obscure fossils in the rocks at Lake Brassua, and these are the only fossils he observed on Moose river, or on the lakes that are expansions of this stream.

* *Third Annual Report upon the Geology of Maine*, p. 44, 1839.

In 1861–'62, when engaged on the geological survey of Maine, I had occasion to traverse the borders of Moosehead lake, then the country westward to the boundary along the west branch of the Penobscot, and the Canada road from the Forks to the Chaudière.* The upper section showed two Huronian areas overlaid by two bands of clay slates, the latter most likely of Upper Silurian age; the other, along the Canada road, exhibited at first strata, most likely Upper Silurian in age (possibly Huronian), overlaid by a band of Oriskany sandstone, to the west of which appeared, first, granite ledges, then the Upper Silurian strata, followed by the Huronian again extending into Canada.† The numerous fossils obtained at the first visit were named by Billings, of Montreal, who recognized in them characteristic species of the Oriskany sandstone. Subsequently, the finding of the *Fucoides Cauda-Galli* made us believe the representative of the Cauda-Galli grit appears on Moosehead lake.‡

In the hope of gaining some additional knowledge of the rocks of this section, particularly in determining their extreme limit, J. H. Huntington spent a few weeks, in 1872, in traversing the country from Moosehead lake westward. He found the felsite of Mt. Kineo in a high ridge to the south-west, on the opposite side of the lake, perhaps dipping north-westerly. On the west shore of Lake Brassua, probably two miles from the southern extremity of the lake, there is an outcrop of a dark colored shale; and immediately north there is another outcrop of felsite. If we follow the line of the strike of the felsite of Lake Brassua four miles S. W. of Parlin pond, we find Bald mountain, with the ridges running W. and N. E., to be composed of a rock similar to that of Mt. Kineo. So it is possible that the rock may be continuous between these two points. See Plate IV for a generalized section across these formations.

Perhaps three fourths of a mile above Brassua lake the rock is a ferruginous sandstone, cut by numerous joints, and the strata dip S. 20° E. 10°. The fossils are quite numerous, and some of them very distinct. The following are the genera: *Avicula*, *Modiolopsis*, *Orthis*, *Leptocœlia*, *Flabellites*, *Spirifera*, *Fucoid*. For the next three miles the rock is a very hard, light brown sandstone, without fossils. At the mouth of Stony brook, a point some two miles from Long pond, he found another fossiliferous band of rock. There the sandstone is compact, but it frequently contains fragments of slate an inch or more across. Thus it is evident that this rock is newer than the slates on either side. The dip of the rock here is S. 31° E. 2°. The fossils are not so numerous as in some other places, but they seem to be more generally distributed through the rock. This is the only locality where the coral *Favosites* is found. From this point to Long pond the outcrop is the same compact brown sandstone that is seen in several places between the Little Brassua and the mouth of Stony brook. The first outcrop of rock on the south shore of Long pond contains concretions of iron pyrites, but no fossils. About half-way up the lake the strata run diagonally across, and there are several outcrops of fossiliferous rock at some distance from the shore. Six miles from the outlet on the south shore there is quite an extensive outcrop of rock, and an abun-

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* *Second Annual Report*, p. 343, 1863. † *Id.*, p. 283. ‡ *Id.*, p. 331.

dance of fossils. The dip of the strata here is S. 20° E. 55°. The sandstone is of a lighter color than that which is generally found farther east, and the strata dip at a greater angle. The fossiliferous portion of the rock is more argillaceous than the non-fossiliferous.

Going south across the strata to Mountain brook, a stream running east from Owl's Head, there are a few fossils, but rather indistinct. The dip of the rock here is S. 40° E. 10°. In the south-east corner of Long Pond township, near Mud pond, fossils are abundant. The dip is N. 3° W. 6°. The rock generally is of a brownish-gray color, and nearly everywhere cut by joints; so that where there are no fossils it is difficult to recognize readily the position of the strata. Taking the fossil locality where the rock begins to dip north as the middle of the axis, we have, by trigonometrical calculation, the thickness of 2880 feet for the Oriskany sandstone. The rock north-west of the sandstone is in general an argillaceous schist, and dips toward the sandstone, with little or no unconformability. If we follow Moose river above here, we shall find a granitic gneiss. The first outcrop is on an island near the outlet of Wood pond. The fossils from Parlin pond are *Strophomena magnifica*, *Orthis musculosa*, *Rhynchonella oblata*, *Rensselæria ovoides*, *Leptocœlia flabellites*, *Spirifera arrecta* and *pyxidata*, *Modiolopsis*, *Cyrtodonta*, *Avicula*, *Murchisonia*, *Orthoceras*, and *Dalmanites epicrates*.

The rocks on a section from Lake Megantic to Lexington are as follows: At the north end of the lake there is a dark gray arenaceous schist that frequently contains iron pyrites. On the west side of the lake, and south of Victoria river, there is a wrinkled argillaceous schist, with a fossil brown slate having small cavities filled with a yellowish-brown powder. The dip is S. 45° E. 70°. These rocks are referred to the Upper Silurian by Sir William E. Logan, and they extend down the Chaudière river to St. Francis. South-west we have found them in Ditton and on the boundary of New Hampshire. Their eastern limit is near the head of Perry Stream. On their southern extension they pass into mica schist. Following the road parallel with the lake six miles from Lake Megantic, the rock changes, and we have green chloritic schists containing light green epidolitic nodules. The rock here dips N. 35° E. 36°. Farther up the lake we have fine, dark gray sandstones. These rocks were examined by Sir Wm. Logan on the lake shore, and by him they were referred to the Quebec group, and were supposed to underlie the wrinkled argillaceous schist just described. This seems quite probable, from their relations elsewhere. We have the same succession of rocks in New Hampshire, in the vicinity of Connecticut lake, and name the first Coös group, the second Huronian. Near the boundary of Quebec and Maine, and forming the water-shed between Chaudière and Dead rivers, we have a band of granite, probably eruptive. Following the granite, and extending along Dead river for four or five miles, we have a granitic gneiss, the strata of which are apparently horizontal. The high mountain ridge at the Chain lakes is an eruptive granite; and this is followed near the outlet of the lake by a fine-grained gneiss that dips 67° and 70° W., and probably extends two miles down the river. We then have for a quarter of a mile a granular talcoid schistose rock, that dips 80° N. 20° W. This is followed by an impure serpentine of a very dark color, often asbestiform in the joints, and appearing to form a synclinal axis. It is followed on the south-east by a granular crystalline rock somewhat coarser than that on the north-east, but otherwise similar. This rock is so cut by joints that it is impossible to determine the dip, though the strike corresponds with the granular crystalline rock north-east of the serpentine.

Leaving the river and following the old road, the next outcrop is a dark green crystalline rock, succeeded by quartzite that dips 63° S. 20° E. This is followed by a breccia composed of greenish slate, quartzite, and serpentine, and also what appear to be reddish grains of felsite. The breccia seems to be composed of rocks found on either side of it. It is followed on the south-east by a quartzite that dips 75° S. 30° W. At Eustis village, extending a mile north-west and three and a half miles south-east, there is a band of tender fissile slate, generally of a greenish-gray color, but having bands of light purple; and south-east of the village are bands of quartzite. This slate forms a distinct synclinal axis. On the Magalloway river we have granular schistose rocks, quartzites, serpentine, and slate. The similarity of these to those on Dead river makes it quite probable that the latter are a continuation of the former. Between Eustis village and Mt. Bigelow there is a greenish chloritic rock that seems to pass into porphyritic gneiss. This rock occupies a large area in Dead River plantation and Flagstaff. Since a similar rock was seen in Range 6, Lot 3, and north-west at Attean and Wood ponds, a continuous band may extend thirty miles northward. There is a striking similarity in this rock to one found in Northumberland, N. H., and southward. Here, as at Littleton, N. H., there is a band of Helderberg limestone containing corals that are remarkably distinct. The rock where the fossils are most abundant outcrops on an island in Flagstaff pond. On the west peak of Flagstaff mountain there is a band of limestone, but the fossils are very obscure. South of the green chloritic gneiss there is a mica schist or imperfect gneiss that resembles very closely the White Mountain series. On the west peak of Mt. Bigelow the dip is 50° N. On the ridge extending from Mt. Bigelow east, where the road passes over it in Range 11, No. 2, the rock is mica schist. It dips 60° N. 5° W., and carries an abundance of small crystals of andalusite. These rocks rest on a porphyritic gneiss that outcrops a few rods south of the height of land. The gneiss resembles the rock of the basin north-west in the valley, and is followed on the south in New Portland by a granitoid gneiss that resembles very closely that associated with the gneiss in the vicinity of the White Mountains.

Adopting the conclusions derived from our study of the rocks in northern New England, we think the porphyritic gneiss south of Mt. Bigelow is the oldest of all the rocks enumerated. This area is represented in the north-east corner of the map, page 512, Volume I. The gneisses of Mt. Bigelow and the ridges eastward abound in crystals of andalusite, and appear to belong to the White Mountain series, and to rest upon the porphyritic variety. The series of chloritic and talcoid schists, quartzites, and serpentines appears to be still more recent, and to be allied to the Huronian system. The granite and gneiss from the lake outlet on the east to the Megantic basin on the west, may be older than the Huronian upon both flanks.

Conclusions.

Four important conclusions may be drawn from the distribution of the formations in north-western Maine, when compared with the rock-exposures in New Hampshire and elsewhere.

1. The Oriskany sandstone reposes gently upon Eozoic gneisses, the first bearing scarcely more traces of alteration than the corresponding group in New York, while the second seems to have been metamorphosed and elevated before the Devonian formation was deposited. No further trace of this group has yet been found towards the White Mountains. It has been followed through Maine from one hundred and fifty to two hundred miles, and similar rocks are described in Nova Scotia by Dawson. It can, therefore, no longer be maintained with reason that these strata pass into New Hampshire in a metamorphosed condition. Furthermore, since the Oriskany and Helderberg formations are so distinctly fossiliferous in immediate juxtaposition with the crystalline strata, it affords a presumption that the latter groups have not been altered from any other Paleozoic sediments.

2. The Oriskany is several times thicker than its extension in the interior and farther south in Pennsylvania. The greatest thickness mentioned by H. D. Rogers is five hundred and twenty feet, about one fifth its dimensions in Maine. The greatest observed thickness in New York is only thirty feet.

3. The discovery of new localities of Helderberg limestone indicates a wide-spread submergence of eastern America, in Upper Silurian and Middle Devonian times, of nearly fifteen hundred feet. These fossils have been detected at Bernardston, Mass., Lyman and Littleton, N. H., perhaps Orleans county, Vt., Montreal, Lake Memphremagog, and other localities to the north-east in Quebec province, Eustis, Flagstaff, and Spencer mountain, in the field described above in Maine, and still greater developments in the northern part of Maine, too extensive to be specially mentioned;—hence,

4. There must have been, subsequently to the Helderberg, a period of elevation to bring New England to essentially its present condition. Possibly this epoch may be indicated in the later elevating force seen upon

Mt. Washington. The highly inclined Helderberg strata at Littleton and Owl's Head, P. Q., certainly bear witness to the exertion of a powerful elevating agency.

LABRADOR SYSTEM.

There seem now to be seven areas of labradorite rocks among the White Mountains. Some that have hitherto been supposed to consist of this mineral prove to be another variety of feldspar. The genuine areas are the following: 1, upon Norway brook, and 2, upon Sabba Day brook, the opposite sides of Tripyramid mountain in Waterville; 3, on Mt. Washington river; 4, Loon Pond mountain, near Pollard's in Lincoln; 5, south end of the Lafayette range; 6, Bean's Purchase; 7, Mill mountain, Stark. I will describe each of these areas in turn, so far as known.

The older geologists regarded all the crystalline rocks as those first formed, or "primary." The granites were considered as remains of the original crust, cooled down from the condition of intense fusion; and the gneiss, mica schists, etc., resulted from the action of eroding agencies, tearing off fragments of the granites and depositing them in the lower areas. These unstratified and stratified rocks have also been styled *Azoic*, from the supposed absence of life in these early periods. Only lithological names had been applied to the different Azoic rocks till 1855,* when Sir William E. Logan and T. Sterry Hunt proposed that the Azoic formations in Canada beneath the Potsdam sandstone should receive local appellations; and they accordingly separated them into two groups, calling the older *Laurentian* and the newer *Huronian.* These terms expressly excluded the crystalline rocks of New England, which, by many authors, had already been considered to be of Paleozoic age. So early as 1845 Logan had perceived that the gneiss of Canada, afterwards termed Laurentian, could be divided into two groups, dependent upon the presence or absence of beds of limestone, and in 1857 † suggested that such a division would probably be found desirable. The suggestion was not carried out, since the studies of Dr. Hunt, from 1852 onwards, upon the feldspars, led him to question the appropriateness of this classification of the Laurentian, because the lime-feldspars seemed of greater importance in the distinguishing of new groups. In the report upon the

* *Esquisse Geologique du Canada.* † *Proc. Amer. Asso. Adv. Sci.,* Vol. XI, Part II, p. 47.

geology of Canada for 1863,* great vertical thicknesses of the Laurentian gneiss are distinguished mineralogically from the others by the presence of triclinic feldspars, and the rocks termed *anorthosites*. I understand that there are scarcely any orthoclase gneisses interstratified with the anorthosites. Later in the same volume certain facts are stated, rendering it probable that the anorthosite series unconformably overlies the gneiss having beds of limestone in it.† The formal proposal of this subdivision is presented in the atlas accompanying this report, issued in 1865, where the anorthosite group is distinguished as the *Upper Laurentian* or *Labrador* series, and the other the Lower Laurentian. The nomenclature of this atlas is based upon further exploration. Had this not been satisfactory, the distinction would certainly not have been delineated in the atlas. The evidences of unconformity consist in the concealment of beds of limestone by the upper rocks covering them, and the change of strike. The testimony of Mr. James Richardson, to the relations of the Lower and Upper Laurentian on the north shore of the St. Lawrence, in 1869, confirms the reality of the division. He represents the dip of the Laurentian to be nearly vertical, with a north and south strike, while the labradorite rocks dip at comparatively moderate angles, with a strike nearly east and west.‡ Seven areas of labradorite rocks outside of New England are represented upon Plate I of this volume,—five north of the River St. Lawrence, one in Newfoundland, and one in New York. It is spoken of as occurring in Alabama, in the recent report of Dr. Eugene A. Smith, and much of the mineral occurs at other localities along the Atlantic range, as in North Carolina and Pennsylvania. None of the Labrador areas, whether in America or Europe, have yet been carefully studied stratigraphically, so that we have not the means of knowing their thickness. The lines of iron ore and other foreign minerals better agree with the idea of stratification than to suppose the masses are eruptive. In the study of New England rocks, the labradorite aids us greatly, since most geologists are prepared to accept it as indicating formations of Eozoic date; and, if these triclinic feldspar layers rest upon strata formerly thought to be Paleozoic, they render it probable that both the underlying and contiguous masses belong to very ancient systems.

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* *Geol. Survey of Canada*, Report for 1863, pp. 22, 23, 478, and 586. † *Id.*, p. 839.

‡ *Id.*, Report 1866–69, p. 306.

The mineral labradorite was found at Waterville, among the mountains, the first of any locality in New Hampshire. The history of its discovery, and the diverse opinions expressed concerning the rocks, especially by Professors Dana and Hunt, have been already stated in Volume I, page 37, *et seq.*, so that we may confine our descriptions at this time to noticing the occurrence of the rocks in nature, with whatever light may be derived from the controversies respecting them. The first two areas mentioned occupy the south and north flanks of the mass of mountains in Waterville called Tripyramid.

Southern Area of Labradorite in Waterville.

In the east part of Waterville three pyramidal peaks attract the attention of observers, from whichever side they are seen. A fourth makes its appearance when the pyramid is viewed attentively. Mr. Morse's profiles, taken from Mts. Chocorua, Pequawket, Tremont, etc., exhibit well the shape of the mass; and the topographical aspects are represented, also, upon the special White Mountain map. Tripyramid is washed on the west and south by the head waters of Mad river, and on the north and east by the tributaries of Swift river, notably Sabba Day brook. Bond figures the peaks without names, but with the altitudes from south to north of 4100, 4100, 4200, and 4000 feet respectively, with a course of about N. 10° W. Guyot mentions but one altitude—taken by a pocket-level—of 4086 feet. Upon his map, published in 1860 from observations made six or eight years previously, Guyot calls the mountain Tripyramid. The Grafton County map, published also in 1860, gives the name of Passaconnaway to the same elevations, and the first publications relating to its geology, by Prof. Perkins and myself, used the latter name. Only this last summer I ascertained definitely that Messrs. Greeley and Mason first proposed to call these peaks Passaconnaway in 1860, without knowing of Guyot's suggestion. In our present report the name Passaconnaway is applied to a peak south-easterly from Tripyramid in Waterville, called North Whiteface by Guyot; and later authors seem to approve of this nomenclature, so that it will be retained by us henceforth. These explanations will prevent any misunderstanding hereafter as to the peaks called by us Tripyramid and Passaconnaway.

The notable storm, ending October 4, 1869, gave rise to a remarkable freshet upon the south-western slope of the most southern of these pyramids. The mountain side seems to have been covered by spruces growing above loose blocks carpeted abundantly with moss, very much as is common all over the White Hills wherever the climate permits temperate vegetation to flourish. No valley furrowed the slope; and it seems difficult to understand why the waters should have accumulated so enormously at this point, and nowhere else in the neighborhood, if we may judge by the effect produced, especially since the bare mountain side exposed at this time has rendered the area conspicuous as a landmark fifty miles away. It were easy to imagine that some atmospheric disturbances had collected the waters naturally dispersed in an area having the diameter of a mile, and discharged them in a narrow stream upon the forest beneath. Clouds are sometimes said to "burst," when their contents are poured very quickly into some limited area, most usually when a tornado or rapidly-formed nimbus flits by; and something of that nature, though not approved by the best meteorologists, will best explain the phenomena displayed in Waterville during this never-to-be-forgotten storm.

Almost immediately after the storm this locality was visited by a party consisting of Prof. G. H. Perkins, PH. D., of the University of Vermont, Rev. M. T. Runnells, of Sanbornton, and Charles Cutter, of Campton. Prof. Perkins wrote a description of the changes wrought in the country, and published it in the *American Journal of Science* (ii, vol. xlix, p. 158). As he made careful estimates of distances in the upper part of the mountain, I will use his figures in the paragraph which follows.

The sliding commenced about forty rods from the summit, a little one side of the highest point. The beginning of the bare earth is only a rod in width. The breadth increases gradually for fifty or sixty rods. For the following seventy rods down hill it widens rapidly, attaining at one hundred and thirty rods distance a width of twenty-five or thirty rods. Thirty-six rods lower, the breadth is seventeen rods. The course is nearly straight to this point,—one hundred and sixty rods,—where it begins to curve towards the north-west instead of continuing south-westerly, and eighty rods below is what Prof. Perkins regarded as a termination of the slide. The waters excavated a gorge through the boulder-clay or hardpan of the country, after passing the Elbow, often twenty-five feet deep, the material being almost as firm as solid rock. The whole course thus far mentioned is two hundred and forty-six rods, of a general fusiform outline, with the lower end curved to one side. The inclination of the *débris* is often as much as forty-five degrees, perhaps higher for a dozen yards, and generally somewhat less. The underlying ledges appear in two or three places, but do not exhibit any marks or scratches made by the sliding mass.

The curve at the bottom of the hill is nearly a right angle, and was determined by the configuration of the land, for, directly in the way of the slip, there is a low ridge covered by the universal forest. Were the phenomenon a true slide, the materials would have been arrested by this obstacle. But no more earth lies before this obstruction than along any part of the two or three miles distance of the steepest descent below. The forest must therefore have been torn up by a prodigious freshet,—trees, earth, and rock-fragments mingling with the water, as if all a liquid mass, winding through the curved valley of a stream, and excavating a deeper channel below the turn in its direction. In a clearing of fifty acres at the base of the mountain, called "Beckytown," great piles of rubbish, rocks, and trees accumulated, while only earth was transported further.

For nearly two miles below the Elbow mentioned above, the current descended rapidly, occasionally depositing gravel in protected nooks, which, with their sloping surfaces, may be called terraces. Quite high up is an interesting excavation in the form of a notch, where one side is long, sloping gradually, and the other steep and short. Half-way down the stream,—which may appropriately be termed Norway brook, on account of the name "Norian," at one time applied by us to the formations traversed by it,—the water falls precipitately over a ledge of the dark labradorite rock. Elsewhere the valley is like that of any mountain torrent.

This locality is easily accessible. During the summer a stage runs from Plymouth to Greeley's hotel in Waterville, a distance of twenty miles. From Greeley's the first of the labradorite ledges is less than two miles, over a well-defined foot-path, which passes near a picturesque cataract. Mr. Greeley can direct visitors to these rocks.

In following Mad river up from Greeley's saw-mill, no ledges appear for a great distance. In the neighborhood of "Swaseytown," a small clearing near the mouth of Norway brook, there are abundant outcrops of porphyritic gneiss. The stream has cut down several feet into the ledge, and there is something of a fall here. Dykes of trap traverse the gneiss. The dip is south-westerly. Passing up the stream, in the neighborhood of a mile, we are brought to "Beckytown," the base of the slide, where the great piles of rubbish first become conspicuous in making the ascent. A few rods above is an exposure of the same rocks with those seen at the falls, dipping 80° S. 10° W. The strata are indicated by folia of mica and a little of a dark hypersthenic mineral, often forming nodules. There are jointed planes, also, with a dip westerly of 25°. The feldspar is nodular, the crystals not being so perfect as is common in this formation, or as may be seen upon Cascade brook to the south (p. 103). Between Norway and Cascade brooks there seems to be an anticlinal axis in the porphyritic gneiss. At first I was satisfied that this rock was gneiss, but did not recognize its true place with the porphyritic group. Subsequently I referred it to the "trachytic" or Albany granite, but a reëxamination in 1875 shows that it belongs to the oldest of our formations, and is distinctly stratified, traversed by trap dykes and narrow banded veins of quartz. These exposures do not occupy more than two hundred feet of distance.

A few rods up Norway brook appears the first ledge of the ossipyte. Its junction with the gneiss is concealed by drift. For about a mile similar ledges occur, some exposures being sixty or seventy feet long. Considered as an isolated case, it is difficult to determine the planes of stratification, since two prominent sets of jointed planes exist, either of which might be taken for strata. One set dip about 20° northerly, and are the most numerous. The other dip about 75° westerly. More definitely, the following are the supposed strata dips seen in ascending: about 20° to N. 26° W., N. 86° W., N. 34° E., and N. 46° W. The joints have these strikes, N. 22° W., N., and S. Analyses of both the labradorite and chrysolite, which form the constituents of the ossipyte, have been given in Volume I, pages 37–40, by Hunt and Dana. It appears that small portions of magnetite and biotite are also present in the rock.

Sienite of Tripyramid.

The ossipyte is abruptly succeeded by the gray rock called sienitic, being sometimes labradorite, with hornblende and some mica, then orthoclase, labradorite, and mica, with scarcely any hornblende. The line of junction is irregular, averaging the course N. 10° E., being sometimes N. 78° W., while the dip of the plane of separation is about 85° westerly. Some of this feldspathic rock has been injected into irregular cavities of the ossipyte. The irregularities of these veins are shown in Fig. 18. The length of the vein there represented is thirty feet, the greatest width being four feet. The general impression is, that the sienite was an eruptive rock, cutting nearly vertically across the ossipyte.

Perhaps an eighth of a mile above this junction the interesting assemblage of coarse crystals of whitish labradorite, hornblende, titanic iron, mica, and epidote (see analysis, p. 40, vol. i) occurs at the Notch. These ledges disintegrate very rapidly. Large nodules of the sienitic rock less liable to decomposition are scattered through the mass; and there are geodic cavities containing orthoclase, albite, quartz, and rarely stilbite. The Notch is produced by the erosion of a ferruginous band, resembling a stratum, and dipping both E. 25° S. and E. 25° N. Above the Notch, as far as the Elbow, there is a recurrence of the finer-grained sienite, containing geodes and feldspathic veins. At the Elbow there is a somewhat different mineral combination, extending to the top of the pyramid. Quartz is rare; but there are two kinds of feldspar. Mica is abundant, and some specimens show hornblende. The same minerals occur in the geodic masses as below, also, actinolite, amethyst, and others yet undetermined.

A light-colored feldspar, from a reddish-tinted variety of the "sienite," gave to Prof. C. A. Seely, silica, 59.2; alumina, 28.8; iron oxyd, trace; lime, 7.40; soda, 8.54; potash, 0.6. In this case the silica, alumina with iron oxyd, and lime were determined first. Afterwards, the alkalies were determined separately from a different sample of rock. Judging from these results, the feldspar corresponds very well in composition with andesite. The type-mineral of this species is said, in *Dana's Mineralogy*, to come from a "sienite-like rock" in the Andes. Some analyses of andesites from Chateau Richer in Canada, by Dr. Hunt, agree well with this. The red feldspar associated with the andesite in this rock gave to Prof. Seely, silica, 57.6; alumina and iron oxyd, 24.6; lime, 3.2. It seems, therefore, to be related to the same species rather than to orthoclase, but it is not well defined.

Towards the top of the slide and the mountain there is considerable hornblende, with less mica, and the rock is of a reddish cast. Specimens precisely like these came from the north peak of Tripyramid. On the north slope of this peak there is a recurrence of the more grayish variety found between the Notch and the Elbow. In this a black mica excludes most of the hornblende. Near the head of Sabba Day brook the coarser white aggregate containing epidote, etc., is found again, though our specimens do not indicate the presence of that particular mineral. On the ridge north of the north pyramid are gray sienites with labradorite, resembling those immediately adjacent to the ossipyte on Norway brook. The rocks from the west side of the ridge east of Tripyramid correspond better with the coarser white rock of the Notch. From this inspection of specimens, taken from almost a section line up Norway brook to North Tripyramid, and thence to the labradorites on Sabba Day brook, it appears that the different varieties of this sienitic rock correspond well with each other, very much as if the mountain were a synclinal axis, consisting of four leading varieties of strata, with only slight inclinations. The contact of the ossipyte with the sienite seems to show clearly the cutting of the former by the latter, while this stratiform arrangement of the different varieties of sienite is analogous to the mutual relations of the Conway, Albany, and Chocorua granites. Until further advices, this sienite must therefore be regarded as an eruptive rock.

There is but one other New Hampshire locality known where a similar rock appears. That is in the adit of the Jackson tin mine. I am not sure that the ledge crops out at the surface; but the fragments brought out by excavation reveal an abundance of sienite, which cuts the schists, in company with the Albany granite. The principal part of the rock is a coarsely crystalline labradorite, with considerable hornblende and orthoclase crystals in small amount. Quartz is scarce, as at Tripyramid. Mr. Huntington states that Mt. Pleasant, in Maine, one of the outlying peaks of the White Mountains, carries the same rocks as Tripyramid. The area of Pleasant is about the same with that of Tripyramid, and it is given on our general geological map.

While the sienite is of later age than the Labrador formation, we cannot yet ally it with the sienites of Gunstock and Exeter. Its nearest analogue is the sienite of Frankenstein cliff and Mt. Whiteface, which are for the present placed with the Chocorua granite.

Labradorite Area north of Tripyramid.

Mr. Huntington discovered fine exposures of labradorite and the related formations in ascending that tributary of Swift river called Sabba Day brook. Near the mouth of the stream there is a cataract falling over Conway granite, which is the common rock of the country. The same appears a mile higher up. It also occurs on Downs's brook, another tributary of Swift river, running very nearly along the line between Waterville and Albany. The Albany granite was not observed here, possibly because we had not learned the importance of distinguishing it at the time of the visit. But higher up Sabba Day brook Mr. Huntington found compact labradorite in place, apparently devoid of chrysolite, and fragments whose cleavable crystals displayed the play of colors usually seen in this species. Higher up the mountain (the north Tripyramid) the sienitic rocks of the slide reappear in the same order as in the ascent of Norway brook, apparently cutting the labradorites. Farther south the labradorite passes into a breccia apparently overlying gneiss. It is probable that the Albany granite joins the labradorite on the north, since specimens apparently referable to it came from the Flume brook, about two miles to the north of Tripyramid. The small area of gneiss south-east has been mentioned upon pages 131 and 133. Otherwise, most of the rocks on the east belong to the Conway granite series. On the south and south-west this Labrador area is flanked by porphyritic gneiss. Fig. 19 will show the position of the ossipytes, compact lime-felsites, and the sienites between Beckytown and Swift river, passing over Tripyramid, and their supposed relations to the adjacent porphyritic gneiss and Pemigewasset granites.

Labrador Area upon Mt. Washington River.

Upon pages 125–127 the Montalban rocks upon the Mt. Washington river are spoken of in connection with labradorite. This is an important locality, as it shows the relations between the Montalban and Labrador systems. The details of the former series have been already given, with as much precision as possible. The latter area extends only about a mile along the river. Its width is not ascertained; but G. N. Merrill, of Jackson, assures me he has seen this rock on a tributary stream midway between Giant's Stairs and the Mt. Washington river, thus giving it an extension of over three miles in a south-easterly direction. At the north end there is an excellent exposure of the contact between the two formations. It is upon the west bank of the river, two or three hundred feet away from the water, and fifty or sixty feet high. The gneiss is the slightly porphyritic variety of the Montalban schists, dipping 80° N. 80° W., or towards Mt. Clinton, and much disturbed by trap dykes. This position is rendered plain by the stripping of the hillside for more than a hundred feet by a brook. The line of the brook is about twenty-five feet distant from the labradorite rock, with the dip of about twelve degrees south-westerly. The actual junction is covered by earth of little thickness. Were one not satisfied with the way in which the formations unite, it would be very easy to observe the actual contact after a little labor expended upon digging. On descending to the river, and over its whole course, the dip of the labradorite is not far removed from horizontal. Next the schists, at the lower end, the masses lie horizontally; then, a few rods above, there is a short synclinal, with the dip of 30°, and after that a nearly horizontal disposition to the northern extremity, where the dip is south-westerly. Fig. 20 shows the junction of the two rocks at the upper end. Perhaps an eighth of a mile above the lower extremity of the formation, there is a seam somewhat resembling a stratum, with a north-west strike, and standing vertically. The rock adjacent on the south is a flinty gneiss, dipping 60° N. 40° W.

A reëxamination of the lower portion of this outlier in 1875 revealed nothing new of any importance. All the ledges are much jointed, and there is a strong contrast between the massive blocks of labradorite and ossipyte and the gneissic rocks adjacent.

The stratigraphical relations of the two formations seem very simple. The labrador rocks lie unconformably upon the upturned edges of the Montalban gneisses. The discordance varies from forty-five to seventy degrees. In going up the stream, it is easy to see that the labradorite rocks rest upon the gneisses, as both dip in the same direction; and when the upper limit is reached, the dissimilarity between the two is marked fully as strongly as is indicated in the figure. It may be thought, because the labradorite lies in a deep valley, with mountains of gneiss upon both sides, that it must perforce possess an anticlinal structure, and underlie the latter. In many regions the valleys are of anticlinal origin, and, if these rocks occurred in such a district, the view might be tenable. It does not seem to us,—for reasons to be stated elsewhere,—that such a law of connection between stratigraphy and topography is of universal application, and, furthermore, the observations of the actual dips in the neighborhood are against that view. In coming up the river from the Saco valley, after leaving the granite, the first dips are south-easterly. Not very much is seen of this dip, since the strata possessing it are covered by granite, but enough appears to make its occurrence certain. But the north-westerly dip is common beyond, so that an anticlinal axis certainly occupies the valley below the labradorite, in agreement with what is often the case in valleys elsewhere. Our studies lead us to believe, also, that the range to the north-west, embracing the Webster-Washington range, possesses an anticlinal structure. The details mentioned previously concerning the strata up the streams to Mts. Clinton and Pleasant show a prevailing north-westerly dip, with local variations. Thus, as advised at present, the outlier of labradorite seems to occupy the country between two anticlinal axes, not necessarily the middle or synclinal line, but the upturned edges. In either case there would be a great want of conformity between the two groups, the uppermost, or the Labrador system, being the younger formation.

The prevailing variety of rock in this basin is ossipyte. Prof. B. T. Blanpied found the labradorite, when carefully separated from the chrysolite, to contain silica, 51.50; alumina, 25.90; peroxide of iron, 5.00; lime, 14.29; soda, 2.95; potash, .50—total, 100.14. These results correspond essentially with the analyses of the same mineral from Waterville (Vol. I, pp. 37 and 39). The grains of magnetic iron were also observed. In lithological appearance there is little difference between the localities, save that the labradorite crystals from Mt. Washington river are better characterized than those from Waterville.

Many of the layers contain an abundance of hornblende, much more so than at either of the Waterville areas. Large boulders of chrysolitic sienite are common in the river, but their source has not been ascertained.

The locality may be reached easily, though it is desirable that those who visit it be prepared to spend a night in camp. I have reached it by the way of the tributary stream flowing down between Mts. Franklin and Pleasant, between Mts. Clinton and Jackson, and also by ascending from the Saco. No path has yet been marked out for horses, but the road is easy to find, by simply following a watercourse. It is about six miles from the Saco, six from Mt. Washington summit, three from Mt. Pleasant, and four from the Crawford house, following up the bridle-path to Mt. Clinton, and thence passing down the stream to Mt. Washington river. When the latter route is taken, the explorer must remember to walk up stream as soon as he has reached the Mt. Washington river.

Other Labrador Areas.

The remaining localities of labradorite have not been much explored, and are quite limited in extent. In passing from the south end of the Lafayette range in Lincoln to the road near Walker's falls, I found an exposure of this rock, which gave, when examined, results almost identical with the analysis of the labradorite from Mt. Washington river. Prof. Blanpied found in it, silica, 52.01.; alumina, 26.60; iron oxyd, 4.20; lime, 13.30; soda, 3.50; potash, .65=100.26. The rock is a dark, compact mass, not composed of different minerals, as at the other localities, but has crystals of labradorite scattered through a dark paste of the same material, with an occasional bit of quartz. As far as from the spur at the north base of Mt. Lafayette, to where the range first falls off rapidly towards Mt. Liberty, a distance of five miles, there is a narrow range of dark, compact felsite, apparently resting almost horizontally upon the Albany granite, never more than two or three hundred feet wide; and, as the specimen analyzed did not differ greatly in appearance from the great mass of the rock, I had supposed the whole mass consisted of labradorite, in the report for 1871, page 17. Specimens from the summit of Lafayette, obtained in 1875, are evidently not labradorite; but the relations of the rock, at the south end of the range, to the rest have not been reëxamined. Boulders of labradorite occur at one or two places on the west flank of the Lafayette range, so that it is likely there will be found, upon further examination, a considerable exposure of the Labrador system. Still, it is an open question whether the dark, compact labradorite felsite may not be igneous in origin, and be connected closely with the orthoclase felsites, of which the greater part of the range consists.

At Loon Pond. A similar rock crops out a little east of Loon pond, seven miles distant. The area is probably a quarter of a mile in length. The specimen brought from there agrees closely with that just described from the south end of the Lafayette range. Between Loon pond and the most southern end of the orthoclase felsite on Mt. Flume, the distance is four and a half miles, so that the last named area is entirely isolated from all related rocks. The mountain east of the pond is composed of Albany granite.

In the report for 1871 the orthoclase and labradorite felsites were regarded as intimately associated together, and forming parts of one system. As some doubts have been expressed by geologists upon this point, I will now describe them separately, and represent them as distinct from each other upon the map. The latter will be spoken of under the head of Porphyry. A few of the small areas, formerly thought to be labradorite, prove now to be orthoclase. Such are the rocks on the west side of Mt. Tom, and the first peak north of Mt. Andalusite near the Crawford house, Rocky Branch in Bartlett, and the west side of Sable mountain in Jackson. There is labradorite in a breccia from the last named locality, and also from the head of Sabba Day brook in Waterville, and upon Little Deer brook in Albany. It was thought at one time, also, that certain portions of the Chocorua granites contained lime-feldspar. All these specimens will be studied more carefully hereafter; and, in the part of the report devoted to mineralogy and lithology, the reader will find their characters stated with much precision. The necessity of devoting our whole time to the general description of the formations has prevented us from giving the proper amount of attention to lithology, that is really demanded as preliminary to stratigraphy. There can be no mistake as to the localities, since the catalogue and map, at the close of this chapter, will make all the positions plain.

Labradorite in Bean's Purchase. Mr. G. N. Merrill, of Jackson, informs me that he has seen labradorite in rock masses upon Thompson's brook, on the east side of Ellis river, in Bean's Purchase. I understand it is situated on the west slope of Wildcat mountain, some three or four miles back from the Ellis river. It is in the midst of the Montalban series, like that on Mt. Washington river; but we have no facts in respect to the position of either the labradorite or gneissic strata.

PORPHYRY.

The term porphyry has long been used to denominate rocks with a homogeneous, compact, or earthy base, through which are disseminated crystalline masses of the same character with the matrix, and formed at the same time with it. The porphyry of the White Mountains seems to be allied to a common orthoclase feldspar porphyry, orthophyre, or petro-silex. In the annual reports it has been termed felsite, and grouped with the Labrador system. The localities of this rock are mostly far away from settlements, so that it has not been easy to examine its relations to other formations. The rock has a tendency to weather into pinnacles or sharp ridges like the Twins, Mts. Liberty, Flume, the Lafayette range, Starr King, etc.; and the decomposition extends so deeply into the ledges, that one may obtain from a hasty visit to a mountain a very inadequate idea of its composition. Reserving all special details of nomenclature and composition to the chapter on lithology, we will now be content to describe briefly the areas where it occurs.

As porphyry occurs both as an igneous and a stratified rock, it is difficult to know to which class to refer this member. Our first impression suggested the idea of stratification, based upon the horizontal arrangement of the masses. Of late some facts have been brought to our notice, seeming to imply protrusion through strata, and lateral expansion by an overflow. This theory would explain the horizontal situation of so much of the rock, while it is a fact that no other kind of igneous rock has been found to assume the position of an overflow in New Hampshire.

It may be that the porphyry mountains of New Hampshire should have been mentioned in the chapter on Scenographical Geology, as constituting a distinct type of rock sculpture. The peaks are somewhat like the isolated granitic summits, yet a practised eye would never confound the two together. The latter are usually more rounded: the former might easily constitute a pinnacle. The porphyry summits remind one of a triangle, with one slope much steeper than the other. Sometimes two summits are connected together by a surface line, like a catenary curve, as seen from a distance. Other areas, like the Twin mountains and Lafayette are disposed in the form of long, narrow ridges. Mt. Carrigain might easily be confounded with a granitic cone, at a distance, but not so the sharp peak to the north of it before reaching the "Notch," or Mt. Lowell. All these mountains are full of precipices, often inaccessible. In the Pilot range so much *débris* has accumulated about the porphyry peaks, that the ledges cannot be seen except very near their summits; and it is for this reason that it has been so difficult to learn the relations existing between this and the adjacent Huronian.

There are a dozen different areas of rock in the White Mountain district referable to this division, which I will describe under the following names: 1. Lafayette range. 2. Twin Mountain area. 3. Mt. Carrigain. 4. In Waterville and Albany. 5. Mt. Tom area. 6. In Bartlett, Jackson, and Chatham. 7. Pilot Mountain range.

The Lafayette Range.

There is little to be added to the general statement, on page 220, respecting the shape of this area. It is a narrow strip, about six miles long, sometimes half a mile wide, from the north slope of Mt. Lafayette, through Mt. Lincoln, the south peak, and Mt. Liberty to Mt. Flume. Between the last two there is a marked curve to the east. The south end of Mt. Flume is precipitous for several hundred feet.

The saddle between Lafayette and Lincoln has been cut down to the Albany granite, leaving upon the former mountain a porphyritic cap about one hundred and fifty feet thick; and a small hummock in the depression has only fifteen feet of porphyry upon it. Beyond it to the south is a dyke-like felsite mass, thirty feet wide. On Mt. Lincoln the porphyry seems to slope south-easterly about ten degrees. From this peak to the south end of the ridge, the summit is entirely composed of a dark-colored porphyry. At the south end the divisional planes slope as before; and, about three hundred feet down, on the south-west side, we found exposures of compact labradorite. These figures may express the thickness of the dark porphyritic cap.

Direct observations between the south end of the Lafayette mountains and Mt. Liberty are wanting. Liberty is capped by Albany granite; but we suppose its eastern slope is porphyry, which extends from the peak south of Lincoln across to the pinnacle of Mt. Flume. It is at least six hundred feet thick at the last named summit. (See vol. i, p. 42.) It is a fact to be remembered, that where the uppermost part of the Albany granite comes in contact with the porphyry, it is full of distinct crystals of orthoclase and quartz, just like the rock on Mt. Willard next the slate breccia. The porphyry upon the top of Mt. Flume seems to slope northerly.

Between this ridge and the Franconia branch there is an area of twenty or more square miles,—concerning which we have no information,—supposed to be occupied mainly by the Albany granite.

Twin Mountain Area.

This comprises, first, the broad, elevated range between the most northern of the Twin mountains, and well on to the south end of the higher part of the mountain mass, about three miles in length; second, a long ridge on the west, between the Franconia and Redrock brooks; third, a north-easterly extension into Little River mountain (or perhaps the latter may be isolated); and, lastly, a development on the east to include the divide between Little river and New Zealand pond.

From the side of the long, elliptic-shaped ridge on the west towards Franconia Branch, we have specimens of Albany granite, but finer-grained porphyritic varieties near the summit and the east side. The stream on the east side, in descending from the west slope of South Twin, falls over abundant ledges of red compact feldspar. Boulders from this locality are strewn from here to Mr. Pollard's house in Lincoln, especially between the mouths of the Franconia and Hancock branches. Their prominence has suggested for this stream the name of Redrock brook.

There are several varieties of the porphyry on the summit of the South Twin. The most common is fine grained, drab-colored, with reddish crystalline spots, all of it probably orthoclase, though at first sight suggestive of labradorite. Our best specimen from this locality shows a few crystalline grains of clear quartz in the drab portion; and there are bunches of reddish-gray porphyry intermixed, holding the same red orthoclase bits with the darker portions. In the descent towards Little river, on the way to New Zealand pond, the rocks are varied with a sprinkling of something like Chocorua granite. The felsite contains much quartz, and a few small masses of a decomposing, dark greenish mineral. Somewhat lower down Little river than its crossing, on the line of description, there is a reddish granite. On climbing the ridge east of the stream, the slope is found to be quite precipitous, allowing only a scrubby growth of trees. From one fourth of a mile west of Little river to the slope towards New Zealand pond, including the precipice and the divide, the rock is a fine-grained porphyry carrying numerous distinct grains and crystals of quartz, weathering whitish. On the east it is supposed to join the finer-grained variety of Conway granite.

In ascending the most northern Little River mountain from the north, after leaving gneiss, I found what is termed in my note-book a feldspathic sandstone, much like the rock of Mt. Carrigain. At the very base of the mountain a compact, dun-colored porphyry is present. The west side of the mountain is like the ridge farther south, made of porphyry, with numerous crystalline grains of quartz. It also has black patches of dark porphyry in it. Our specimens from these more northern localities have been unfortunately lost, through malevolence,—the only ones collected by us from the whole mountain region not at present safely in the museum. It is likely that the porphyry is continuous from South Twin to the northern Little River mountain.

There is also a small porphyritic area on the northern slope of the water-shed between Little and Ammonoosuc rivers, about a mile south of Twin Mountain station. Its place and dip of 65° S. 25° E. are indicated upon Fig. 11.

3. Mt. Carrigain Area.

The principal portions of Mts. Carrigain and Lowell are known to be composed of dark-colored porphyries, with disseminated small crystalline bunches of orthoclase, the general character corresponding with the rock upon South Twin. It is likely that the rock of Mt. Anderson is the same. Mt. Lowell is known in the older writings upon the White Mountains as "Brick-house mountain," so called from the unusual abundance in it of the red orthoclase crystals. It seems to stand east of the straight line from Carrigain to Anderson, though not so represented upon any map made before ours in the atlas. There is a slight resemblance between the stratigraphical position of this porphyry and the slate on Mt. Willey. Both rest upon the Conway granite, and they dip in opposite directions, while between them is a much lower territory composed of the supposed older rock. A believer in metamorphism might find resemblances between the porphyry and slate sufficient to authorize the investigation of the question of their identity. As one stands upon Mt. Willey, at the upturned end of the slates (see p. 176), and looks southerly for its continuation, he would naturally fix upon Mt. Nancy as the place for it to appear. Observation proves Mt. Nancy to be composed of the Conway granite (p. 183), but the porphyry covers it to the south, with a slope towards Carrigain; and this might possibly represent the slate in an altered condition. The statement made recently respecting the nearness of the porphyry on Mt. Flume to the crystalline Albany granite, as compared with Mt. Willard, is worthy of remembrance in this connection.

The essential part of our information concerning the Carrigain area of porphyry is given in the description of Fig. 15, a section from Tin to Hancock mountain (p. 147). The view of the Notch (vol. i, p. 596) exhibits finely the south side of Mt. Lowell, with the precipice along the middle, and three small slides. Mts. Anderson and Nancy appear immediately behind. Between Carrigain notch and Carrigain is a conical peak about six hundred feet below the former, and nearly of the same height with Mt. Lowell. It is one of the porphyritic mountains, and is well shown in the panoramic view from Mt. Tremont in the atlas. No. 58 of Section VIII is a grayish porphyry, from an interesting dyke six feet wide cutting porphyritic gneiss, at the mouth of Carrigain brook. (See p. 103.)

4. Porphyry in Albany and Waterville.

The first and most important of these areas has been described upon pages 148–150, in connection with a breccia of possible later origin. Upon Little Deer brook there are outcrops of the red compact feldspar, and a breccia chiefly composed of divers-colored porphyries, including labradorite, quartz, and gneiss. This may possibly be the same with the Mt. Mote and Mt. Pequawket breccias, which are largely composed of andalusite slate, though with a feldspathic paste.

In Waterville there is a breccia of limited extent, adjacent to labradorite rock upon the head waters of Sabba Day brook. And along Mad river, in the vicinity of Greeley's hotel, and for two or three miles above, there are numerous large boulders of red and purple compact and brecciated feldspars, which I have thought may have been derived either from the east spur of Mt. Osceola, or some of the mountains not far behind it in Elkins's Grant. The locality on Redrock brook seems too remote for their source. Many of these boulders have been collected by Mr. Connable, who has spent eighteen summers at his cottage near Greeley's, and they are tastefully arranged about his grounds in rustic seats, and disposed in piles so as to intensify the colors by the water falling from an artificial fountain.

5. Mt. Tom Area.

Not far from New Zealand river there are ledges of a feldspathic rock, consisting of orthoclase and quartz with a fine-grained base, weathering nearly white. Several shades of this rock occur all the way from the western base to near the summit of Mt. Tom,—some of it resembling sandstone,—having a northerly dip. There is more of it on the east side, about as far down as Mt. Andalusite. It joins the andalusite and similar slates upon the east, that which is nearest the supposed porphyry being indurated. Scarcely any observations of the dips have been preserved; but the general impression is, that the feldspathic rocks overlie the slates. In passing north-easterly from Mt. Tom the slates are succeeded directly by the Albany granite, without the intervention of the porphyries.

I have found other ledges related to that on the west side, in ascending Mt. Field from the saddle between that and its eastern spur, and upon the north shoulder of Mt. Field (p. 178). The Mt. Tom area is quite limited in its extent, and may be almost incorporated with the andalusite slate group.

6. Bartlett, Jackson, and Chatham.

These are inconsiderable. The first is a small series of outcrops in the valley of Rocky Branch, two miles above its mouth. It is grayish, and was at first thought to be labradorite. The second is noticed upon page 128, an area of two miles' extent upon the south-west side of Sable mountain. If it occupies the limits suggested, as far south as Mountain pond, the area would be four miles in diameter. Part of this rock is brecciated, belonging to the later group. The porphyry in Chatham lies upon a two-thousand feet mountain in the west part of the town, more than a mile from the Jackson line. No facts have been preserved in regard to the extent of this area, but it must be small.

7. The Pilot Range.

This has been spoken of heretofore (p. 70, *et seq.).* The principal area occupies parts of Northumberland, Stark, Kilkenny, and Jefferson, twelve miles in length, and is coterminous with remote mountains rarely visited, save Mt. Starr King, near the Waumbek house in Jefferson. There are two smaller areas, scarcely disconnected from the main mass, in Northumberland. On the south side of Mill mountain, in Stark, vertical strata of arenaceous schist abut against the porphyry, with a strike nearly at right angles to the course of the former. At first, I supposed this indicated an elevation of the schists by the side of an older, harder mass. A recent visit to outcrops east of A. Sawyer's in Northumberland would seem to indicate the protrusion of the porphyry through fissures in the schists, and hence the later origin of the former. If this be the correct view, it follows that the whole Pilot Mountain area is an overflow of igneous rock, resting upon the upturned edges of Huronian schists and Atlantic gneisses. That is the view presented in the fuller account of this region, already referred to.

SIENITE.

The principal sienitic area in the White Mountains has been spoken of in connection with the labradorite rocks of Waterville (Fig. 19). It was described in connection with those rocks for the sake of sketching its relations to them. Moreover, the composition of that mineral aggregate is peculiar, containing triclinic feldspars. The specimens from other localities differ in that respect, no feldspars having yet been detected in them, except orthoclase. None of them,—neither that with the triclinic feldspars nor the Chocorua varieties,—seem to agree exactly with those in the other districts of the strata, unless it be a few about Lake Umbagog and Island Pond, Vt., in the Coös and Essex region.

We have noticed sienite at Jackson, Frankenstein cliff, Mt. Whiteface, Mt. Passaconnaway, several places in Albany, and boulders, from some unknown locality, near the Crawford house and Mt. Washington river, besides that of Mt. Tripyramid and the Jackson tin mine.

In climbing Mt. Whiteface, the lower portion, so far as known, consists of porphyritic gneiss, and the balance, perhaps a thousand feet, is made up of sienite. The hornblende is in small crystals, disseminated sparsely through crystalline orthoclase. It weathers readily, showing the coloration of peroxyd of iron, and rarely manganese. A specimen from the top of Mt. Passaconnaway proves to be of the same character, and one from the northern ridge contains the mineral in profusion. These summits are three and a half miles apart. No one has gone from one to the other, so that it is only by conjecture that we place the intermediate space in the same group. As this variety seems to be intimately connected with the Chocorua granite, it is likely that the region east of Mt. Whiteface will be found partially composed of sienite, as appears upon many of our specimens. Those which show hornblende came from the summit of Chocorua, the ravine east of the main peak, and the end of the south-east spur. The colored heliotype of Mt. Chocorua, described upon page 232, will show the location of these parts of the mountain. Other Albany localities are at Ellen's, Champney's, and Swift River falls. Similar specimens came from Camel's Hump, south of Sawyer's river, and from Silver Spring mountain. It is probable that hornblende will be found occasionally disseminated through any mountain mass of the Chocorua granite.

This is notably true of the ledge called Frankenstein cliff, through which the railroad has cut. There seems to be a mass of this rock slightly inclined north-easterly, starting from some unknown point on the north flank of Mt. Nancy, and extending a little beyond the railroad. Nothing needs to be added to the notice of it upon page 181.

Sable mountain in Jackson is composed of a sienite abounding in hornblende, much like that on the north side of Passaconnaway, and is connected with porphyry and breccia. Three other localities are Chocorua pond, a mile from Berry's saw-mill, and at Great Hill pond, all in Tamworth. Near the Crawford house a single large boulder of sienite, very like that from the Chocorua group, has been found, in which Prof. Dana discovered chrysolite. Its source is unknown. It is probable that the same mineral will be found in some one or all of the localities that have been mentioned, as the specimens from all of them are very much alike. We searched the Frankenstein cut carefully for chrysolite, but found none. Boulders of sienite containing chrysolite occur, also, upon Mt. Washington river.

Chocorua Group.

The study of the sienites and other rocks from Albany shows that our Chocorua group may be divided lithologically into three parts:—First, the crystalline aggregation of coarse orthoclase crystals, both alone and mixed with quartz, containing, also, mica in a few localities, so as to be properly a granite. The feldspar is often greenish in color, and was known by us, when exploring, as the "green granite," such as occurs about a mile above the mouth of Hancock Branch (No. $\frac{8}{80}$). The second variety is a fine-grained, grayish-green, compact potash-feldspar. This is common about Mt. Chocorua, particularly in the ravine on the east side of the pinnacle. This variety merges into a porphyry, and both of them pass into the Albany granite, such as constitutes Sawyer's Rock. None of the kinds mentioned is so easily confounded with labradorite as this. The third division is the sienite, whose particular distribution has just been described. Whether these three kinds really belong to different eruptive periods, or should be properly grouped as one, is a question for the future never suggested before this moment of writing. No attempt will be made to distinguish them upon the map.

Chocorua group in Vermont. Upon page 529, Volume I, it is stated that there is a small area of Chocorua granite at Cuttingsville, upon the Rutland & Burlington Railroad. The second and third of the above named varieties are present there. Although the mineral is not labradorite, as there stated, the argument for the age of the Green Mountain rocks is valid, since there is a close agreement between the two granites and their associations. In the briefest terms possible, the argument may be stated thus: Along the axis of the Green Mountains there occurs a large overflow of granite, apparently identical with the Chocorua granite of the White Mountains. In a limited region igneous rocks, having the same mineral composition, must have been ejected from one vast caldron of melted material, or at least at the same epoch. Therefore the granites of Cuttingsville are of the same age with those of Mt. Chocorua. Furthermore, the Chocorua rocks cut formations of Eozoic age;—therefore the strata disturbed by the Cuttingsville outburst are of Eozoic date, or older—they cannot be newer. And, as the rocks about Cuttingsville belong to the Green Mountain gneiss, that whole system must be as old

PLATE XI.

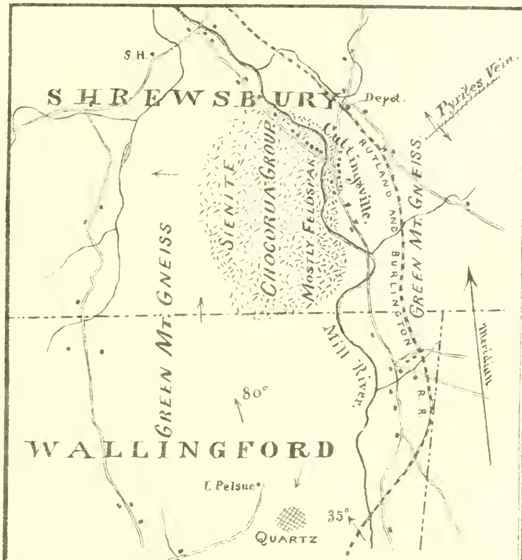

Fig. 21. Rocks about Cuttingsville, Vermont.

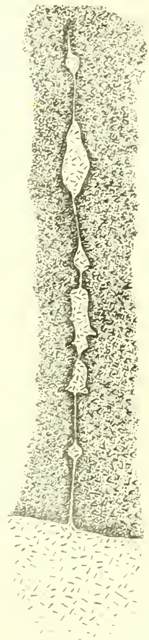

Fig. 18. Vein of Sienite in Labradorite, Tripyramid Mt.
Length, 33 feet.

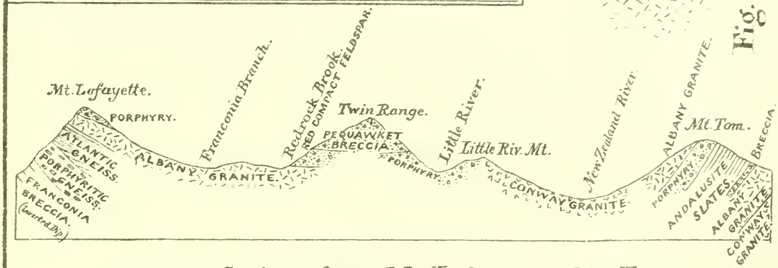

Fig. 25. Section from Mt. Lafayette to Mt. Tom.

SCALE OF FIGS 25 AND 26; — 2½ MS. TO AN INCH, HORIZONTALLY; 6000. FT., VERTICALLY.

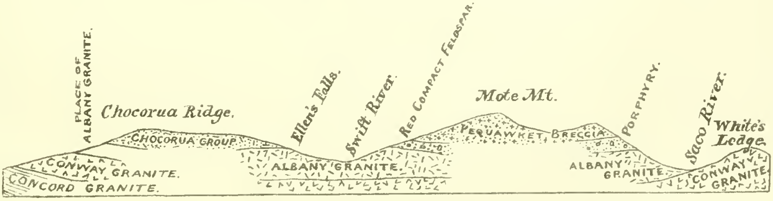

Fig. 26. Section from N.E. corner of Tamworth to White's Ledge.

as the Eozoic,—probably the same with the strata disturbed in the White Mountains,—or the Montalban group. Hence it is not proper to say that the Green Mountain rocks are of Silurian age, as is claimed by some authors.

I will add a few words descriptive of the Vermont locality, that those who are interested may examine the region for themselves. Fig. 21 exhibits the relations of the granite there to the surrounding groups, as portrayed upon a map of the Cuttingsville region, in the towns of Shrewsbury and Wallingford. The Chocorua area is oval in shape, and about a mile and a quarter long. Its western border is a rather coarse sienite. The eastern part is a somewhat fine-grained variety of feldspar, with a bare sprinkling of hornblende in it, but no quartz. The whole constitutes a large hill, with a higher mountain of gneiss to the south, in the edge of Wallingford. Mill river flows by the eastern base of the hill, parallel with the railroad. The dips of the gneiss, at a few points around Cuttingsville, are given. On the east is a vein of magnetic iron pyrites, which has been stripped for a quarter of a mile on the western slope of the hill back of the depot. Its course is N. 65° E., and it seems to constitute an anticlinal ridge. Limestone and hornblende schist accompany the ore, all of these bands pointing directly for the granite hill, which has interrupted their continuity. Where the railroad crosses Mill river, two miles south from Cuttingsville, the dip is 35° N. 80° W.; on passing up the hill west of this, hornblendic gneiss dips S. 5° W. Midway between the railroad and J. Pelsue's house, at the end of a road, there is a large exposure of the Potsdam quartzite, with some calcareous layers. North of Pelsue's the gneiss dips 80° N. 25° W., and resembles the Laurentian gneiss of Whitehall, N. Y. The highest and principal part of this hill is composed of similar material. The gneiss and hornblende adjacent to the gneiss dips northerly, and farther north it dips westerly, so that its strike is irregular in direction. The jointed planes of the sienite dip northerly. Some of these seams are lined with manganese peroxyd. The sienite hill may be three hundred and the other five hundred feet above the valley of Mill river.

We conclude, from these statements, that this felsite mass is truly eruptive; that it issued from a rent transverse to the course of the strata, but parallel with the main range of the Green Mountains. Its age must therefore be subsequent to that of the gneiss, and probably synchronous with the period of upheaval of the range. As before remarked, its mineral character suggests the Chocorua granite. No similar rock has yet been discovered from any part of this range. The rocks on the western slope are largely covered by drift, so that areas much larger than this near Cuttingsville might exist and not be known.

A heliotype of Mt. Chocorua, taken from the hill about a mile east of Tamworth Iron Works, has been colored to show the situation of the several rocks in the field of view. The details in regard to the rocks have been given upon pages 153 and 154. The pinnacle and south-east spur are composed of Chocorua granite; the eastern ridge, of Albany granite; the lower part of the right flank, of Conway granite. The foreground belongs to the Atlantic series of gneisses. Certain parts of the mountain area are left uncolored, as we have not the necessary data to represent them.

ANDALUSITE SLATES.

Clay slates, or argillo-mica schists carrying andalusite occasionally, and clayey sandstones constitute the bulk of this formation, attaining, perhaps, a thickness of 1200 feet, supposing the strata to be folded once. The two principal areas of these slates have been described upon pages 116 and 175, the first at its crossing by the Mt. Washington carriage-road, and the second under the name of the Mt. Willey range. The third area consists of two small patches on the north and south sides of Mt. Pequawket. It is probable that these three areas were once joined together, the first two effecting a junction near the third, the line of strike having a V shape. A glance at their present wide separation from each other, as portrayed upon the map, will illustrate powerfully the magnitude of the dislocations and extent of denudation to which the rocks of New Hampshire have been subjected.

The mineral character of the variety of this rock carrying andalusite is shown by the analysis of G. W. Hawes, herewith presented. Allusion has been made to it upon page 179.

NEW HAVEN, CONN., Aug. 24, 1875.

Prof. C. H. HITCHCOCK:

Dear Sir—Inclosed you will find the analysis of the slate, which you requested. Calculations from the analysis, confirmed by microscopic observations upon a thin section, show that the rock is composed of orthoclase feldspar, a foliated mineral resembling chloritoid, titanic iron, and a few flakes of mica. The titanic iron is disseminated all through the rock, in very minute particles, and the analysis shows that it constitutes four per cent. of the whole. The feldspar is very poorly crystallized; and the percentage of alkali shows that nearly half the rock is common feldspar. Deducting the titanic iron and orthoclase, we have a percentage which nearly represents the mineral chloritoid, and the variation from it is accounted for by the presence of the hydrated mica, which can easily be seen. The low percentage of silica accounts for the great difference from the granites on each side, which, Prof. Dana has told me, are so placed; and the analysis shows that this was a much more muddy layer, which did not possess the necessary ingredients to be changed into granite by metamorphic action.

Yours faithfully, GEORGE W. HAWES.

Analysis of the Andalusitic Slate, from the Portland & Ogdensburg Railroad bridge over Willey brook.

Silica,	46.01
Alumina,	30.56
Ferric oxyd,	1.44
Ferrous oxyd,	6.85
Manganous oxyd,	.10
Magnesia,	1.42
Potash,	6.66
Soda,	1.12
Titanic acid,	1.93
Water,	4.13
	100.22

There are rocks on the east slope of Mt. Madison containing immense staurolites (described on page 114), which may possibly be the northward continuation of those occurring along the Mt. Washington carriage-road, amply illustrated upon Plate VII and page 116. There are also the Pine Hill rocks (p. 113), which are suggestive of the slate series. On the south it crops out between the Pinkham notch and Crystal falls. To the south in Jackson and west of the Ellis river is a large district that none of us have traversed, where this rock may be found, as along New and Cutler's rivers. A specimen collected for us by Prof. Vose, four miles above Jackson falls, is placed with these slates in our museum, and may possibly represent such an extension. The few ledges cropping out along Ellis river are referred to the Montalban series.

An examination of the dips along the Mt. Washington carriage-road suggests readily the structure of this formation. It is a crushed, nearly inverted synclinal axis, overlying the Montalban system, perhaps unconformably. Both systems are characterized by the presence of crystals of andalusite. These are usually much larger in the newer than among the older strata, save where they have been altered into Damourite, as at Willis's Seat. The Montalban andalusite commonly occurs like chewed pieces of toothpicks, scattered indiscriminately through the ledges.

The slates about Mt. Pequawket occur in two limited isolated localities, one on the south side, and the other opposite, on the east branch of the Saco, about a mile and a half above its mouth. The two are nearly in their proper place for a continuation of the range southerly from the valley of Ellis river. It may be that these two areas are continuous beneath the granitic and brecciated cap of the mountain, although the strike of the southern mass does not point towards the northern. The disturbances which accompanied the formation of the breccia may have deranged the course of the slate, so that its original direction is lost, or there might be a bend in its course similar to that below Mt. Willard. These localities are over two miles apart. The northern one is the largest, extending easterly from the river. No andalusite has been noted in these slate ledges; but the boulders derived from them in Conway display the silicate in profusion, so that the affinities of the formation are unmistakable. It occurs to us now, that the "dark siliceous schists" of Jackson, described upon page 130, may perhaps be referred to this series. If so, there would be opportunity afforded for showing further the truth or error of the supposed connection between the different areas of andalusite slate.

Further reflection upon the character of these schists from Jackson suggests their similarity to a supposed part of the Huronian system already described as occurring along the Upper Ammonoosuc region, and also to be spoken of hereafter in Rockingham county. The small outlier east of Berlin falls is of the same sort. At various times the possibility of an intimate connection between the Andalusite slates and the Huronian schists has been thought of. This suggestion will receive speedy attention from us. By reference to the catalogue and the map illustrating the distribution of specimens, it will appear that the quartzites and ferruginous schists,—Nos. 84, 129–132, 135–137, 142, 144, 146, 147, 149–152, 160, 289–293, 297–301,—belong to this group, and that they extend in a narrow belt north-easterly from Iron mountain, in Bartlett, through Jackson, essentially parallel with the range in Coös county. There seems to be an anticlinal axis in it, also; but this probably does not express the proper structure of the whole mass. The strata are generally monoclinal, constituting an overturn synclinal, like the rocks on the Mt. Washington carriage-road.

PEQUAWKET SERIES.

The last of the groups of rock among the White Mountains to be considered are the Mt. Pequawket or Mt. Mote breccias and porphyries. The andalusite slates are the most recent of the stratified formations known to exist in this district; and consequently a breccia formed by its dismemberment, as well as the accompanying feldspathic ejection, must have been of later origin. The Pequawket and Mote areas are alike in composition, and may have been parts of the same original mass, cut in two subsequently by the Saco river. In the west parts of Albany and Waterville are other breccias, perhaps to be referred to the same eruptive period. If so, the porphyry period is probably coeval with it. There is also a mass of somewhat similar material constituting the more northern Twin mountain, while upon Mts. Willard and Tom the breccia is identical with that of Pequawket. For convenience, we will describe in turn the breccia and the rocks associated with it in each area, considered geographically.

Mt. Pequawket.

The state of our information respecting the structure of this mountain has been given partially in Volume I, page 43. Very similar statements concerning this mountain were made by Dr. Jackson, in his report, which I will quote for the sake of perfecting the record of the history of opinions about our geology.

On ascending the mountain on its south-eastern side, we came first to a coarse variety of granite, consisting of feldspar and quartz, without any mica, which is overlaid by a breccia of granite and argillaceous slate, above which rest the regular strata of argillaceous slate, which run N. 75° E., S. 75° W., and dip to the N. N. W. 30°, the strata dipping towards the mountain. This slate is compact, and is much broken and twisted, so that it would not answer for covering roofs. Occasionally a few good slabs may be obtained, which might answer for tombstones or for platforms, but no attempt has yet been made to quarry them. Higher up the mountain we discovered a very singular breccia, made up of the large broken fragments of the argillaceous slate rocks, mixed confusedly with the granite which closely invests them. This breccia was evidently formed by the eruption of granite through a thick bed of argillaceous slate rocks, the strata having been broken into fragments of a rhomboidal form, and into pieces which vary from a few inches to a yard or more square. The fragments lay in every imaginable position, just as if they were swept up by a thick, pasty mass of semi-fluid granite, which indurated around them by cooling. Some of the masses were rendered scoriaceous, and resemble vesicular trap rock, but generally they do not appear to have been much altered by heat. The granite contains no mica, but is composed principally of feldspar, with a little quartz. There are no rounded or waterworn pebbles in the breccia; hence it cannot be considered as a conglomerate of aqueous deposition. This locality proves most incontestibly * * * that the eruption of the granite rock of this region took place immediately after the deposition of the roofing slate. * * * On reaching the summit, the rocks were found to consist of a very hard breccia, composed of the same kind of granite before described, containing small fragments of slate rarely more than an inch in diameter.*

The accompanying heliotype of Mt. Pequawket will show better than words the relations of the several rocks to each other. The view was taken from a small hill east of the McMillan house, and south of the Portland & Ogdensburg Railroad depot in North Conway. The lowest rock receiving a color is the Conway granite, which also occupies all the foreground not otherwise designated. About three hundred feet of the lower part of the mountain are entirely composed of this granite. It has been found at about the same elevation above the sea on three sides of the mountain,—hence the conclusion naturally suggested is, that its surface is a nearly horizontal floor. The next strip is likewise nearly horizontal, thickening at the western side towards Bartlett. This is the Albany granite, perhaps fifty feet thick, on Section VIII, No. 6. This has been seen at several localities on the south side; and, on the path usually taken in the ascent of the mountain, it is thought to be from one hundred and fifty to two hundred feet thick, and still thicker on the slope towards Saco river in Bartlett. The position of the slate is indicated by the small patch of color overlying the narrow belt of Albany granite. The upper part of the mountain consists of a breccia, in which the feldspathic paste may vary from three to ninety-nine per cent. of the mass,

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* *Final Report*, p. 81.

and it is all represented by a single color. Further exploration would enable us to subdivide this upper portion. The lower eminence to the left of Pequawket is now called Bartlett mountain.

In the ascent up the bridle-path west of the slate ledge, one remarks the presence of trap-like fragments in the Albany granite; and, before reaching the breccia, there are a few feet thickness of a fine-grained quartz-porphyry, in which both the quartz and orthoclase occur as distinct and perfect crystals. The first part of the breccia,—perhaps one hundred feet,—is almost entirely composed of slate fragments, insomuch that a search with a lens is needful to discover any cementing feldspar or quartz. In the midst of the breccia, also, there is either a ledge of slate or a fragment thirty feet thick, dipping east, in the same direction with solid masses of the same material higher up the mountain in the path. The path lies to the west of the chief mass of the slate, on the south side of the mountain. As the strata dip east along the path, there is evidently a synclinal axis in the mass of slate. As we ascend the mountain, the proportion of slate fragments in the breccia diminishes. The other rocks present are white quartz, probably from veins in the slate, and several varieties of porphyry. As the cementing material begins to predominate, it slightly resembles the Albany granite, with the porphyritic aspect indicated by crystals of feldspar somewhat less distinct. Occasionally the resemblance will be so great as to excite the query whether the Albany and Pequawket granites are not identical.

The following is a list of the specimens obtained in a section (VIII) over Pequawket and Bartlett mountains, which may illustrate better than a protracted description the succession of lithological variety. The first one named comes from the east side, it being the first ledge succeeding the Montalban system in Chatham.

6. Albany granite—orthoclase crystals, one fourth to one half inch in length; a small amount of amorphous quartz, and a dark pepper-and-salt base. From the east base of Pequawket, one mile east of the west line of Chatham.

7. Porphyry—dark slate-colored base; crystals of quartz and orthoclase disseminated, and scattered fragments of uncommonly flinty compact feldspar, from one twentieth to one half an inch in diameter. From near No. 6.

8. Porphyry—gray base or paste; crystals of quartz and orthoclase present; black fragments very conspicuous, on account of the contrast in color between them and the base, usually one fourth of an inch in size, and much like a granular slate. From the

summit. Other specimens from the summit contain a smaller number of fragments, conspicuously large crystals of orthoclase, and have a reddish color.

9. Porphyry—very much like the preceding—with black slaty fragments an inch long. Near the summit.

10. Slate breccia from near the slate. Pieces, one fourth to an inch and a half long, of veritable slate, and one white quartz pebble. From eight to ten per cent. of feldspathic cement.

11. Fragment of black compact slate; 12—of gray quartz; 13—white quartz; 14—reddish compact micaceous feldspar,—all components of the breccia. Other specimens represent genuine porphyries.

15, 16. Slate. Nos. 9–16 are from the south slope of the mountain.

17. Breccia, composed chiefly of dark compact feldspar fragments, with about fifteen per cent. of paste. From top of Bartlett mountain. Nos. 18–26 are from the west slope of this spur.

18. Porphyry, with reddish base; pieces of dark compact feldspar and quartz crystals in the base.

19. Gray compact feldspar or porphyry holding numerous minute crystals of quartz.

20. Porphyry, with reddish-gray, somewhat crystalline base; quartz crystals abundant; contains an inch fragment of trap-like porphyry, itself carrying feldspar crystals.

21. Both drab and light gray base, each color carrying small crystals of quartz and feldspar, and bits of dark porphyry.

22. Like 19. 23. Like 21.

24. Compact drab-colored feldspar, very like the fragments seen all through the mountain imbedded in the porphyry.

25. Porphyry, with dun-colored base, minute crystals of quartz, and white, irregular blotches of feldspar from an eighth to one quarter of an inch in length.

26. Porphyry, with an abundance of dark brown paste, carrying numerous crystals of quartz and minute crystals of orthoclase, and one or two small pieces of compact feldspar.

27. Albany granite, like No. 6. This ledge is about a mile east of the road from North Conway to Bartlett.

It is noticeable that the distinctively slate breccia is confined to the proximity of the slate ledges on the two sides of the mountain, while the balance of the dark pieces consists of compact feldspars, a mass of which occurs at No. 24, on the west side. Explorations might discern other areas of it on other surfaces of the mountain. The length of this porphyritic area is about three miles east and west—somewhat less north and south.

Mt. Mote.

There is an extensive area of brecciated porphyries, similar to those just described upon the two mountains west of North Conway, between the Saco and Swift rivers, known as the Mote mountains. On examining the specimens, in connection with the full description given of this area upon pages 148–150, it appears that there is a considerable porphyry present distinct from the breccia. It occurs all the way from Bartlett to the summit of the ridge following up Stony brook, above Diana's Bath and Farnum's, in all cases beneath the breccia. The more central part, or the north peak, contains the greatest amount of andalusite slate fragments, the pieces averaging coarser than on Mt. Pequawket. At the southern extremity, as at the western, in the other case, there is an abundance of porphyritic cement without slate.

The identity of the Mt. Mote with the Mt. Pequawket breccia seems well established. But farther west in Bartlett, Albany, Waterville, etc., there are breccias associated with porphyry composed of different classes of fragments, still with a similar cement. As we found a variation upon Mt. Pequawket, occasioned apparently by proximity to particular ledges, it would seem probable that all the breccias with feldspathic paste must be of the same age, and formed subsequently both to the eruption of the original porphyry and the deposition of the slates. The area in the west part of Albany contains fragments of mica schist, labradorite, porphyry, and quartz, and, when near the outcrop, bits of bright red compact feldspar. These ledges are connected directly with the breccias of Mote mountain, and have been noticed upon page 148. Another case has been mentioned as occurring about the head waters of Sabba Day brook in Waterville. Wherever boulders of red porphyry occur, there are many of a brecciated character, showing a probability of their formation at the same time with those in Albany, Bartlett, and Chatham. This was remarked in particular at Waterville.

Twin Mountain.

After ascending Twin mountain, in 1871, which was before the examination of the Bartlett and Chatham area, I referred the rock of the north peak to the Albany granite; but later investigations prove that it belongs to the same class of porphyritic breccia with that upon Mts. Mote and Pequawket. From the crossing of the axis of the ridge by Little river, to a short distance south of the north Twin mountain, the granite is specked by small black pieces of mica or hornblende schist, and quartz crystals are abundantly disseminated through the feldspathic paste; and jointed planes dip about ten degrees northerly. The north-west spur, or the mountain mass west of the small stream flowing northerly from the summit, is of the Albany variety. The south Twin mountain has been mentioned as being composed of porphyry. The length of this mass holding black fragments of schist is a little over two miles.

Mts. Willard and Tom.

On page 177 allusion is made to the presence of a narrow band of breccia on the south face of Mt. Willard, and on page 165 to the same upon Mt. Tom. On page 178 it is remarked that masses of the same slate breccia occur just behind the north spur of Mt. Field. All these cases I conceive to be examples of the same breccia occurring so abundantly upon Mts. Pequawket and Mote, though none of the masses found are known certainly to exceed twenty feet in thickness. They all occur, also, on the eastern border of the slate adjacent to the Albany granite. They are of too limited extent to be represented upon the general geological map.

A large portion of the Mt. Willard breccia differs from that on Pequawket in being much more compact, in containing a variety of pebbles, and in having a different cementing material. The rock superficially resembles trap with a glazed coating or tarnish in the joints, and frequently no fragments are displayed, except after weathering. The materials are principally a compact slate, a looser schist, with pretty black mica (phlogopite?) sprinkled through it, gneiss, granite from veins in the Montalban series, and numerous very small bits of glassy quartz not crystalline. The paste is dark gray, considerably lighter than the schistose fragments, and is notable for the very black scales of mica (muscovite?) scattered through it. Some irregular patches of white feldspar may be connected with the paste rather than with the fragments. This breccia, though quite near the Franconia group topographically, is very distinct from it in the character of the paste and the included fragments. The porphyry containing perfectly formed crystals of quartz and orthoclase, mentioned upon Mt. Pequawket, is much more finely developed upon Mt. Willard; and the band has been mentioned heretofore (p. 177) as belonging to the Albany granite.

[NOTE TO PAGE 100. Since the printing of the statement concerning the section from Mt. Lafayette to Bald hill, additional observations at the Wing road have confirmed our supposition that the porphyritic gneiss underlies the Bethlehem group. The particular details of structure appear in the illustration, Pl. VI, Fig. 7.]

[NOTE TO PAGE 119. A reëxamination of the ledges enables us to modify certain statements upon page 119. Above the fifth mile-board, for a quarter of a mile. the dips are mostly low and undulating, like those at the end of the fifth mile. The high dips mentioned here have an existence, they being the occasional plunging downwards of one side of the curves. I could not satisfy myself that the dip of 50°–60° N. 73° W., at No. 44, pertained to a ledge. And it is erroneous to state that the ledge in the sharp angle of the road overlooking the Great Gulf is one hundred and fifty feet long. The sedgy plat near No. 47 is now known as the "cow pasture." Instead of saying "ten rods north of mile-post No. 7," it would be more correct to put it "ten rods before coming to mile-post No. 7." There is a ledge at the first great easterly bend, corresponding essentially with No. 48. Below the barn the first ledge dips 50° S. 82° W. I have not preserved the observation respecting a dip at No. 50.

We remark that the steep side of all the curves is on the east, or down the mountain. One of the zigzags at the fifth mile-board is now called "Willis's Seat." Since the drawing of the plan, the sixth and seventh mile-boards have been moved down the mountain, so that, as measured on the plan, the distance between five and six is less than a mile. I have retained the old positions for them. No. VI is now placed more than half-way towards No. 45 of the space between 6 of the plan and 45; and, consequently, VII has been shifted to stand at No. 48. In the neighborhood of Willis's Seat the large andalusite crystals have been altered into quartz and Damourite.

For comparison, I have drawn upon the section through Mt. Washington (Pl. VII) the dips along a nearly parallel line, down Tuckerman's ravine to the Pinkham Notch road. The anticlinal and synclinal axes correspond well with each other. The lower end of the section at the Notch represents the eastern boundary of the Montalban system, which appears on the carriage-road at the Half-way house; though I have sometimes thought the rocks about Willis's Seat belonged to the newer group. The greatest amount of crushing is manifested in the area of the slates between Nos. 12 and 36. The structure of the latter seems to be a complicated and crushed inverted synclinal.]

[NOTE TO PAGE 182. There are a few points concerning the representation of the boulder showing curvatures in the strata requiring mention. It is figured in Plate X, Figs. 22, 23, and 24. Fig. 22 is the one spoken of as on the left, and Fig. 23 as the one on the right. Fig. 24 is an additional view of what may be termed the bottom, nearly opposite Fig. 22. The stone is rather triangular in shape. The figures referring to the lines of curvature will be found placed to agree with the description. Owing to a slight change in the position of the stone, the top view is more extensive than as originally described. What is called the shorter fault is the one nearest the letter A, the changed position permitting its representation larger than at first seen. We can also see the smaller fault of the side view at its beginning on the top. The letters A, B, and C indicate where the edges of the adjacent sketches join each other. Every side is represented. The two faults do not seem to join on the lower side, but to approach near each other and then diverge again. The black crystals seen all through the layers are of hornblende.]

[DESCRIPTION OF HELIOTYPES. Since the printing of the account of the Franconia breccia along the Portland & Ogdensburg Railroad and the Flume upon Mt. Willard, I have had heliotypes taken to illustrate them, and placed opposite this page. The cement of the fragments is the "Breccia granite" described upon page 169; and the ledge photographed is a rock cutting where the railroad makes a sharp turn westerly, nearly at the northern limit of the Conway granite. The large fragments so well shown are the Montalban schists, fractured by lateral pressure, and cemented together without removal by transportation. A reëxamination of the breccia of the same apparent age at Franconia indicates the cement there to be very much like this in the Notch.

The larger flume described on page 172 is represented on the other side of the heliotype. The view was taken from the inside, near the top, looking out towards Mt. Webster. It is impossible to obtain any photograph that will adequately represent the whole of the chasm. The name of the discoverer was first applied to this interesting cleft in the ledge by a large party of tourists from Massachusetts, shortly after the description of its geological character on the aforementioned page had been written.

Another double heliotype illustrates Mt. Crawford and the Lake of the Clouds (p. 182). The first represents the appearance of Mt. Crawford from the hill back of Dr. Bemis's house. Most of the precipitous slope visible is composed of Conway granite. Glen Crawford appears at the extreme right. The rock at the Lake of the Clouds is the common andalusite mica schist of the main White Mountain range. The ice still partly remained when the negative was taken, in the month of May, on account of its great altitude—5000 feet.

Several of the heliotypes have been colored to show the distribution of the formations. It is not possible at this time to say what these colors are; but it is hoped that, by comparing the heliotypes with their descriptions, the significations of the several tints will be perfectly understood. One is the view of Mt. Willard, noticed upon page 177. The other view upon the plate represents a mass of breccia granite, situated in the midst of Montalban schists, in the Silver Cascade. The colors of the Mt. Pequawket heliotype may be explained by studying page 236. The Mt. Chocorua heliotype is spoken of upon page 232. The double plate showing the Eagle Cliffs of Franconia breccia, by the side of Pemigewasset granite, is noticed upon page 139.]

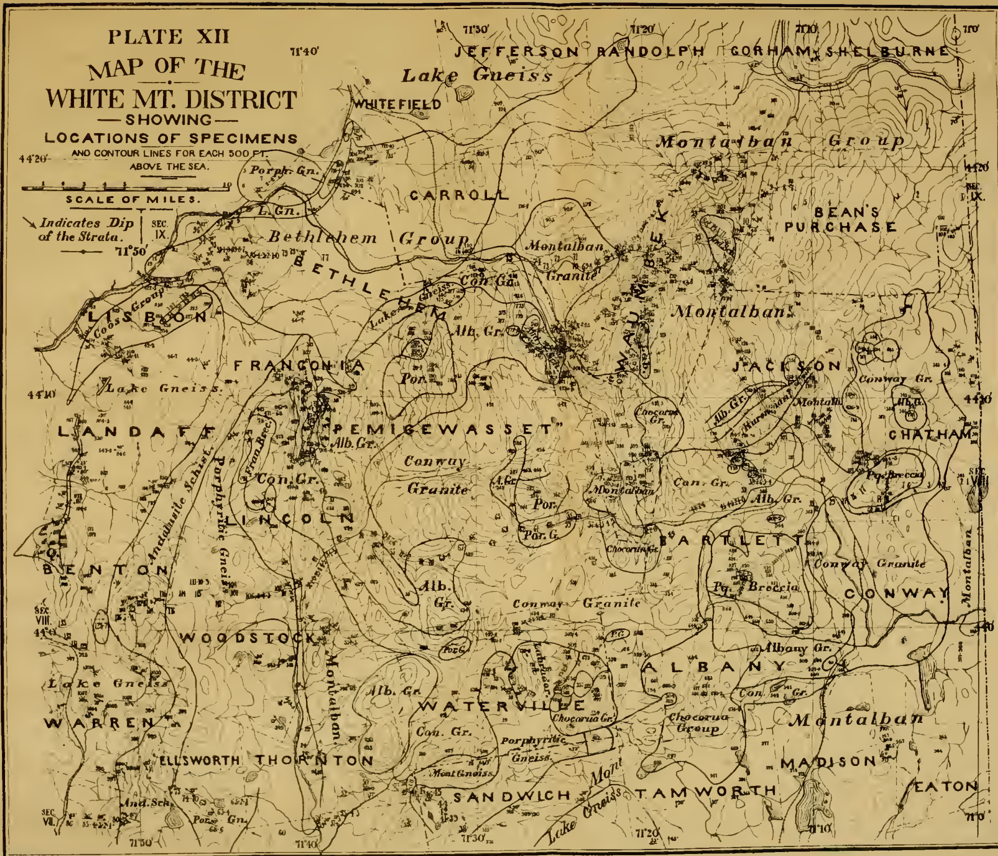


PLATE XII
MAP OF THE WHITE MT. DISTRICT
SHOWING
LOCATIONS OF SPECIMENS
AND CONTOUR LINES FOR EACH 500 FT. ABOVE THE SEA.
SCALE OF MILES.
Indicates Dip of the Strata.
SEC. IX.
JEFFERSON
RANDOLPH
GORHAM
SHELBURNE
Lake Gneiss
WHITEFIELD
Montalban Group
CARROLL
BEAN'S PURCHASE
Bethlehem Group
BETHLEHEM
LISBON
Coos Group
FRANCONIA
JACKSON
LANDAFF
PEMIGEWASSET
CHATHAM
Conway Granite
LINCOLN
BARTLETT
BENTON
CONWAY
WOODSTOCK
ALBANY
WARREN
WATERVILLE
ELLSWORTH
THORNTON
MADISON
SANDWICH
TAMWORTH
EATON
Andalusite Schist
Porphyritic Gneiss
Montalban
Chocorua Group
Albany Gr.
HELIOTYPE

Catalogue of the White Mountain Collection.

The area included in this catalogue corresponds essentially with that of the White Mountain district, save that the specimens from the north of Moose river have been incorporated into the Coös County collection, given on pages 81–86. The locations of the specimens will be found accurately portrayed upon Plate XII. Owing to discoveries and additions made after the writing out of the catalogue, the order is not strictly a numerical one, but it can be easily comprehended by those who choose to compare the positions of the specimens on the plate with the colors on the final map, or the descriptions of the stratigraphical and lithological parts of the report, or to study the rocks themselves in the museum at Culver Hall. The arrangement by age is not quite perfect, but will not produce embarrassment. Where several specimens came from very nearly the same locality, all their numbers are not drawn upon the map. Unimportant numbers are often omitted, as in the case of many traps and small beds. In the museum there is a manuscript catalogue specifying the lithological character and localities with all needful particularity. The same is true of the Coös and Essex District collection.

PORPHYRITIC GNEISS.

Franconia.

1–6, 8, 12, 15, 17, 23, Porphyritic gneiss.
7, 14, Trap.
10, 13, Coarse granite veins.
11, Mica and feldspar, mica predominating.
333, Fine-grained gneiss.

Lincoln.

9, 19, 20, 21, Porphyritic gneiss.
16, Hornblende schist.

Landaff.

18, Porphyritic gneiss.

Thornton.

22, Fine-grained gneiss.
24, 26, 32, Porphyritic gneiss.
27, Coarse granite vein.

Waterville.

29, 30, 31, 35, 495, 496, 640, 642, 652, Porphyritic gneiss.
33, Gneiss.
34, Trap.
641, Banded quartz vein.

Sandwich.

36–39, Porphyritic gneiss.

Conway.

40, Porphyritic gneiss.

BETHLEHEM GNEISS.

Franconia.

41, 42, 48, 49, Granitic gneiss.
43, 46, Chlorite schist layers.
47, Chlorite schist, with magnetite.

Lincoln.

50, 52, Chloritic gneiss.

51, Gneiss, with black mica and much orthoclase.

Pemigewasset.

53, Gneiss.

Carroll.

54, 54 a, Granitic gneiss.

176, 177, Porphyritic gneiss.

408, 409, Chloritic gneiss.

Jefferson.

407, Chloritic gneiss.

FRANCONIA BRECCIA.

Franconia.

55, 56, 63, Gneiss, with black mica.

61, Porphyritic vein—quartz and orthoclase in crystals.

62, Porphyry, with hornblendic cement.

64, Compact granite—the cement of 65.

65, Breccia.

From head of Eagle Cliff to Echo Lake, 66–74.

66, Dark gneiss—top of Eagle Cliff—holding 78 a.

67, Porphyritic gneiss—a fragment in breccia.

68, Mica nodule in 66.

69, Almost Concord granite, with larger crystals of mica and feldspar.

70, Granite—top of middle peak.

71, Coarse dark gneiss—top of third peak.

72, Like 69—top of third peak.

73, Pebble from eruptive granite vein near Echo lake.

74, Granite, with black mica—below porphyritic gneiss.

75, Porphyry, with much dark micaceous cement.

Lincoln.

57, 58, Breccia of fragments of porphyritic and Lake gneisses, cemented by fine-grained granite. Basin.

59, 60, Dark porphyry, with mica. Basin.

76, Granitic, with dark mica.

77, Granitic cement of breccia between Mts. Profile and Kinsman.

78, Dark gneiss.

78 a, Coarse granite vein from No. 66.

Mt. Willard.

78 b, Coarse breccia.

78 c, Gneiss from 78 b.

LAKE GNEISS.

Franconia.

25, Gneiss. East of Lake of Clouds.

321, Gneiss. N. W. flank Mt. Lafayette.

Carroll.

315, 316, 317, Gneiss.

Bethlehem.

318, 319, 320, Coarse granite.

Sandwich.

369, Micaceous gneiss.

Waterville.

28, Gneiss. Summit Sandwich Dome.

MONTALBAN SERIES.

East Part of White Mountain District.

Shelburne.

79, Concord granite.

80, 80 a, Fine-grained dark gneiss.

Bean's Purchase.

81, Chloritic gneiss.

82, 87, 92, Gneiss, with blotchy mica.

88, Gneiss.

89, Mica schist, with blotchy mica.

90, Vein of quartz and hornblende.

91, Dark Concord granite.

379, Concord granite.

380, 381, Granite veins.

Jackson.

83 a, 126–128, 143, Concord granite.

85, 86, 117, 123, 156, Gneiss, with blotchy mica.

83, 140, Gneiss.

120, 122, 124, 125, 148, Mica schist, with blotchy mica.

116, Andalusite gneiss.

118, Porphyry.

119, 134, 138, Trap.

121, 133, 139, 141, 154, 391, Granitic veins.

84, 129, 130, 135, 136, 137, 150–152, 160, Quartzite.

131, 144, 146, 147, 149, Fine-grained mica schist.

132, 142, Ferruginous schist.

145, Andalusite mica schist.

153, 158, 159, Limestone.

155, 157, Dark Concord granite.

391, Granite, with tourmaline and garnet.

Chatham.

93, 94, Coarse Concord granite.

95, 97, 102, 103, 385, Concord granite.

99, Very fine-grained granite.

96, 98, 107, 109, 110, 112, Gneiss, with blotches of mica.

100, 101, 104, Gneiss.

105, 108, Trap.

106, 111, 385, Granite vein.

Maine.

113, Gneiss. Lowell.

114, Granite vein. Lowell.

115, Granite vein. Stoneham.

MAIN RANGE OF WHITE MOUNTAINS.

Gorham.

161, Andalusite mica schist.

162, 163, Mica schist.

164, 165, 166, Concord granite.

Randolph.

167, Coarse mica schist.

168, Ferruginous vein.

169, 171, Hornblende schist.

170, Coarse granite vein.

172, Micaceous gneiss.

Jefferson and Carroll.

174, Trap.

175, Mica schist.

Waumbek.

178, 189, 190, 194–196, 199, 210, 219, 222, 225, 231, 232, 234–236, 240, 242, 244, 246–249, 252, 253, 255, 256, 265, 268, Gneiss, with blotches of mica.

179, 186, 204, 205, 213, 229, 272, 279, 285, Mica schist.

180, 191, 192, 193, 197, 267, 381, 406, Concord granite.

181, Muscovite.

182, 183, 187, 280, Staurolite mica schist.

184, 206, 207, 233, Andalusite gneiss.

185, Gneiss, with garnets.

188, White quartz vein.

200, 201, 203, 208, 211, 224, 228, 230, 254, 269, Mica schist, with blotches of mica.

202, 216, 245, Hornblendic beds.

212, 217, 218, 281 a, Dark, fine, compact gneiss.

198, 215, 227, 241, 380, 381, 270 b, 270 c, 404, 415, 281 b, 398, Granite veins.

209, 220, 258–262, 273, 275, 302, White trap.

214, 233, 239, 257, 263, 264, 277, 303, 312, Trap.

226, 237, 238, 271, 278, 283, 284, 304, Ferruginous schists.

266, Gneiss, with much silica.

270, Chloritic gneiss.

270 a, Hard gneiss.

274, 276, Fine-grained gneiss.

Jackson and Bartlett.

286, Hematite.

287, Porphyry.

288, Tourmaline granite.

289–291, 297–301, Quartzite.

290 a, Chlorite, with calcite carrying copper.

290 b, Ferruginous siliceous limestone.

292, 293, Ferruginous schist.

294, Gray gneiss.

295, Ferruginous gneiss.

296, Coarse mica schist.

West and South-west from the Saco River.

Near the Saco.

250, 250 b, 250 d, Concord granite.

251, 251 b, 251 c, 417, Hard gneiss.

251 a, Gneiss, with much mica.

250 a, 251 f, 251 g, Trap.

250 e, Feldspathic vein.

251 d, 251 e, Breccia granite.

305, 307, Gneiss, with mica patches.

306, Curved strata. Part of boulder figured upon Plate X.

308, Granite dyke.

309, Mica schist.

310, 313, Gneiss.

311, Chloritic granite.

419, Compact feldspar, with grains of quartz.

419 a, Gneiss, with much feldspar.

Franconia.

322, 323, 326, 329, 331, 332, Gneiss.

324, Hornblende schist.

325, Gneiss, with irregular patches of mica.

327, Trap.

328, Granular quartz friable from decomposition.

330, Soft clayey mica schist.

Landaff.

334, Mica schist.

Lincoln.

335, 336, Gneiss.

337, Dark fine-grained gneiss.

338, Coarse granite vein.

Woodstock.

339, 340, 341, 345, 346, 348 a, 350, Gneiss.

342, Gneiss, with fine black mica.

343, Concord granite.

344, Trap.

347, 351, Granite veins.

348, 349, Gneiss, with much black mica.

Thornton.

352–354, 356, 378, Gneiss.

355, Granite bed.

357, Feldspathic mica schist.

358, Andalusite gneiss.

359, Andalusite gneiss, with garnets.

Pemigewasset.

360, Gneiss, with pyrites.

Albany.

361, 362, Fine-grained granite.

363, 539, Gneiss, with black mica.

364, Granite vein.

Tamworth.

365, Gneiss, with much mica.

366, Dark Concord granite.

367, Granitic gneiss.

Sandwich.

368, Concord granite.

369, Lake gneiss.

370, Junction of gneiss and sienite.

371, Gneiss, with much mica.

372, White quartz.

373, Gneiss.

374, Fine-grained dark gneiss.

375, Gneiss, with decomposing pyrites.

376, Gneiss, with irregular mica.

377, Mica schist.

PEMIGEWASSET SERIES.

Conway Granite.

Chatham, Jackson, and Bartlett.

382, 383, 386, 387, 389, 390, 392–395, 397, Normal Conway granite.

384, Finer reddish granite.

388, Red granite.

396, Manganesian granite.

432, Trap.

435, 435 a, 436, 437, 439, Finer variety resembling the normal, save in coarseness of texture.

438, White porphyritic feldspar, with a little mica.

Waumbek.

399, 431, Granite.

400, 401, Dark brown granite—manganesian.

402, Tourmaline granite, the quartz crypto-crystalline.

403, Normal Conway granite.

428, Reddish porphyritic feldspar, with little mica.

429, 430, Compact feldspar.

442, 443, 447, Dark granite.

444, 453, Mostly red feldspar.

446,

457, Fine-grained feldspar, with coarse crystals, and quartz crypto-crystalline.

Pemigewasset—west part.

460, 461, 461 a, 462, 465, 466, 468–471, 635, Finer-grained variety.

463, 464, 478–481, 485–490, Normal Conway granite.

472, 475, 476, 477, Granite.

474, Very fine-grained granite.

483, 484, Trap.

Waterville.

491, Granite, feldspar predominating, both compact and in coarse crystals.

492–494, 501–504, 506, 629, 630, Normal variety.

499, 500, 631, Finer-grained variety.

497, 498, Fine-grained quartz, very feldspathic, with crypto-crystalline quartz, approaching porphyry.

505, Trap.

510, Normal granite, with greenish feldspar and tourmaline.

Albany.

467, 506, 511, 512, 520, 522, 523, 527, 529, 531, 532, 534, 537, 542, 644, Normal variety.

507, 517, 519, 521, 524, 526, 540, 541, Finer-grained variety.

508, 514, 518, Trap.

509, Finer porphyritic granite.

513, 516, 530, 536, Fine-grained, compact granite.

528, Porphyry vein.

538, Compact feldspar—nearly.

Conway.

543, 545, Normal variety.

544, Fine-grained vein.

ALBANY GRANITE.

Chatham, Jackson, Bartlett, and Conway.

545 a, 547, 552, 553, 556, 561–563, Porphyritic granite. 549–551 have quartz in form of crystals.

546, 566, 558, 560, 564, the same, without quartz.

554, Junction of granite and banded mica schist.

555, 557, Porphyritic granite — two feldspars and little quartz.

559, Crystalline and compact feldspar.

565, Granite.

Waumbek.

567, 568, 569, 571, Granite.

Pemigewasset.

566, 572, 575, 578, 579, 583 a, 589, 603, 607, 608, 628, Feldspar, porphyritic, and mica.

573, 574, 577, 580, 581, 587, 591, 592, 596, 599, 602, 609, 610, 625, 627, 634, 636, 637, Quartz and feldspar, porphyritic.

582, Large reddish crystals of feldspar in dark dioritic base.

583, Porphyritic granite, with dark base.

583 b, Well-formed quartz and feldspar crystals.

585, 590, Granitic—mostly feldspar.

588, Granite.

593, 594, Porphyritic diorite.

598, 604, Quartz crystals in compact feldspar.

626, Compact sienite.

Franconia and Lincoln.

611–614, 618, 619, 620, 621, Mostly crystalline feldspar.

615–617, Fine-grained porphyritic granite.

622, 623, Porphyry.

624, Porphyritic granite.

Waterville and Thornton.

632, Trap.

633, 634, 637, 638, Mostly crystalline feldspar.

636, 639 a, 643, Porphyritic granite.

639, Granite.

Albany and Conway.

645–650, 658, 663, Mostly crystalline feldspar.

651, 652, 653, 654–657, 662, 664, 665, Porphyritic granite.

659–661, Mostly compact feldspar.

CHOCORUA GROUP.

North and east of Saco River.

433, 435, 548, 681, 683, 684, Fine-grained sienite.

434, Sienite and trap.

520, Feldspar, with a little hornblende.

695, Sienite, passing into Albany granite.

South and west of Saco River.

515, 533, Sienite, with two feldspars.

535, 667, 672–676, 678, 679, 685–690, 693, 696, 697, Fine-grained sienite.

666, 687, Coarse sienite.

668, 669, 671, 680, Crystalline feldspar, with quartz.

670, 691, Compact feldspar.

677, 682, Granite.

677 a, Trap.

692, Coarse mica bunches in 690.

694, Sienite, with chrysolite.

LABRADOR SYSTEM.

Mt. Washington River.

698, 703, 704, Ossipyte.

699, Crystalline labradorite, with biotite.

700–702, Labradorite, hornblende, and biotite.

705, Compact labradorite.

706, Ossipyte, with hornblende.

Lincoln.

707, 708, Compact labradorite. Analysis, page 220.

709, Compact feldspar, perhaps orthoclase.

Waterville.

710, Ossipyte, with hornblende.

711, Crystalline labradorite.

712, Dark ossipyte. Analysis, vol. i, p. 39.

713, Labradorite masses in finer-grained matrix.

714, 715, Dykes of trap.

716, 717, Compact labradorite.

718, Fine-grained porphyry.

719, Labradorite and hornblende.

720, 721, 724, 730, Andesite, orthoclase, and hornblende in small crystals.

722, Fine-grained feldspar and mica.

723, 738, Labradorite, biotite, and hornblende.

725, Orthoclase, from very coarse granite vein.

727, Coarsely crystalline labradorite.

728, 736, Coarsely crystalline labradorite, biotite, titanic iron, epidote. Analysis, vol. i, p. 40.

726, 729, 732, Fine-grained sienitic dykes cutting 728, etc.

731, 733, 739, Fine-grained orthoclase and hornblende.

734, 735, 737, Coarse ossipyte, with biotite.

Jackson Tin Mine Adit.

741, 742, Coarsely crystalline labradorite and hornblende, with few crystals of orthoclase.

ANDALUSITE SCHIST GROUP.

743, 744, 750, 752, 754, 757, Clay slates.

745–748, 751, 753, 756, Micaceous quartzite.

749, 755, 761, Andalusite schists.

758, 759, Mica schist.

760, Banded vein, chiefly calcite in 759.

Moosilauke.

762, Andalusite mica schist.

763, 764, Micaceous quartzite.

765, Quartz vein in 763.

765 a, Granite.

PORPHYRY.

Jackson, Bartlett, and Chatham.

766, 769, 770, Greenish compact feldspar.

767, Porphyritic breccia.

768, Breccia of porphyry, mica schist, and quartzite.

771, Porphyry.

Pemigewasset.

482, 772, 778, 779, Porphyry.

773, 781–785, 787, 791–793, Porphyries, with more or less quartz.

774, Sandstone, with 772.

775, 780, 794, 796, 797, Greenish compact feldspar.

776, 777, 786, Porphyries, with reddish crystalline spots.

778, Amygdaloidal porphyry.

779, Porphyry, passing into Albany granite.

790, Light drab compact porphyry.

795, Gray porphyry, with bits of dark schist.

798, 798 a, Red porphyry.

MT. PEQUAWKET BRECCIA.

Pemigewasset.

597, 605, 606, Porphyritic breccia.

799, 804, Porphyry, with crystals of quartz and orthoclase and fragments of schist and porphyry.

800, 801, Hornblendic porphyry.

802, 803, Porphyry.

Mt. Willard.

805, Porphyry, with crystals of quartz and orthoclase.

576, 806–809, Breccias, with fragments of slate, porphyry, gneiss, mica schist, quartz, and feldspar.

Mt. Pequawket.

811, 817, Slate breccia.

812, 813, 814, Breccia, with porphyritic base holding crystals of quartz and feldspar.

815, Porphyry, with very little slate.

816, Porphyry, with large piece dark felsite.

818, Fragment of quartz porphyry—819 of trap from 817.

Waterville.

820–823, Breccia, with minutely crystalline feldspathic and micaceous paste.

Bartlett and Albany.

824, Porphyritic dyke.

825–827, Quartz porphyries.

828, 829, 831–834, Porphyritic breccia.

830, 835, Micaceous quartz porphyry.

836, Gneiss, (?) with 835.

837, Porphyritic breccia—red and dark porphyry fragments.

838, Red porphyry.

839, Dark compact porphyry, with diorite fragment and pyrites.

840–842, Porphyritic breccia — fragments of reddish, gray, dun, and black porphyries, labradorite, and gneiss. Cement of light gray porphyry holding amorphous quartz and crystals of feldspar.

Jackson and Bartlett.

843, Breccia, with granitic paste.

844, Black compact brecciated feldspar.

845, Brecciated trap—granitic paste.

846, Dun-colored quartz porphyry.

Mote Mountain.

847, Porphyritic breccia—bits mica schist —compact paste holding quartz crystals.

848, Quartz poryhyry.

849, Light-gray compact feldspar.

850, 851, Slate-colored porphyritic breccia.

852, Quartz porphyry paste, with quartz fragments.

853, 854, Slate breccia.

855, Compact feldspar holding crystals of quartz, and feldspar and slate fragments.

856, 857, Dun-colored porphyry, with numerous crystals of quartz and feldspar.

858, Purple porphyry.

859, Dark quartz porphyry, with crystals of quartz and feldspar.

860, 861, Slate breccia.

862, 863, Breccia—greenish porphyry fragments—dark base holding crystals of quartz and red feldspar.

864, Black porphyry.

865, Purplish porphyry, with crystals of white feldspar and quartz.

866, Compact greenish feldspar, and piece of dark micaceous porphyry.

867, 868, Compact greenish porphyry, with crystals of red feldspar and quartz.

The following numbers of the catalogue were accidentally overlooked: 44, 45, Fine-grained and granitic gneisses of Bethlehem group, from Franconia; of the Montalban group, 173, Coarse mica schist, Chatham; 221, Granitic rock, from half a mile south of Glen Ellis falls; 243, Ferruginous gneiss, a little more than three miles from Crawford house towards Mt. Clinton; 281, 282, Mica schists, from Mt. Hope. No. 314 is the same with 251. On page 245, line 14, second column, 233 should be 223; and, eleven lines below, 415 should be 405. Insert 409a after 409, page 244, line 9. Of the Conway granite there should be added for Pemigewasset, the north and east parts, Nos. 410–416, 422, 422a, 422b, 423, 423a, 423b, 423d, 424, 424a, 426, 440, 445, 449, 451, 455, 459, for the normal variety; 418, 418a, Compact feldspar and andalusite schist fragments in this rock up Cascade brook; 420, 423c, 425, 427, 446, 451a, 452, 454, 456, 458, Fine-grained variety; 423e, 446a, Trap; 447 approaches Chocorua granite. Of Albany granite, 595, from Pemigewasset. The numbers 442–457, under Waumbek, came from Pemigewasset.

Note. Plate XII, the map illustrating the position of the specimens belonging to the White Mountain collection, shows, in addition, the location of the numbers pertaining to Sections IX, VIII, and a little of VII west of Sandwich. These are drawn of a larger size. I have, also, for convenience, given the numbers, in a few cases, of specimens collected outside of the district. They will be referred to hereafter in the description of the adjoining territory, save what belong to the Coös and Essex district, which have been already catalogued. In Whitefield, Nos. 694–719 have been mostly enumerated upon page 86, but are here classified more intelligently. No. 694, with the majority of the others, may be seen to be situated to the south and east of the upper boundaries of the Bethlehem group. 695 and 719 belong to the Lake gneiss. Then there are two small areas of the Coös mica schist. All the numbers bordering the Ammonoosuc river in West Bethlehem and Littleton, save those belonging to Section IX, will be found enumerated in the catalogue of the Ammonoosuc region, likewise everything in Lisbon. The smaller numbers in Landaff, Benton, Warren, Ellsworth, parts of Sandwich, Tamworth, Madison, Eaton, and Conway, are mostly from the general catalogue of lithological specimens, numbered in continuation of that ending on page 86. The areas of the several formations are inclosed by heavy lines, the narrow ones representing the 500-feet contours. The names of the various locations, grants, mountains, ponds, rivers, etc., may be learned by comparison with other maps in the Atlas. The dips of the strata are given so far as we have reliable information concerning them.

Final Statement of Opinions.

This chapter will not be complete without a *résumé* of the present opinions held by the writer respecting the age and elevation of the White Mountains. I have quoted everything of importance written by others respecting them, from the convulsion theory of Dr. Dwight to the proposal of the existence of an undescribed formation, by Dr. Hunt. I cannot further advert to the gradual progress of our views, than to refer to the chapters upon the history of the present survey, and a few improvements upon them suggested while this volume has been passing through the press. A few statements in the early part of this chapter have been modified by later explorations, and the changes are mentioned farther along. I propose now to state briefly the general conclusions obtained respecting the age and equivalency of the formations, and the principal physical changes effected in the condition of the district.

The order of the systems seems to be the following: First, the Laurentian, represented by the porphyritic gneiss and the Bethlehem group. Second, the Atlantic, consisting of the Lake or Berlin and Montalban gneisses, and the Franconia breccia. Third, the Labrador. Fourth, the Huronian. Fifth, the Merrimack schists. Sixth, the Andalusite schist group. Seventh, eruptions of porphyry. Eighth, eruptions of the Conway, Albany, and Chocorua granites and sienites. Ninth, the formation of the Mt. Pequawket or Mt. Mote porphyritic breccia. This order is somewhat different from that stated at the beginning of the chapter.

1. Laurentian. Dr. Hunt has expressed to me his opinion that both the porphyritic and the Bethlehem gneisses agree essentially in lithological character with the schists he has observed in typical Laurentian regions; and Prof. Dana (p. 109) has discovered similar resemblances in the upper member of the second group. Our observations lead to the belief that they are the oldest formations in this district, and suggest that they may belong to the upper division of the Laurentian system as it is developed in Canada and New York. We have two leading and divergent ranges of the porphyritic group, each suggestive of an anticlinal structure (Pl. VI, Fig. 7 and Fig. 12), the first underlying the Bethlehem gneiss. The Bethlehem group is noted for a nearly east and west strike, is marked by an anticlinal structure when flanked by the Lake gneiss (Fig. 11), and has porphyritic beds in its lower member. The Bethlehem synclinal, if correctly interpreted, is inverted. We may note the improvement of Plate VI, Fig. 7, above the statements upon page 110, and the development of the eastern range in Waterville, coming up again also in Albany, near the western line. More irregularities appear in its course in Sandwich.

2. Atlantic. The lowest division of this newly-described system is best developed in the more northern part of the White Mountain district, the rocks having been partially described in Chapter II. They are the "Older rocks" (p. 67) and the "Granite and granitoid gneiss (p. 73). The Berlin gneiss seems to constitute an anticlinal axis, with both Huronian and Montalban schists overlying each flank (Figs. 4, 5, and 6). This band possesses a very inferior development in this district south of Jefferson, because the principal mass lies to the west of it. The limited range from near Mt. Hale across to Franconia appears to overlie both the porphyritic gneiss and Franconia breccia, and to correspond to the Whitefield, Jefferson, and Littleton outcrops on the other flank of the older groups. Its continuity across Franconia is interrupted by a southerly extension of the Bethlehem, as if it had been worn away down to a lower formation. In Sandwich we perceive the commencement of the large Winnipiseogee Lake development of this series, as well as the smaller area embracing the Dome.

The Montalban portion of the Atlantic system has a large representation in this district. It constitutes the foundation of the principal higher range of mountains from Success across the Androscoggin river to Mt. Webster, and is then supposed to continue beneath the granites and porphyries to connect with the same series in Thornton and Waterville, and by a fold with similar exposures in Tamworth and Madison. The presence of newer formations indicates two synclinals, though inverted, along the east flank of Washington and in Jackson. We find a marked anticlinal in the valley of Mt. Washington river, and between Jackson and Fryeburg, Me. The Thornton section (Fig. 12, p. 135) indicates a degree of unconformability between the Laurentian and Atlantic systems.

Structure of Mt. Washington. The section across the highest mountain of this range may be taken to represent the structure of the range; and the facts along this route have been given with much particularity. (See p. 116, *et seq.*, and Pl. VII.) The predominating dip is somewhat north of west. What may perhaps be the main anticlinal axis is that extending from the "cow pasture" to the upper part of Tuckerman's ravine, while a second runs parallel to it three fourths of a mile farther east. The common condition of the folds seems to us to indicate an inversion, the easterly-dipping strata being crowded beneath those inclined in the opposite direction. There will be a low, undulating easterly dip for several rods; then the strata suddenly change and stand upon their edges, or else dip at a very high angle into the mountain. This sudden change in the dip is supposed to be caused by the enormous pressure crowding the eastern flank beneath the western. Moreover, so far as investigated, there are no easterly dips on the west side. I think the westerly dips in the deep Ellis and Peabody valleys may be the continuation downwards of strata dipping easterly on the surface of the mountain.

The view had been proposed by Prof. Vose, that the westerly-dipping schists of the Washington range represented the western part of an anticlinal, the Carter mountains being probably the commencement of the eastern dip (p. 198). The measurement of Section IX across Bean's Purchase does not confirm this suggestion. The westerly dip prevails across to the line, while there are minor variations, as a limited synclinal about the upper part of Mt. Carter. Passing south-easterly more nearly across the strike, the north-westerly dip continues to the state line at Fryeburg, and perhaps farther, save a limited area in Jackson of newer rocks, which may indicate a synclinal fold. After reaching Maine, the dip changes to easterly and south-easterly all the way to Sebago lake, as shown upon Plate III. On the Grand Trunk Railway the easterly dips are reached in Gilead. We have, therefore, a problem of this nature: Given, a formation about forty-five miles wide. One third of the width on the western side possesses a north-westerly dip, with at least two newer bands disposed within it. The other two-thirds width on the eastern side posses a south-easterly dip, with supposed newer bands of unknown number. The structure of the whole mass is certainly anticlinal in aspect; but the western part has not more than half the thickness of the eastern, and there are evidences of synclinals in it. The proper explanation of these phenomena would seem to be that inversion is the normal condition of the whole area. A somewhat local pressure might produce a uniformly inverted dip in the western area. Independently of this, other peculiarly acting forces might invert the eastern area with its subordinate bands in the other direction. I think it will be shown farther on, that this main anticlinal line is the place for the subterranean development of the Lake gneiss, or one of the other lower groups. This fact would indicate a rising of the underlying terrane, but not sufficient, perhaps, to bring it to the surface in the elevatory period, while in the formative epoch the older series existed as a shoal or island, upon both sides of which the same kind of Montalban schists was being deposited. To the south-west, the lower formation now crops out at the surface; but from Tamworth, across to Oxford county, Me., the upper schists covered it, perhaps because of its submergence. Granting this explanation, it is easy to understand how, in the later elevatory periods, each side of an anticlinal line should be inverted separately, and the forces exerted so that the inclination shall be in opposite directions. A similar example is afforded by the Connecticut Valley and New Jersey Triassic areas. The former basin invariably dips easterly, the latter westerly, while there is a broad area of older rocks between. The question has been raised whether each of these Triassic areas has not been inverted. If it is possible that each one could be inverted, so that the apparent dip shall be in opposite directions, much more truthfully can the same supposition apply to the two flanks of the Montalban anticlinal, where inversions are the rule rather than the exception.

By measuring the course of the waved strata upon the east side of Mt. Washington, we can determine the direction in which the force of elevation has been exerted. The course of the range is about N. N. E.; and the direction, N. 23° W., S. 23° E., is the one that seems the most common in the measurement of dips. In the case of inversion, the force is commonly conceived of as acting in a direction opposite to that of the dip; hence the course upon Mt. Washington would be S. 23° E. Along the Atlantic border the direction is usually stated as proceeding invariably from the ocean, or at right angles to that indicated among the mountains. The pressure of the older gneiss area of Randolph and Berlin towards the ocean would therefore seem to have been greater than that of the submerged formation in Carroll county, from Madison to Fryeburg, towards the north-west.

Much might be said respecting the date of this elevation that would be profitless, since the facts indicating the epoch of disturbance are meagre. After the conversion of the Montalban strata into schists, whether by metamorphism or original chemical deposition, we have evidence of powerful disturbances among them;—in other words, this was the time of the formation of the Franconia breccia, when ledges of mountain size were first shivered into fragments, and then cemented by eruptions of fine-grained granite. As this same series occurs at Franconia and the Notch, fourteen miles apart, and possibly in Essex county, Vt., thirty-five miles away from Franconia, the action must have been widespread, and therefore powerful. That this period of eruption is distinct from that of the Pemigewasset granites, is shown by several considerations: 1. The lithological character is different. The breccia cement is the fine-grained rock described above (p. 169) as the "Breccia granite," bearing some resemblance to the so-called Concord granite, and very little to any of the Pemigewasset series. 2. The latter are of later origin than the breccia, because none of it has been found either in the fragments or cement of the formation. 3. The Pemigewasset granites are usually developed in massive overflows, while the Franconia cement is more limited in amount. 4. The coarser granites are found constituting the cement of clay and andalusite slates, the fragments of which have not undergone metamorphism. There is, therefore, a Franconia and a Pequawket breccia, formed at widely different periods, the materials of which are very different from each other. It should be remarked, however, that the numerous large veins of Breccia and other varieties of granite usually occur quite near the later series, as upon Mts. Webster, Willard, and Crawford; and the veins do not extend far away from the ragged edge. 5. The relations of the Labrador system to the Montalban are of much importance in this connection. Fig. 20, Pl. VIII, shows the Montalban elevated at angles of sixty degrees, overlaid by labradorite rocks dipping ten or twelve degrees upon the average. Similar sections could be drawn for the Waterville area, save that the lower formation is older than Montalban. These sections appear to indicate that the first elevation was very extensive, and that it was mainly effected before the deposition of the Labrador system. Granting that the Labrador system is well established as a geological horizon, it follows that the whole Atlantic system precedes it in time, and is to be regarded as a subdivision of the Laurentian group rather than of anything later.

These considerations lend probability to the suggestion, that not long after the close of the Montalban period there were disturbances resulting in the ejection of melted rock, and the beginning of the elevation of the Mt. Washington range. At this epoch it is probable that the principal part of the elevation was effected, the range having attained a great altitude. It is likely that there has never been a more important epoch of elevation in the physical history of New England.

The next period of elevation, of which evidence is afforded by the structure of the range, occurred after the deposition of the andalusite schists. It may be premised that there were ridges upon both sides of the later schists, so as to constitute the hydrographic basin in which they were deposited. Two epochs of this elevation can be insisted upon, the first to bring the secondary series into the same position with the primary; and, lastly, an interesting upheaval that seems to have determined the great altitude of Washington. On page 118 it is stated that the second fold has its axis almost at right angles with the first. The axes of the smaller curves along the road near the third mile-post run N. 30° W. Others higher up, that are more constant, dip N. 87° E., twenty-seven degrees more southerly than those first mentioned. It is not common, or at least it has not been often stated in geological treatises, that the same ledge will show evidence of forces acting nearly at right angles to each other in successive periods. It is the minor curves that run N. 30° W. The result of this reduplication has been the intensification of the altitude, just as a change of wind produces higher waves in the ocean.

What should have caused the force to spend itself in this northerly or southerly direction is not so easily apprehended. On the north of the mountains, the Bethlehem and Lake groups run nearly east and west. Is it possible that this area served as a buttress against which the south-easterly masses of rock (in the Lake district) were crowded, and, being immovable, reacted upon the pliable upper schists, bending them to conform to its own shape? Perhaps an inspection of the maps may suggest other and better explanations. The age of this last elevation will be referred to again, as it belongs to the Paleozoic period.

Another limited area of Montalban rocks in Pemigewasset has been discovered since writing pages 131–137, and it is shown upon the map (Pl. XII). It is situated along the west side of Hancock Branch, between Black mountain and the Greeley Pond notch. Nothing is known of the position of the strata there, nor are the proper limits of its distribution ascertained. It is mentioned upon page 109, in connection with the Bethlehem group.

Franconia Breccia. Much of what needs to be said about this formation has just been stated. In brief, there are two areas of it in this district,—in Franconia and Lincoln, where it is overlaid and divided into two parts by the Conway granite,—and in the White Mountain notch. The ledges consist of angular pieces of porphyritic gneiss and Montalban schists, cemented by a fine-grained granite. In the Notch the fragments do not seem to have been transported at all. The ledges have been shivered, and the pieces cemented again so near each other that one can see the same line of fracture in those that are adjacent. The breccia was thought at first to be a local formation (p. 141). Now, in consequence of the discovery of similar rocks in the Notch, and the ejection at the same time of granite veins all along the sides of Mts. Webster and Crawford, the disturbance seems to have extended over more than a local district. Specimens from other parts of the state are like this granitic cement, and future research may suggest the occurrence of the breccia in the other topographical districts.

3. Labrador System. The modifications of the first five groups are of less importance than those which follow. The evidence is plain that the Labrador system does not include, besides the triclinic feldspars, the porphyries and all the Pemigewasset granites. Hence the statements respecting the nature of the events transpiring in the Labrador period,—given in the chapter upon the physical history of the strata,—pertain to a later epoch. The Pemigewasset granites have no connection with the labradorites. The theory of a connection between them was based partly upon the nature of the rock underlying the Waterville labradorite. Our first account of it was correct, in substance, that it was gneiss. Subsequently it was thought to consist of the "trachytic" or Albany granite; and the erroneous estimate of the Pemigewasset series based upon it. Our further study of the specimens proved the rock to be a part of the porphyritic gneiss area (p. 156); and the reëxamination of the ledges confirmed the return to nearly the original supposition. Then a reconsideration of the mutual relations of the porphyries and labradorites elsewhere has not yet given any decided proof of their intimate association, nor of their superposition upon the Albany granite. We are therefore led to believe that the labradorites alone represent the Labrador system, and, as thus limited, it has been described (pp. 209–221). There are seven small areas of it, cut by a sort of "sienite" containing triclinic feldspars, and therefore supposed to close the period. The reduction of the Labrador White Mountain areas will render it necessary to abbreviate also those described upon page 11, Chapter I. The reality of the system is not affected by the removal from it of these various porphyries and granites. Their elimination makes the correspondence perfect between the New Hampshire and Canadian areas, thus establishing more firmly the existence of the series.

Some difference of opinion may exist among geologists as to the relations between the Montalban and Labrador systems. We have not found reason to change the conclusions derived from the section along the Mt. Washington river (Pl. VIII, Fig. 20). The labradorite rocks, with a very moderate dip, rest unconformably upon the greatly upturned edges of the Montalban schists, as if there had been large upheavals at the close of the Montalban period, and comparatively little disturbance since. I understand that Dr. Eugene A. Smith, state geologist of Alabama, finds a similar state of things in his field of labor—labradorites resting upon Montalban schists. The facts as interpreted are of great consequence, since they fix the geological horizon of the whole Atlantic system, while considerations of a stratigraphical character confirm this impression.

4. Huronian. As at present defined, the Huronian barely touches the edge of the White Mountains in Lancaster and Northumberland. On the east side of the Stark porphyry mountains exists a large development of hydro-mica, argillo-micaceous, and hornblende schists, with quartzites, which seems better allied to the Huronian than to any other group. The area on the map (Pl. V) is made to begin in Stark and Milan, extend north-easterly through Dummer to Errol, and then diminish to an extremely narrow band passing north-westerly to join a range of upper Huronian in Dixville and the divisions of Carlisle's Grant. The rocks agree with much of the area mapped as Huronian in Columbia and Stratford.

Closely connected with this area in character are the Jackson quartzites, the rather nondescript schists west and north of Umbagog lake, the Merrimack group of the southern part of the state, and, more remotely, the andalusite slate group of the White Mountains and elsewhere. The first will probably be colored as Huronian upon the map; the others will be distinguished from it for the present.

5. Merrimack Schists. This formation will be described in succeeding chapters, as it is best developed in the south part of the state. It is probably the equivalent of the eastern band of Huronian in Stark and Dummer. Further study of it may afford us better views of its proper character.

6. Andalusite Slate Group. In Massachusetts this group is found associated with the preceding in such a way as to suggest its later age. In Michigan a similar rock is given as the uppermost member of the Huronian. The mineral chloritoid found in the specimen from Willey brook by Mr. Hawes (p. 233) is suggestive of the Huronian. The range running through Mts. Moosilauke and Carr preserves a closer resemblance to the Montalban andalusite or fibrolite schists than those in the White Mountains. In our preliminary reports this has been ranked with the Coös group along Connecticut river, which it resembles chiefly through the similarity of the minerals andalusite and staurolite. The associated rocks are different in the two areas. I desire to call the attention of future explorers to the possibility of finding more of this formation upon the east spur of Mt. Madison and Pine mountain.

A possible clue to the age of this formation is afforded by its lithological resemblance to the lower Skiddaw slate of the Cumbrian mountains in England. These are Cambro-Silurian.

Prof. Sedgwick divides the Cumbrian rocks of northern England into three parts: (1) Skiddaw slate or Lower Cumbrian; (2) chloritic slate and porphyry, or Middle Cumbrian; (3) Coniston group or Upper Cumbrian. These are regarded as the equivalents of the Cambrian, from the Longmynd to the Bala group, or, in this country, from the Potsdam slates to the Trenton.

Concerning the Skiddaw slate, we have the following language from the introduction to a systematic description of the British Paleozoic fossils in the geological museum of the University of Cambridge (p. lxxxiii, 1855):

> Immediately over the central granite of the Skiddaw forest we have a very complicated metamorphic group, superior, perhaps, in importance to any other metamorphic group in South Britain. It has mineral veins which, though apparently of a much older epoch, present very interesting analogies to the mineral veins of Cornwall. This subgroup passes almost insensibly into the ordinary lower Skiddaw slate, through the intervention of a chiastolite rock and a porphyritic chiastolite slate.

7. *Porphyry.* This rock often passes insensibly into the feldspathic part of the Chocorua group. Dykes of it cut the porphyritic gneiss, all the divisions of the Atlantic group, and the Huronian. In one of our annual reports it was ranked with the upper Huronian, because it resembled closely the stratified porphyries referred to this series in Massachusetts, New Brunswick, Ontario, etc. It seems best now to call it eruptive, since so many dykes of it are found in the White Mountain district. Its period of eruption is thought to have preceded that of the Pemigewasset granites, because fragments of the porphyry are contained in the Albany granite, on Mts. Pequawket and Flume, and in the Conway on Cascade brook.

8. *Pemigewasset Granites.* These have cut the andalusite slates, and are therefore of later origin, whether that be Eozoic or Paleozoic. The theory of an overflow may not be tenable,—certainly it is not applicable to certain portions of the field occupied by the granites.

Two additional sections crossing these granites have been added upon Plate XI, in order to illustrate their surface outcrops and supposed interior connections. Fig. 25 shows the rocks between Mt. Lafayette and

Mt. Tom. On the west side of Lafayette there is an outcrop of porphyritic gneiss at Eagle lake [Clouds], with Franconia breccia lower down the mountain, having a supposed inverted position beneath the former. Above both is a narrow band of Lake gneiss, succeeded by Albany granite, the summit being capped by porphyry. The granite is supposed to occupy all the surface as far as to Redrock brook, when it is succeeded by red compact feldspar. The porphyry upon Little river, east of the Twin range, has a different texture and color from that on Redrock brook, but is supposed to have been erupted essentially at the same time with it, as well as with that upon Mts. Lafayette and Tom. The Pequawket breccia occupies the summit of the Twin range, being an ejection of later date than the porphyry. The Conway granite has not been certainly detected on the west side of the Lafayette range, on the section line, though it occurs abundantly a short distance south of it. Judging from its usual topographical position, it extends beneath the Albany granite, from just above the Lake gneiss, to the east slope of Little River mountain and New Zealand river. For similar reasons, the two outcrops of Albany granite upon Mt. Tom are supposed to unite beneath the slates; and the Conway is beneath the Albany series. No attempt is made to show the internal relations of these several igneous rocks to each other, as decisive evidence on this subject yet remains to be gathered.

Upon Fig. 26 will be found a section from the Montalban series near Chocorua pond, Tamworth, to White's ledge, north of the Saco river, in Bartlett. In Tamworth the Concord granite has planes dipping five or six degrees northerly; but the true position of the strata has not been determined. Probably it dips at an angle of seventy degrees in a northwesterly direction. The Conway granite has a fine development in the neighborhood of Knowles's pond, but is less conspicuous directly upon the section line back of Piper's house (p. 153), where it is situated higher than the Montalban ledges. Between this outcrop and the first appearance of the Chocorua granite, the ledges are concealed. This is the place of the Albany granite, which covers a very large area to the northeast of this spur. The Chocorua granite occupies all the area from the end of the spur to Ellen's falls, near Swift river. The Albany granite then makes its appearance, occupying the whole of the lower part of the valley. It is not capped by the Chocorua granite upon the north side, but by red compact feldspar and the Pequawket breccia, which occupies a greater space here than in its other area east of the Saco. No ledges of slate have yet been found upon Mt. Mote, while the breccia is full of its fragments, inclined a few degrees northerly. On the north side a porphyry makes its appearance underneath the breccia, followed by the Albany, and then the Conway granite. The supposed continuation of the latter sheet from Tamworth to Bartlett, beneath the other eruptive rocks, is forcibly suggested by the position of the outcrops upon the opposite sides of these mountains.

The general arrangement of these granites agrees with what has been stated heretofore, in respect to their topography. As a rule, the Conway granite is overlaid by the Albany; while the Chocorua series and the porphyries are never seen below either of those first named. The first mentioned has the widest distribution, from the Pemigewasset valley to the Green hills of Conway in one direction, and from the Sugar Loaves in Carroll to Tamworth in the other. It is also the most abundant in the East Branch and Saco valleys.

The principal Albany granite areas are these, and they fall mostly within the outer line of the Conway: 1. Mts. Welch and Tecumseh. 2. From Mt. Osceola northward across the east branch above Pollard's, branching at Mt. Liberty, most of it passing north-easterly, encircling the porphyry of the Twin range, crossing New Zealand river, and divided into two parts by Mt. Tom. 3. A very small area in the north-east corner of Campton. 4. North of Mt. Carrigain. 5. East of Tripyramid in Waterville. 6. Occupying the principal part of Albany, passing northerly into Jackson, and easterly beneath Mt. Pequawket. 7. In the north part of Jackson. 8. West part of Chatham. 9. North-east part of Jackson (Mt. Sable). 10. Dykes between Tin and Thorn mountains in Jackson.

Further study continues to increase the bounds of the Chocorua group. The largest and most irregular is the one having Mt. Chocorua for its main elevation, with a narrow spur reaching nearly to the Saco on the north, and a broad overflow to the south in Tamworth. The others most important are the Whiteface-Passaconnaway, Silver Spring and Tremont, Giant's Stairs and Resolution, and one not mapped out embracing Frankenstein cliff. There are also smaller ones in Jackson and Chatham.

9. Pequawket Breccia. The production of this breccia is the latest occurrence of moment in this district. Its paste bears some resemblance to the Albany granite. Inasmuch as fragments of porphyry occur in it, the ejection of the paste must have been subsequent to the pouring out of the compact feldspars over the Mts. Twin, Lafayette, Tom, Carrigain, and other areas.

Last Period of Elevation.

We have already described a very important period of elevation at the close of the Montalban period. There have been two later ones in Paleozoic times of considerable importance, of which little is known. The first is the disturbance which performed most of the elevatory work upon the andalusite slates of Mt. Washington. It was probably coëval with the eruption of the Pemigewasset granites. Such an enormous amount of melted matter came forth at this time, that the convulsions attendant upon it must have equalled those occurring at the close of the Montalban period. Upon examining the strata in western New England, we find evidence of upheaval at about the close of the Lorraine period. This may have been the same with the one in question. It is the most probable one of all that are known to have elevated our formations.

The latest epoch of elevation in these comparatively early times must have occurred in the Devonian era, and it was one of great importance. All New England and the middle Atlantic section was deeply submerged before the deposition of the Helderberg limestones. The widespread coralline limestones throughout this section indicate this, and we can find no evidence of a greater submergence after Eozoic times. This section must have been vigorously crowded after the deposition of the Helderberg rocks, since they have all been elevated at a considerable angle. They stand vertical in Littleton, and as high as seventy-five degrees in many parts of northern Maine. In that state we find resting upon them, at small angles, the middle or upper Devonian sandstones. I find I have remarked concerning those that are developed near Eastport, in my first report upon the geology of Maine, that "they seem to have been spread over the Silurian [Helderberg] rocks, just as alluvium is spread over the solid ledges." There is positively less inclination to many of these sandstones than to the Connecticut Valley sandstones of a much later age.

Now, as the Helderberg rocks occur at a considerable distance from

Mt. Washington, it may be that this elevation would hardly effect much alteration in the andalusite strata, or no more than is evidenced by the smaller curves along the carriage-road. But the amount of disturbance upon the Helderberg rocks themselves, in the edge of the mountains, was enormous.

The attempt to localize in time these several disturbances is quite unsatisfactory, as our data for generalization are so meagre. These suggestions may be regarded as merely inviting the attention of scientists to the problem. Some would doubtless prefer to refer one of these epochs to the Appalachian revolution, at the close of the Carboniferous, or to an earlier one at the beginning of the same era. I have thought these latter disturbances inapplicable to the mountains, since none of the upper Devonian or Carboniferous beds occur within a hundred and fifty or two hundred miles of them; and their foundations had probably become well fixed before these dates, so that they were not sensibly affected by either of the Carboniferous convulsions.

Eozoic, or Paleozoic?

The proper place for presenting arguments in favor of the Eozoic or the Paleozoic age of the White Mountain rocks will be at the end of the subject of Stratigraphical Geology; but our present expression of opinion would not be complete without a brief statement of the principal arguments upon both sides of the question, whether the bulk of the White Mountains belongs to the Eozoic or the Paleozoic system.

As seen by the review of opinions, the first theorists accepted the view that these rocks were Primary or Eozoic. Subsequently it became fashionable to call them all altered or metamorphic Devonian or Silurian, for these reasons:—1. There is a marked lithological difference between the Adirondack and White Mountain gneisses. 2. The north-easterly unaltered continuation of the formations consists of Devonian and Silurian groups;—therefore the White Mountain rocks are the same in a metamorphic condition. 3. In proceeding south-easterly from the St. Lawrence and the Adirondacks, the strata dip easterly most of the way to the sea-shore. Therefore we rise in the geological scale after leaving the Laurentian; and hence the White Mountain rocks must be Devonian, as they follow the Silurian of the Champlain valley. 4. A section from Labrador across the peninsula of Gaspé to Nova Scotia carries us from the Laurentian to the Carboniferous; hence, as we have both these formations at the same distance apart—a few hundred miles along the line of strike—the intermediate strata in New England must be the same with those in the British provinces, or the Paleozoic in a metamorphic condition. There may be other considerations; but these are the most important, and are the ones which have carried conviction to many minds. As the process of metamorphism is supposed to be capable of modifying the mineral character of rocks, whether by abstracting, altering, or adding constituents, it has afforded a very convenient method of explaining why there should be little or no chemical resemblance between the original and derived strata.

I would answer the arguments as follows, in the same order:—1. We accept the difference between the Atlantic parts of the White Mountain series and the Laurentian, while insisting that the latter is represented in our two oldest groups. The Atlantic and later rocks are not represented at all in Laurentian regions. 2. We have presented the results of special explorations in north-western Maine (pp. 204–209), which entirely disprove the assertion of the passage of the Gaspé into the White Mountain rocks. 3. The dips, in proceeding south-easterly from the Adirondacks, are uniform to the east in many sections. Where this is the case, it simply proves inversion. If the strata have been inverted, then we descend the scale of formations instead of rising; and therefore the Green and White Mountain rocks are older than those of the Champlain valley. Furthermore, many sections display a number of axes in pursuing this course, as is illustrated upon Plates II, III, and IV. In the Vermont report there are fourteen sections crossing the Green Mountains. Eight of these show distinctly an anticlinal structure for the Green Mountains, the most clear cases being in the Winooski and Lamoille valleys, where rivers have cut through them to their base. Two others possess the same structure, as learned by careful reëxamination of their routes since the printing of the report. Of the four others, all are monoclinal,—that is, have an inverted dip. 4. If the argument held good, we should not find the *Paradoxides* in a slate adjacent to the Carboniferous in Massachusetts, since the formation containing the trilobite is older than anything in the Champlain valley.

The following considerations are strong arguments in favor of the

Eozoic age of the Green and White Mountain gneisses:—1. They are the northward continuation of the Eozoic rocks of New Jersey, the highlands of New York, and their extension across the Connecticut line. We can trace them all the way from Alabama to Canada,—twelve hundred miles,—and they are flanked by the same broad, fertile Cambro-Silurian Appalachian valley on the west side all the way. An orographical map of the coast regions of America will show this fact in a very satisfactory manner. If the valley formations are the same through East Tennessee, the great valley of Virginia, the limestone region of Pennsylvania, and the Berkshire and Champlain valleys of New England into the St. Lawrence, why should not the adjacent and continuous highlands, on their eastern border, have been formed essentially in one and the same period, especially as they have been almost universally regarded as Eozoic south of Connecticut?

2. Almost all the way the gneisses are bordered by a quartzite, usually regarded as of Cambrian age. North of Adams, in Massachusetts, I have examined four localities of a conglomerate connected with this quartz, containing pebbles derived from the ruins of the formations to the east. I suppose the whole mass has been derived from the same source, but the fineness of the materials prevents its recognition. It should be remarked that there are no other formations from which it could have been derived, save the Adirondack-Laurentian, which is from twenty to a hundred and fifty miles distant.

Two considerations are derived from the study of New Hampshire rocks. 3. The discovery of the Labrador system, overlying the most abundant and characteristic White Mountain strata, makes it clear that the latter are older than the former, which are confessedly Eozoic. 4. Fossiliferous Helderberg strata occur on the extreme west and northeast of the White Mountains, the latter in Maine. There are no other groups so likely to be metamorphosed into the Montalban schists as these, yet they occur side by side with the metamorphic schists, with their fossils. The schists occupy the elevated tracts, and they constituted the continental dry land when corals luxuriated in the calcareous waters of the deep Connecticut Valley sea.

5. The identification of the two oldest White Mountain groups with the Laurentian is satisfactory, so that a portion of the debatable terri-

tory is removed to its proper place in the Eozoic. 6. There is no correspondence between the White Mountain rocks and those of any part of the Devonian formations with which they have been compared, either lithological or stratigraphical. Our predecessors became so enraptured with the "New York system," that all the rocks in the adjacent states were supposed to constitute a part of it. 7. The late satisfactory reference of the altered Quebec group to the Huronian has shed a flood of light upon the age of our rocks, and rendered still more unnecessary the application of extensive and extreme metamorphism to explain the age of the White Mountains. As there seems to be an unreasonable opposition, in some recent publications, to the existence of a Huronian system, I will discuss its claims to recognition in the next chapter.

Appendix to Chapter III.

During the preparation and printing of this chapter, great improvements have been effected in the delineation of the topography and the establishment of the nomenclature of the White Mountains. The past year has witnessed nearly as great advance in these particulars as the whole accumulated surveys and traditions of previous years had amounted to. All this material has been employed in the preparation of our topographical model of the state,—upon the scale of one mile to an inch horizontally, and one thousand feet to the inch vertically,—designed for exhibition at the Agricultural college, Hanover, and the Normal school, Plymouth. The basis of the model is a contour-map, upon the same horizontal scale, showing all the approved and newly-suggested names. The attempt is being made to reproduce, by means of a heliotype or photo-lithographic sheet, the effect of this raised map—with what success will appear in the Atlas. As this is the last opportunity we shall have for speaking of the topography of the White Mountains, I deem it proper to mention here this map-model, and the additional sources from which the information for it has been derived, chiefly during the year 1875.

1. The Portland & Ogdensburg Railroad has been completed through the heart of the mountainous district; and the engineer-in-chief has allowed us to make use of all the data collected by him for the building of the road. Concerning the great value of the excavations to the study of the formations, I have spoken heretofore. 2. Prof. E. C. Pickering, of the Massachusetts Institute of Technology, with several of his students, especially John B. Henck, Jr., spent the summer of 1875 among the mountains, and carefully studied their topography. Mr. Henck carried a plane table upon many of the higher summits, and succeeded admirably in locating their positions upon a map. These gentlemen have kindly allowed us the use of all their results, which have seemed to us to exceed in accuracy the work of Prof. G. P. Bond, which had previously been made the basis of our maps. 3. Miscellaneous sources,—as a few observations of

the geodetic connection survey; surveys of property lines, by George T. Crawford, of Bristol; perambulations of M. F. Sweetser, in preparing a guide-book; decisions of the new Appalachian Mountain Club; the regular work of the geological survey, etc.

A few friends of mountain exploration have united in the formation of a club, whose object is the study of comparative geography, and the scientific and esthetic exploration of the highlands of New England and the adjacent regions. The first field of their labor will be the White Mountains. They propose the preparation of accurate topographical maps of this region, making new surveys, and carefully studying ancient and modern records in search of the proper appellations to be applied to the several geographical objects. At a meeting held in January, 1876, the subject of nomenclature of our mountains was discussed, and many excellent points made. The club voted to adopt a revised nomenclature, based mostly upon the map of the geological survey. On account of the influence which this club will be likely to exert hereafter, I have thought it best to adopt their names upon the map-model in the atlas, and hope the effort to establish a judicious nomenclature will be followed with success. Not all the names used by the geological survey meet their approval. Their canons embraced the following points: first, names of well-established usage should remain; second, in case of disputed euphonious titles, that which has been longest known or was applied first, should be adopted; third, in proposing new designations, the best classes to be selected from are the names of Indian chieftans formerly residing in the state, of the early explorers of the mountains, of persons who have identified themselves with the development of the district, or marked resemblances to hills in other regions. They did not attempt to name all the eminences in this way—only the most prominent. For the whole group they adopted a division according to area and altitude, which will be explained in the appendix to this volume, where the geographical positions of all our New Hampshire mountains will be stated by Prof. Pickering. I will mention, following the topographical subdivisions of the White Mountains proposed in the first volume, the most important suggestions and adoptions of this club, and, where there has been a change from the usage of the report, state it, so that no ambiguity may arise from the employment of one designation upon the map and another in the text. It will certainly be a great gratification to all who are interested in the mountains to know that so much pains are taken by the friends of mountain exploration to render our scenic points attractive in title and easy of access; for, among other objects, the club propose to make paths to new summits, and interest tourists in every nook and dell, ridge, ravine, and summit.

In Northumberland the original name of *Cape Horn* was thought to be singularly appropriate, and therefore its replacement by Mt. Lyon, as suggested in the geological report, uncalled for. There are several improvements in the Mt. Carter district. Mt. Winthrop is a new name for a moderate eminence south-east from Shelburne village. Mt. Carter is the central mountain of the range, a little north of east from the Glen house (4702 feet). Imp mountain, Mt. Moriah, and Bald mountain lie to the north-east, extending into the town of Shelburne. In the south-east corner of Bean's Purchase the names of Wildcat and Carter Dome were adopted for the mountains on the south-west and north-east sides of Carter notch, the last being the southern end and the highest (4830) part of the unbroken Carter range. It replaces Mt. Height. Mts. Eastman and Sable have been altered somewhat in position. Mt. Slope in Chatham should be written *Sloop*, in accordance with local usage since the days of Belknap's (1791) map. Perkins notch, between Wildcat river and Wild river, is now for the first time placed upon a map.

There may be several additions to minor topographical features upon Mt. Washington. Cutler's river seems, according to the best judgment, to be the same with Ellis above the Pinkham road, New river being between this and Glen Ellis fall. Huntington's ravine was improperly described on page 188. It is the second ravine parallel with and north of Tuckerman's, tributary to the valley called by that name in the first volume. Pine hill, formerly Camel's Rump, has become Pine mountain. Hart's mountain is properly the steep bluff just above Wilkes's ledge, opposite Sawyer's rock, but, as I have applied it to the summit of the range opposite Nancy river (not brook), I think it best to leave it as pertaining to the whole range. Wilkes's ledge is often improperly called Hart's.

Owl's Head, at the north end of Cherry mountain, has been styled Mt. Martha, and the name adopted by the geodetic connection survey. The Willey range, from its beginning near the White Mountain house as far as Mt. Tom, may be known as the Rosebrook range, the highest peak to the south being identified now with the Mt. Echo of Guyot. Mt. Andalusite is a small eminence on the north-east flank of Mt. Tom. Mt. Field was adopted by the club for the high mountain south of Tom, and its north spur (p. 177) may be known as Mt. Avalon. Thoreau falls designates the "falls on the north branch of the east branch of the Pemigewasset." Mt. Anderson is the name of the pointed summit between Mts. Lowell and Nancy, after John F. Anderson, of Portland, engineer-in-chief of the P. & O. R. R. Vose's Spur is applied to the very sharp peak between Carrigain notch and Mt. Carrigain, after Prof. G. L. Vose, of Brunswick, Me., one of the former assistants on the geological survey. Passaconnaway and Tripyramid are accepted for the mountains thus called by us. (See p. 211.) Mt. Kancamagus is proposed for the unnamed mountain just east of Greeley pond; Mt. Paugus for the highest peak between Mts. Chocorua and Whiteface; and Mt. Wonalancet for what has been known as Toad mountain.

The mountains around Upper Bartlett are now coming into prominence, with the increased facilities for their ascent. From the cliffs near the mouth of Rocky Branch to the neighborhood of Mt. Crawford, east of Razor brook and north of the Saco, is the following array of names: White's ledge, Mts. Stanton, Pickering, Langdon [Blackwell], and Parker. Willoughby ledge is at the east angle of Razor brook and Saco river. On the south, there was not such a unanimity of sentiment as to names. *Moat* seems to have been the original spelling of the high mountains west of Conway. Silver Spring mountain having been applied to the summit rising back from Sawyer's rock by Prof. Bond, in 1853, has since then been adopted by Guyot, Snow & Bradlee's model, and the geological survey. Owing to engravers' errors, its position has not been clearly understood; but an inspection of the original manuscript of Bond's map removes all doubt as to its application to the peak just spoken of. Table mountain appears first on Guyot's map, another name being Bear. On looking at this elevation from Mt. Willard and other peaks to the north, the appropriateness of the name Table for this mountain is very apparent. A small peak to the north-east of Moat, showing square, precipitous sides towards Jackson, has been designated as Mt. Attitash, after the Indian name for blueberries.

In the Twin Mountain range, it has been proposed to commemorate Guyot and Bond in the two most southerly peaks, about a mile apart, Bond being the one farthest south. In Campton, Mt. Weetamoo (misspelled on p. 204) is a new name for the mountain west of Sandwich notch. Beech hill in Carroll and Bethlehem is beginning to be called the Sleeping Giant. Peaked hill in Bethlehem is known to the residents as Mt. Agassiz. Black mountain in Benton, the one nearest Moosilauke, is named Mt. Clough, in honor of the late Amos F. Clough, of the Mt. Washington expedition. There are already several Black mountains, so it seems strange that there should be a desire on the part of any to retain this appellation for Sandwich Dome. Eagle lakes is a revival of Guyot's term for the Lakes of the Clouds upon Mt. Lafayette. Tamarack pond (p. 158) is now known as Mouran lake. (See vol. i, p. 504.)

Much was said at the meeting of the club about the use of the term Pequawket for the mountain in Chatham, sometimes called Kiarsarge and Kearsarge. Confusion arises from its similarity to Kearsarge in Warner, whose claim to the name has never been called in question, while its application in Chatham has been discussed for more than half a century. Two mountains, only sixty miles apart, should not in these days of rapid transit be known by the same name. In this juncture, therefore, the question becomes one of priority. Examination of the maps shows the application of the name to the Warner mountain by Blanchard and Langdon in 1761, and by Holland in 1784 (see Atlas), while nothing appears for the Chatham peak. Belknap's map in 1791, and others of 1796, first show the application of the name to the latter mountain. In this connection it is proper to state why it was ever proposed to call Pequawket Kiarsarge. It appears probable that the Conway pioneers came chiefly from Concord, and that they brought the name of their favorite mountain with them. It is certain that the names of the leading families in Conway, in early times, agree with many of those in Concord. Usage has by no means been unanimous in favor of Kiarsarge for Chatham. Dr. Jackson, in his geological report, Carrigain, in the state map of 1816 (see Atlas), and the United States Coast Survey use the name of Pequawket. The usage in Conway and Bartlett is divided between the two. In view of these considerations, the members of the club present at a late stage of the meeting voted to recommend the following formula, and use the name in brackets only because of the strong feeling manifested in its favor by its partisans—Mt. Pequawket [Kiarsarge]. But the hope was expressed that the bracketed title would eventually disappear.

CHAPTER IV.

GEOLOGY OF THE CONNECTICUT VALLEY DISTRICT.

THE Connecticut Valley district is separated from the rest of the state by features mainly dependent upon geological structure. The eastern border line is not the water-shed between the Connecticut and Merrimack rivers, but the boundary between diverse systems of strata, giving rise to agricultural and topographical peculiarities. This region is limited northerly by the crossing of the valley by the Gardner Mountain range, giving rise to the "Fifteen-miles falls," between Monroe and Dalton, the river descending three hundred and seventy feet, or one hundred feet more than from the falls to the Massachusetts line, a distance of one hundred and thirteen miles in a direct course. The eastern boundary follows the line between the Coös group and the Atlantic gneisses. This usually conforms with the summit or eastern base of a mountainous range of quartzite. The northern and western boundaries coincide largely with the hydrographical boundaries as far south as the granite mountains east of Montpelier, and then include the greater part of the calcareous formations in eastern Vermont. These are narrowest by Mt. Ascutney, opposite Cornish, so that a natural primary division of the area into two parts is suggested by this constriction.

The soils of this district are of three kinds: first, those on the fertile meadows of the Connecticut and its principal tributaries; second, the rich uplands of the calcareous districts, comprised chiefly within the western side of the river, while constituting areas of variable size on the

New Hampshire border, as in Cornish, Claremont, Lyme, and Orford; third, the upland tracts underlaid by the micaceous schists and quartzites. These varieties result from the character of the ledges; and, as stated heretofore, the soils of the Connecticut valley are among the best in the state.

For convenience in our descriptions, the rocks of this district will be described under four topographical divisions: first, the Ammonoosuc Gold field; second, the balance of the northern section, extending sufficiently far south to embrace the Mt. Ascutney rocks; third, the southern section of the district from Charlestown to Chesterfield, opposite Brattleborough, Vt.; fourth, the Helderberg region, embracing Hinsdale, part of Winchester, Vernon, etc., Vt., and parts of Northfield and Bernardston, Mass. Whatever facts we may happen to possess respecting the rocks of the western part of the district, in Vermont, will also be presented, though our information of that part of the area is not extensive. Enough is known of the rocks on the western side of the river to render feasible the presentation of the geology of the whole district. The boundaries of states are not usually the natural limits of formations, so that we must trespass a little upon the Vermont territory. Our general geological map will be seen to extend into that state about the width of two townships, except in Essex county, where more land is included. We have been enabled thus to extend our map, through personal investigations in connection with the Vermont geological survey, and more recently in continuing our section lines across to Lake Champlain, for the benefit of the museum.

THE AMMONOOSUC GOLD FIELD.

This field embraces the territory bounded west by the Connecticut river, north by the town of Dalton, east and south by the older gneissic areas, or from the west border of Bethlehem, through the eastern parts of Lisbon and Landaff, to the northern part of Haverhill, and thence to the Connecticut river. This embraces the whole of the towns of Littleton, Monroe, Lyman, Bath, and parts of Haverhill, Landaff, and Lisbon. It is all expressed on the small geological map in the first annual report (1869), and also in Fig. 27. The large map in the Atlas does not quite cover the whole ground, it being confined to the space between the

Connecticut and Ammonoosuc rivers, and not including the whole of the Helderberg area of Littleton.

The following are the rock formations displayed in the Ammonoosuc Gold field, arranged in the supposed order of their age: 1. Laurentian, consisting of the porphyritic and Bethlehem gneisses. 2. Atlantic gneiss, represented by the Lake division. 3. Huronian, embracing the Lisbon and Lyman groups and the auriferous conglomerate. 4. Cambrian clay slate. 5. Coös group. 6. Swift Water series. 7. Helderberg quartzites, slates, and limestones.

The general arrangement of these formations appears in Fig. 27. The first two gneisses of Laurentian age border the field upon the north-east; and the second is probably repeated in Haverhill, though not here separated from the following division, which borders the field most of the way upon the east side. A spur of this Lake gneiss divides the Coös group for a couple of miles in the north-east part of Lisbon. The western part of the field is a basin of the Lisbon group holding the upper Huronian, clay slate, and Helderberg, the Coös group being confined to the region east of the Ammonoosuc. The clay slates occupy two lines of outcrop, separated by the Lyman group. The more eastern one is auriferous. The Coös group is isolated from all connection with its kind, being separated from its northern continuation on account of the elevation of a range of Bethlehem gneiss. The Helderberg series appears to follow the course of a mountainous ridge along the centre of the field, lying principally in Littleton. The map was constructed primarily for the sake of portraying the peculiarities of these rocks,—hence all the section lines upon it are seen to cross this area. A sketch of the Helderberg rocks of New Hampshire has been published by us in the *American Journal of Science and Arts*, for May and June, 1874, in which Fig. 27 appeared; and it is used now, with the approval of the editors of that magazine. We are also able to present additional information concerning these rocks, and the other formations arranged about them.

1. Laurentian.

Very little needs to be said concerning the Laurentian areas, as they just touch the borders of the field, and have been amply discussed elsewhere. The porphyritic gneiss area occurs at the corners of the towns of Littleton, Whitefield, Bethlehem, and Dalton, forming an oval-shaped isolated area of about four square miles in extent. The Ammonoosuc flows along its eastern border; and there is a large hill in the western or central part, about six hundred feet above the river. This area is the most northern exposure of the porphyritic gneiss in the state. It is supposed to be connected with the great Lafayette-Moosilauke range beneath the overlying Bethlehem group, and to be the oldest formation in New Hampshire.

The determination of the dip of this rock near the Wing Road station has been a difficult matter. There are jointed planes, with scarcely any inclination that might be taken for strata. At the suggestion of Dr. T. Sterry Hunt, a crystalline arrangement of materials dipping 75° S. 40° E. was decided upon to represent the strata. The first set of nearly horizontal divisional planes presented no variation of mineral composition, but the second exhibit an alternation of coarse gneisses, fine feldspathic layers, and other varieties, separable only by a difference of character. They are also more irregular than the others. The gneisses show two feldspars,—orthoclase and oligoclase,—two micas,—muscovite and biotite,—and amorphous quartz. On the north town line of Bethlehem, and at the west base of Kimball hill, I found a ledge of the rock having in it a gneissic seam, two inches thick, dipping 25° N. 20° W. The hill west of the Ammonoosuc, sometimes called Bald hill, is composed of a bare ledge of this rock. It is most conspicuous as seen from the village of Bethlehem, and is a spur of Mann's hill, with but a slight valley between. The feldspar crystals are conspicuous on Mann's hill, near the junction with the mica schist, and the dip is about vertical, perhaps 70° N. 75° W. It is presumed this rock outcrops in the south-east corner of Dalton.

The south-western end of the most important area of Bethlehem gneiss projects into the Ammonoosuc field, crossing the river just above North Lisbon. The dip is unusually low on the river, being only 30° northerly. At the "lead mine" the dip is 36° north-west. Farther to the north-east the dip rises to 75°. As the strata are monoclinal, from an inversion, it is difficult to determine whether the axis is anticlinal or synclinal, without reference to other parts of the terrane. It would seem to be an overturned synclinal, when all parts of the terrane have been compared with each other and the adjacent formations. The angle of inclination is less

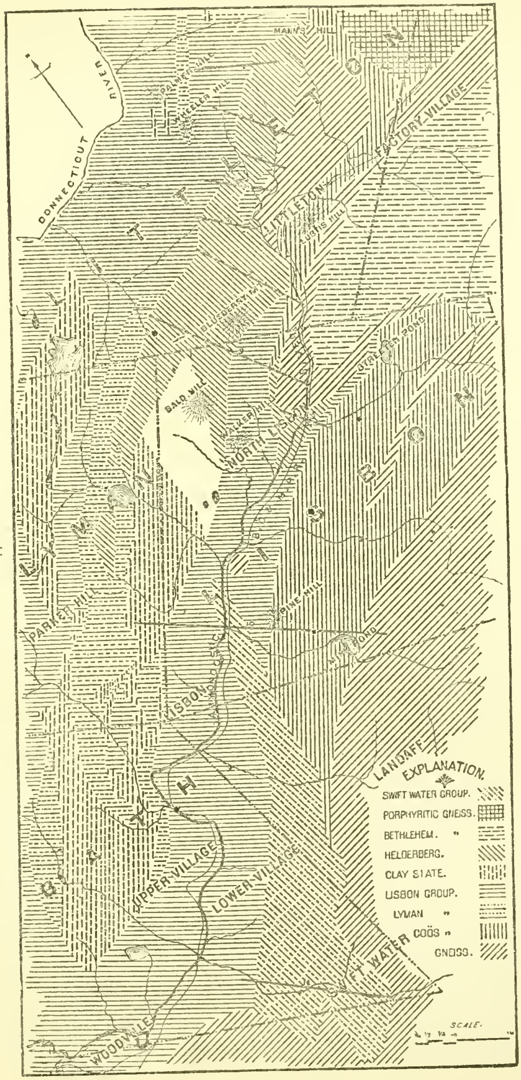

CONNECTICUT
RIVER
MANN'S HILL
PALMER HILL
WHEELER HILL
FACTORY VILLAGE
LITTLETON
CURTIS HILL
BLUEBERRY MT.
STREETER POND
BALD HILL
WALKER HILL
NORTH LISBON
PARKER HILL
PINE HILL
LISBON
LANDAFF
UPPER VILLAGE
LOWER VILLAGE
WOODVILLE
EXPLANATION.
SWIFT WATER GROUP.
PORPHYRITIC GNEISS.
BETHLEHEM. "
HELDERBERG.
CLAY SLATE.
LISBON GROUP.
LYMAN "
COÖS "
GNEISS.
SCALE.

Fig. 27.

than that of the newer formations upon both sides. Hence it is believed there is an unconformity, the older rock really possessing a greater angle of inclination, as we must add to its present dip 90° for inversion. The hill east of North Lisbon is covered heavily with drift; and explorations have not been made extensively away from the road, so that our dip observations there are scanty.

The upper layers, or outer border of this area, are different from the characteristic Bethlehem rock, containing an abundance of black mica in place of the chloritic mineral, and occasionally lacking an abundance of feldspar. Some layers are epidotic. In my first article this narrow outer band was referred to the next division of gneiss. It is better to place it in the Bethlehem group, partly because of its recurrence in the older rock in terranes lower down on the Connecticut river. The map shows a small outcrop of this member just below the mouth of Salmon Hole brook, nearly on the line of the continuation of this formation. I have sometimes thought it passes from this locality to the Atwood gold mine, a mile east of Lisbon village. The dip at the first-named place is inverted. As the same formation appears in Haverhill, it may be continuous near the surface from Bethlehem. If so, it may determine axes in the later formations.

2. Atlantic Gneiss.

This belt is the south-west continuation of the Berlin-Randolph and Whitefield ranges. The first lies mainly to the east of the Coös group in Lisbon and Landaff, belonging to the territory assigned to the Merrimack topographical district. The latter is nearly cut off by the Wing Road porphyritic gneiss, and spreads out more largely in the east part of Littleton. The village seems to lie upon it, though covered by coarse drift, and having micaceous quartzites in the river. Mann's and Oak hills furnish the first exposures of this gneiss. No evidence of its existence beyond Parker brook has yet been discovered. The narrow band of gneiss in Fig. 27, encircling the Bethlehem gneiss from Factory village to North Lisbon, and thence beyond Streeter pond, is included with the latter formation constituting its upper member. The north-westerly dip is universal over the western area of this gneiss. There is first its representation on Fig. 11 for Whitefield. Between Bethlehem Hollow and the Wing road the position is 80° N. 42° W. Oak hill shows the dip of 40° N. 42° W. The inclination is like this a quarter of a mile north of the Littleton cemetery, at E. P. Miner's. I think the dip is higher at the most northern development of the gneiss, on Mann's hill. Common gneiss and hornblende schists are interstratified there. Two of the sections soon to be presented show this gneiss in its relations to the chloritic strata, it being apparently beneath them unconformably.

3. Huronian.

This formation exists in this field in three parts,—the Lisbon and Lyman groups, and the auriferous conglomerate. The two first are separated upon Fig. 27, and were described for the first time, under these appellations, in the article cited above. The first is the lower division, embracing the greenish schists, conglomerates, copper-bearing strata, quartzites, jaspers, and dolomites, usually referred to this age and regarded as characteristic of the group. This rock is disposed in a synclinal way, dipping north-westerly where it is nearest the Atlantic gneiss, upon the east side of the basin, and south-easterly upon the west side, or on Gardner mountain. The upper series is inclosed within the limits of the Lisbon group, and consists of drab schists, mostly of silica, with small percentages of iron, lime, and magnesia, and weathering very light, so that in the field we called them "white schists." Many ledges are conglomeratic, the pebbles being mostly elongated, and composed of essentially the same material with the mass of the formation. Dolomite is especially abundant in it. The uppermost member is a conglomerate of siliceous pebbles, never exceeding two hundred feet in thickness. It is called auriferous, because assays of it in several places indicate the presence of a small amount of gold. Irregularities of direction and faults are beautifully illustrated by the areas occupied by this member, as will be particularly described. Though somewhat thrown out of place, the general arrangement of the Lyman group and the conglomerate is that of subordination to the Lisbon series, or a synclinal arrangement within the limits of the latter.

In order to illustrate the relations of the three members of the Huronian system to each other, and to the underlying and upper strata, I will insert a section showing the outcrops between Bronson's lime quarry, in

Lisbon, to Smith's brook in Lyman, giving, also, the thicknesses as measured on this line.

At the south-east end of the section there are the ordinary gneisses of the Lake division, dipping about N. 30° W., and holding a band of azoic limestone, perhaps one hundred feet thick, inclined 50°, which has been extensively quarried by Mr. Orrin Bronson. On the hillside toward the pond are friable gneisses, often very micaceous and carrying crystals of staurolite, dipping 30° N. 70° W. This is bordered by a band of hornblende schist dipping in the same direction: 40° is the average for its whole width. The hornblende is an associate of the gneiss formation rather than of that which follows. The estimated thickness of this gneissic group, between the limestone and Mink pond, is 2500 feet. This assemblage of gneisses and associated rocks west of the limestone is slightly suggestive of the Montalban member of the Atlantic system. On the north side of Mink pond is a gray, friable mica schist, holding in profusion the reddish staurolites and garnets, the locality being one well known to mineralogists. The average dip being 56°, the thickness must be 3300 feet. This band is followed by the same garnetiferous slates which occur upon the south branch of the Ammonoosuc. Staurolite is less abundant in this than in the previous band, and it is almost wanting in the western portion. With an average dip of 58°, this slate must be over 3000 feet in thickness. This all belongs to the Coös group.

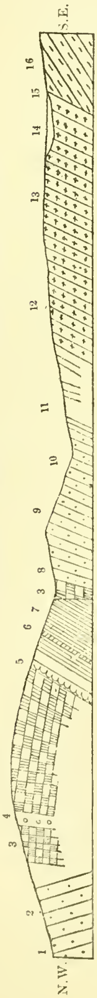


Fig. 28.—SECTION FROM BRONSON'S LIME QUARRY TO SMITH'S BROOK, LYMAN.

1, Smith's brook; 2, Lisbon group; 3, 3, Lyman group; 4, Auriferous conglomerate; 5, Quartz veins; 6, Auriferous quartz vein; 7, Clay slate—Cambrian; 8, Lenticular quartz, near J. Titus's, Lyman; 9, Lisbon group; 10, Lisbon village; 11, Swift Water series; 12, Coös slates; 13, Coös schists; 14, Mink pond; 15, Staurolite gneiss and hornblende of Atlantic system; 16, Limestone.

The Swift Water series follows. For one hundred and forty rods there are quartzites and sandstones, with an average dip of 50°, which gives 1769 feet in thickness. More particularly, an excavation for gold at the eastern border shows slaty layers, quite siliceous, with sandstones considerably vitrified. Next is a sandstone, with whitish cement. Then there are in order actinolite schist, hornblende schist, white mica schist, and sandstone. For twenty rods beyond, the rock is purely hornblende, and is three hundred feet thick. The strata are concealed for one hundred and eighty rods along the line of section, which must be 2400 feet thick, if their inclination agrees with those upon both sides. Just beyond is a black slate, exposed at a railroad crossing at the north end of Lisbon village, which is the last member of the series, and it has been traced along the strike for ten miles, from the south part of Littleton to the line of Haverhill. The total thickness of the Swift Water series on this section seems to be over 4400 feet.

The Lisbon group begins a little east of the village of Lisbon, and reaches into Lyman. The following are the kinds of rocks seen: first, hydro-micaceous conglomerates,—756 feet; second, hydro-mica schists, with cupriferous layers,—3539 feet. The upper division often carries a nodular mass of nearly white quartz, from fifty to one hundred and fifty feet thick. A little to the south of the line of section, and observed very largely elsewhere, is an aggregate of feldspar and chlorite. It is the same with that adjoining the Helderberg rocks in Littleton. The fault which has nearly cut off the Lyman group on the section has caused this rock to disappear beyond the south corner of Lyman.

The Lyman group has a thickness of only two hundred feet adjacent to the fault. It is entirely wanting a quarter of a mile farther north. Beyond the slates it has a thickness of 2330 feet, allowing it to be folded. The clay slates next succeeding are 1500 feet (possibly 1800) thick. They contain the well-known auriferous quartz vein worked at the Dodge mine, yielding, in its better parts, from $15 to $25 to the ton. They resemble closely certain auriferous rocks of Nova Scotia, referred to the Lingula flags of Great Britain by A. R. C. Selwyn, geologist to the Dominion of Canada. In composition it resembles the Lyman schists, and may have been derived from the breaking up of the latter. A study of the structure of the Cambrian slate over the Ammonoosuc area shows it to be a synclinal. I have followed it carefully, from the unmistakable basin form in Bath, to the inverted monoclinal dip of the section line. There is very little variety of lithological character in this series.

After passing the slates, the largest area of Lyman schist in this field presents itself. Near its eastern border are large lenticular-shaped beds of quartz, some of them thought to be auriferous, and certainly associated with veins carrying galena. Though high, the dip increases its angle till the western border is reached. The auriferous conglomerate and beds of dolomite are met with near the western border of the group, the former being about seventy-five feet thick. Near Parker hill the Lisbon group reäppears, dipping south-easterly. This undoubtedly unites beneath the Lyman and Cambrian rocks, completing the synclinal. No effort has been made to measure its thickness beyond Parker hill.

Detailed Maps. Of these there are two. One has been referred to in Volume I, pages 22 and 46. This shows the result of a protracted survey of four square miles in the south corner of Lyman, the principal object being the accurate delineation of the formations with reference to auriferous veins. The other embraces the country between the Connecticut and Ammonoosuc rivers, and illustrates the topography of the region by means of contours, with the locations of the several mining properties Constant reference should be made to these maps for the purpose of verifying our statements.

Lisbon Group. At the south end of the field in Haverhill there seems to be only one range of the green schists, in proceeding north-easterly. This constitutes the floor spread out underneath the whole Ammonoosuc area, the subdivisions about to be indicated being produced by lines of superior groups. In this subdivision we first separate the ranges on the extreme borders, the western being the most extensive, and following Connecticut river to Dalton. The eastern is continuous to the south part of Lisbon, and then seems to pass under the Swift Water series, perhaps unconformably, to reäppear in a modified form on the south branch of the Ammonoosuc, terminating at Streeter pond. For the last part of its course, it adjoins the Bethlehem gneiss. Towards the interior parts of the basin we find limited areas of the green schists. First, there is one in the north-east part of Bath, running into Lyman. This may be ranked as Lyman schist upon the map, as both the green and white schists are represented within it. It is separated from the slates at its blunt south end by means of a fault; and very fine specimens of contorted strata came from this dislocated line. Second, a small area has been discovered in the blank space of Fig. 27, Bald hill, Lyman. Third, there are two narrow bands in Littleton, crossing Parker brook, in the midst of Helderberg exposures. Fourth, I think there is a line of outcrop between the Parker Hill and Gardner Mountain lines of north-easterly roads, connecting the larger areas in the south-west part of Littleton and in the north part of Bath. The two parts are separated by a narrow range of clay slate, which is replaced by the Lyman group in Waterford and Concord, Vt. We remark that the Lisbon group occupies a greater area in this field than in any other part of the Connecticut valley south of the Upper Ammonoosuc river. It is likely there was originally a wider basin here, allowing of the quiet deposition of the upper formations, which are wanting farther south, at least continuously. The average dip of the strata is also less over this basin than in the district south of Bath.

In noting these ranges I will begin with the eastern, commencing at the south end of the clay slates. This is at the point where the formation divides into two parts. A road crosses it exactly along this line, in company with a brook. The schists are not as green as usual, though having a high north-westerly dip. Near the slate there is a large mass of white quartz, extending certainly a quarter of a mile along the strike. Lower down there is very much dolomite. Near the mouth of Perch Pond brook the green schists dip north-westerly. Below Bath station, on the railroad, the rock is conglomeratic, with blue quartz pebbles. A mile from the station the schists dip 78° N. 48° W. The dip near the Bath town-house is similar. The rocks are nearly the same as to variety and position at the station. There is a conspicuous vein of white quartz on the hill west. In Bath lower village are several enormous blocks of hydro-mica schist, which probably indicate the character of the underlying ledges. Similar rocks occur at a starch mill about a mile up the Wild Ammonoosuc river, adjoining the Swift Water series. There are green schists on the Lisbon road, about a mile north of the station, near the top of the hill. Probably most of the rock in the easterly bend of the river in this neighborhood is of the same sort. Near the mouth of Smith brook it seems to be crowded on to the other side of the Ammonoosuc. Nearly opposite the strike is S. 75° W. At the mouth of Mill brook, Landaff, there are green schists dipping 70° N. 42° W. With this is a quartz vein, two feet wide; and the accompanying rocks are slightly calciferous and pyritiferous. The ledges are well exposed at the dam across the river, and also a little lower down. Half a mile below

Lisbon there is a coarse conglomerate in the schists, the strata dipping north-westerly.

These rocks are well developed through Lisbon. General statements respecting them are given with the description of Fig. 28. The following are the details of this, the best section I have crossing this band, from Lisbon village to the town line west. The eastern limit is reached back of the railroad, near a narrow band of clay slate belonging to the Swift Water series. The green schists by the church contain a little limestone, and dip 64° N. 62° W. In the river under the bridge are quartzites and coarse conglomerates, quite suggestive of the Helderberg under the North Lisbon bridge. The more western of these strata hold elongated and flattened pebbles, with the dip 44° N. 77° W. A few rods on the road up the stream are green schists, with limestone seams, dipping 40° N. 60° W. Under the hill west, by E. C. Stevens's house, is a prominent ledge of hydro-micaceous schists dipping 60° N. 30° W., and holding a quartz vein carrying a little galena. At the edge of the woods the same green schists dip N. 55° W. Near the top of the hill we find hard, green pyritiferous schists that dip N. 60° W.; at the very top, N. 70° W.; and there is some easily-decomposing carbonate present in the rock. The whole hill is composed of these green schists. On the western slope, and near the cross roads, the dip is N. 65° W. The rock contains a little galena scattered through the hill in minute particles. North of the line of section a short distance, there has been an opening for copper ore. The metal is present, though not in large amount; but the existence of copper and lead, which are widely disseminated through these ledges, suggests the similarity of the horizon to the richer veins of Gardner mountain. On the west side of the by-road the schist contains hornblende and pyrites. Succeeding layers approach gray quartzite in composition, dipping 57° N. 55° W. About two hundred and fifty feet east of the house of Jason Titus, the last member of the series makes its appearance,—a mass of white quartz dipping 50° N. 55° W., varying from fifty to one hundred and fifty feet in thickness.

This bed of quartz is a matter of importance. There are four outcrops of it along the same horizon, near the Lyman town line. The most southern begins one thousand feet north of the road from Lisbon over Gordon hill, and extends for six hundred and sixty feet in length, and about one hundred and twenty-five feet in width, having a lenticular shape, and a north-westerly dip. The quartz resembles that occurring in the Atlantic gneiss, breaking up into rectangular pieces, and somewhat reticulated by small quartz veins. It forms a prominent feature upon the north side of the road. The next two are smaller patches, on both sides of the road near J. Titus's. The more southern runs into one of large size upon the northern slope of the hill, that is very conspicuous as seen from the road between Lisbon and the Dodge gold mine. The other exposure is about a thousand feet south-west from J. Corey's house, on the last road mentioned. It may be three hundred feet long and one hundred wide. The clay slate butts against this quartz boss, having a dip of 43° N. 20° W., and a sliding between the rocks is obvious. I cannot say that this quartz is certainly represented beyond these limits; but suggest it may be the equivalent of the large mass alluded to above, adjacent to the southern end of the slate in Bath, and the beds upon Fitch hill in Littleton.

This range of lenticular quartz bosses furnishes us with an excellent example of unconformability between the Lisbon schists and the clay slates. The first ledge lies on the line between the Lisbon and Lyman groups, and is removed entirely from all connection with any areas of slate, the nearest one being 1300 feet to the south-west, on the line of strike. The next exposures, at Titus's, are 1150 feet south-east from the principal range of slate lying to the north-west of the range just mentioned, if it were prolonged. Near Corey's house the eastern border of the slate—the direct continuation of that north-west of Titus's—is situated five hundred and thirty feet east of the quartz. We have therefore a strip of quartz crossed transversely by the slate at an angle of seventeen degrees. The length of the quartz between the points measured is nine hundred feet, and the sum of the easting and westing is 1680 feet. In other words, the eastern border of the slate, which was 1150 feet north-west of the quartz at Titus's, crosses it, and lies 1680 feet farther to the south-east, opposite Corey's, than it would were there no unconformity. Evidence is afforded of a fault near Titus's; but this does not seriously affect the fact of unconformability, which is corroborated by the common relations of the two formations explained in detail elsewhere.

There are other ledges along the Ammonoosuc river before coming to the crossing of the formation by the Swift Water series. There seems to be a thick mass of schists and conglomerates crossing transversely over the Lisbon series, in a different direction from that of the clay slates just mentioned. It is difficult to understand the precise relations of these rocks without further study. The green schists crop out on the opposite side of the last-named group at several places, as at the bridge over the river where the railroad bends to the east, overlying the limited outcrop of the Bethlehem gneiss.

There is a band of hornblende rock commonly separating the Huronian from the Helderberg. Between Streeter pond and North Lisbon it barely touches the Helderberg, but is a peculiar rock. It consists of an aggregation of radiated crystals of diallage, with a finer paste, composed largely of pyroxene. At the saw-mill, about a mile and a quarter south of North Lisbon, it is an ordinary fine-grained hornblende rock. This can be traced on the north-west side of the Helderberg into Littleton, cropping out at several places, particularly between D. E. Corey's and the river near the line. At very low water it may be seen in the Ammonoosuc, a mile into Littleton. It is next seen occupying the summit of Fitch hill, forming the ridge for half a mile. It is here a compact, massive hornblende, with no indications of divisional planes traversing it. I have thought these several outcrops may represent one geological horizon; and that it is associated with the feldspar and chlorite aggregate or protogene gneiss, which is better developed in Lancaster. It seems to cap the Lisbon group of schists. The dip just above North Lisbon, at the South Branch, is 50° N. 20° W.; near the saw-mill it is 75° N. 50° W.; about the same near the town line; and probably vertical upon Fitch hill, with a strike of N. 70° E. There is more of it at the very south corner of Lyman, near the line of lenticular quartz beds.

In the south corner of Lyman the protogene rock (upper member) dips 35° N. 30° W. The rock bears a resemblance to elvan, and is more compact here than usual. Half a mile above the ridge, in middle Lisbon, there are hydro-micaceous schists, with a high north-westerly dip. At S. K. Chase's there is a greenish conglomerate, with reticulated veins and pyrites, dipping 60° N. 50° W. The band is about a mile in width here. The clay slates join this group at Perch pond, the green schists on the east side dipping 55° N. 35° W. I cannot find evidence to connect directly the Lisbon schists in central Lisbon with those in Littleton, by way of the Ammonoosuc. They belong to different ranges, connected by anticlinal or synclinal axes. This eastern band seems to terminate near Streeter pond.

Recent observations suggest the existence of a limited outlier of the green schists on the south side of Bald hill, in the north corner of Lisbon. No ledges were discovered, but large blocks were abundant, and among the pieces small boulders of jasper. The top of the hill and the surrounding region show slates and Helderberg rocks. This band of Lisbon rocks occupies a part of the space left vacant upon Fig. 27.

The western branch of the Lisbon schists, if properly understood, is broader than the eastern. At Woodsville the strata dip 80° N. 40° W. This observation may be taken to represent the usual position of all the ledges in the south and west parts of Bath. North of Woodsville the hills rise abruptly, almost precipitously, into the Gardner Mountain range; and there are high cliffs adjacent to the Connecticut river at the "Narrows," above the mouth of the Ammonoosuc, the rock dipping high north-westerly. A trip from Bath lower village across the mountain to Connecticut river (Fig. 29), shows on Child's brook greenish schists, dipping 30° N. 80° W., of the eastern range. Next succeed the clay slates, exhibiting considerable variation,—an anticlinal situated upon a synclinal. Adjacent to the slates upon both sides, but especially on the west, the schists resemble the micaceous quartzites of the Lyman group, near W. Lang's, dipping 80° south-easterly. The dip has essentially the same direction continuous across the mountain, but a smaller angle on the west side. About one third the way up the hill the schists are ferruginous, and strongly affect the compass. The rock is rather like the "killas" of Cornish miners than our typical varieties of Lyman rock, so that I have hesitated about separating it from the Lisbon group, without further study. The same variety follows along the ridge to Connecticut river, carrying the copper veins. Dr. Jackson states that the direction of the strata of the copper mine in Bath is north-west and south-east, which is at right angles to its usual course in the neighborhood. I have noticed a south-east dip in the schists along the west border of the slates, a mile east of the mine.

After reaching Lyman, we discover evidences of an anticlinal fold in this group. The more eastern portion lies to the east of Gardner mountain, reaching to Parker hill on the east, and separated by a band of slate from the more western development. Fig. 30 indicates the positions of the strata along a section from the valley of Smith brook, in the south part of Lyman, over Hart's mountain to the villages of Monroe and McIndoe's Falls on the Connecticut. At the east end, near a schoolhouse, the shales or slates prevail, covering up the supposed underlying Lyman schists. These are inclined towards Gardner mountain. Next the Lyman group makes it appearance, with two supposed outcrops of the auriferous conglomerate. The range on what has been called the Dow farm, but now Martin & Swett's, is believed to stop short at the base of the hill, and to be folded. The eastern developments of the conglomerate and overlying dolomite may be present beneath the slates just mentioned. All the strata exposed dip in the same direction with the slates. Just west of the dolomite, which crosses Smith brook by Steery's house, the slates reäppear in strong force, with a very high south-easterly dip, making, probably, a synclinal originally with those by the schoolhouse before the upthrow of the Lyman group between. The auriferous conglomerate reäppears at Jacob Williams's house, where it has been excavated for gold. A considerable alluvium west of Williams's makes it uncertain whether there may not be a small development of the Lyman group; but in passing up the Smith brook one soon beholds prominent ledges, with nearly vertical dip, of green schists of the Lisbon group. These are as well characterized as any in the whole field, and remind one forcibly of the typical Huronian localities in middle and northern Vermont. Within the distance of a mile is the place for copper schists to appear, for it is believed there is an anticlinal axis between Williams's and Davis's houses, so that the copper rocks of Gardner mountain should reäppear. For the same reason, the accompanying synclinal ought to lie along the valley of the Grafton mine. The south-easterly dips incline at a much smaller angle on the eastern slope of Gardner mountain range than in the valley near Williams's. At the old Grafton mine the dips are 55° S. E. at the surface, and 45° lower down. The copper schists are well developed along this section. At the lead mine the strata dip 62° S. 80° E. It is possible that much of the east side of the mountain belongs to the Lyman group. The resemblances to this member are greater in the sections—Figs. 29 and 31—than on Fig. 30. At the very top of the Gardner range, in the road, schists, which are greenish, dip 50° south-easterly. Where the road turns northerly (now abandoned), the dip changes to 75°–80° N. 55° W. Down the very steep west side of the range, the position is about the same. At the edge of Bath there is a band of light-colored sandstone. The copper schists are believed to occur near Hunt's mountain; and there is probably a synclinal axis between this mountain and Bald ledge. At the latter locality the metalliferous schists have been worked at two openings on the top and west side. These two lines dip in opposite directions, the first dipping 70°–75° S. E., and the second 60° N. 40° W. This same north-westerly dip is now continuous to the river. Near Monroe post-office the green, soft schists, dolomite, and hard slates dip 75° N. 40° W. At McIndoe's Falls the ledges are of the same sort. Farther north-west, they are succeeded by the calciferous mica schist, standing vertical, with the strike N. 60° E. The union of these two formations is apparently one of unconformity, unless there be a local disturbance.

Fig. 32 shows us the order of dips of the same rocks a little more than two miles farther north of the last line described. It extends from the Ammonoosuc river about a mile above Lisbon village to the top of Gardner mountain, behind the Oro mine. At the eastern end of the section are slates and conglomerates believed to belong to the Swift Water series. The slates occur first, with a strike varying from N. 35°–50° E., and the dip north-westerly. This is the continuation of the slates cut by the railroad just at the north edge of the village of Lisbon. The conglomerate associated appears on the hill half a mile back from the river. It weathers whitish, and is known as conglomerate only after weathering. The dark slates west of this rock hold bands of green schist. It is difficult to fix precisely the limits of the green schists by H. Aldrich's succeeding these slates. With our northern is a narrow band of white schist and auriferous conglomerate dipping 80° N. The scattered ledges of slate appearing here and there, just east of the conglomerate, may have some connection with the regular Cambrian formation, which follows on the west, carrying gold. I have found in this immediate neighborhood pieces of Helderberg limestone in such position as to make it clear that a narrow band of it is in place just east of the conglomerate.

The clay slates following rise up into a high wooded hill. The average dip of the whole formation is about 60° north-westerly, agreeing with that shown on Fig. 28. The Lyman argillitic mica schist succeeds, dipping at a steeper angle in the same general direction. A large bed of quartz near the eastern edge has been opened, under the name of the "New Hampshire Gold Mine." This band, though finely characteristic of the Lyman series, is only about 1100 feet wide upon the surface. Next succeeds a width of Helderberg slates and limestones, estimated at eight hundred feet. The exposures are well seen in the pasture south of the road from the New Hampshire mine to that of the New England Mining and Reduction Company. The Helderberg strata dip usually 75°–80° north-westerly. The fossils are minute broken crinoidal stems and corals. Intercalated masses of rock are like the adjacent Lyman schists. These easily-destroyed strata have probably been kept in place by an enormous mass of the auriferous conglomerate, three hundred and eighteen feet wide, which afforded protection on the north-west side. This mass is much greater than ordinary, and must have accumulated through a doubling by lateral pressure. The whole of it lies in the south angle between the two roads meeting at the Reduction Works mine. The conglomerate runs N. 48° E., and stands vertical. On the west side of it are green and white schists, with a dolomite bed, probably altogether belonging to the Lyman group. The dip is high north-westerly east of the road; but at the mine, perhaps two hundred feet to the west, the dip is 35°–70° south-easterly. The band of conglomerate—a stone's throw to the north-east—dips 70° S. 65° E.

There is at this point evidence of an extensive throw to the east. The conglomerate would naturally continue directly from the edge of the Reduction Works mine to its development, a mile farther south; but an inspection of our map of the course of this rock shows that it has been roughly broken apart, and pushed 1160 feet farther east. Of course the schists west of the conglomerate went with it. This great dislocation is illustrated by the broken condition of the strata, both as seen in the ledges, and as further developed by the working of the mine. The change of the dip from that prevailing over the first mile of the section, or that lying west of the clay slates, indicates here the existence of a synclinal axis in the Lyman group. The dolomite and auriferous con-

— SECTIONS ACROSS THE AMMONOOSUC GOLD FIELD. —

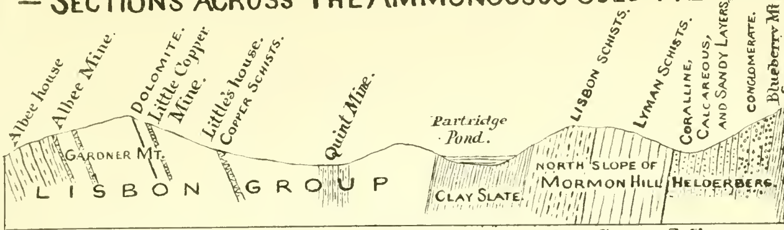


Fig. 33. From Blueberry Mt., in Littleton, to the Albee Copper Mine.

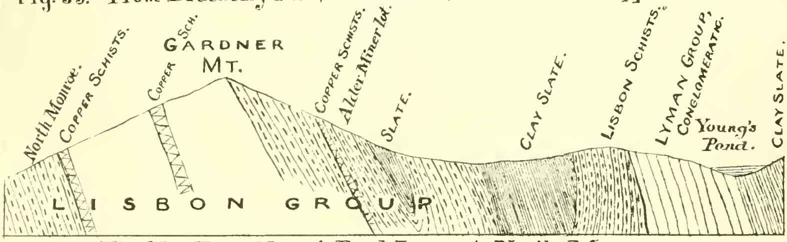


Fig. 32. From Young's Pond, Lyman, to North Monroe.

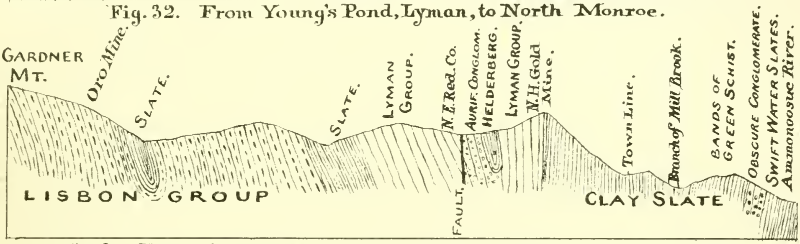


Fig. 31. From Ammonoosuc River above Lisbon Village to the Oro Mine.

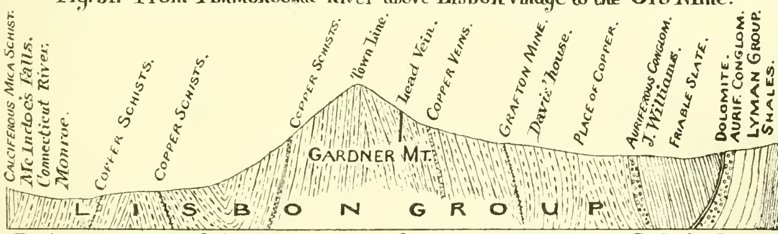


Fig. 30. Along Smith Brook in Lyman, from School House, to McIndoe's Falls.

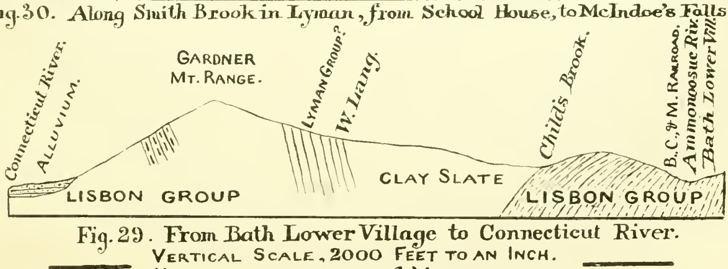


Fig. 29. From Bath Lower Village to Connecticut River.

Vertical Scale, 2000 Feet to an Inch.
Horizontal " , about 1 Mile " " " .

Heliotype.

glomerate lie in the centre of the field, and are therefore the newer members of the series.

I have not traversed the country between this mine and the road running north-east from Parker hill. The examination of the adjacent territory, however, indicates the character and position of the strata here. We have, first, the argillitic Lyman schists, with south-easterly dip; then a conglomerate composed of fragments of the same rock; and, lastly, green-colored schists dipping 85° N. 40° W., indicating the presence of an anticlinal axis before reaching the Parker Hill road and the repetition of the clay slates.

This new slate range begins at Parker hill, and widens northerly, being half a mile wide on the section line, and nearly two miles by the north town line. This slate is usually inclined very steeply in a south-easterly direction.

Passing on to the hill between this slate range and that next farther west, we find a development of the Lisbon group between them. The slate extends about a quarter of a mile west of the road at L. B. Hoskins's. The schists are considerably slaty, and there are narrow beds of jasper intercalated with them. Certain cupreous veins cut across dolomitic strata, dipping 60° a little east of south. This set of cupreous veins is probably continuous from the beds west of the Grafton mine, represented upon Fig. 30. There must be an anticlinal in this area west of Hoskins's, because the slates make their appearance, with the usual high south-easterly dip, at the east base of Gardner mountain. The axis may be an inverted one; but we have no direct evidence from observation along this line. The clay slates occur, with the dip of about 60° S. E., along the carriage-road at the east foot of the mountain. This may be two hundred or three hundred feet thick, but sufficiently abundant to indicate the presence of a newer rock, and consequently of a synclinal fold in the strata. At the Oro mine the position of the strata is essentially the same with that of the slates just mentioned. East of it there is a band of quartzite; and three hundred and seventy-five feet further up the mountain is a band of dolomite. Much of the rock on the east side of the mountain, near the copper belt, is soft and light-colored, and therefore suggestive of the Lyman group.

Fig. 32 shows the position of the Huronian rocks, without so many of the later series as in Fig. 31, and also crosses the mountain, extending from Young's pond into the north part of Monroe. Just below the pond there are outcrops of clay slate. To the south there are ledges dipping 75° S. 30° E., which, if protracted, would pass beneath the pond. Some of them occupy the line of strike of Helderberg outcrops farther south. The north-westerly dip of this band of slate begins about half a mile below the outlet. Running beneath the west end of the pond is a fine lot of Lyman conglomerate. At a mill the dip of it is 80° S. 60° E. The west border of this series, at A. Knapp's, shows the dip S. 40° E. The green schists succeed the white on the west, dipping 85° N. 40° W. This is succeeded by the slates of the Dodge Pond vicinity, supposed to dip south-easterly. After that comes in the westerly belt of Lisbon green schist, agreeing in position with its description on the three previous figures. The slate comes out near the school, by A. L. Dike's, at the east base of the range, indicating a fold. The copper schists occur in the Alden Miner pasture lot, where excavations to a slight degree have been made. They probably pass into the Swan and Garland property, in the next lot adjacent upon the north. The dip of the cupriferous beds is 57° S. 35° E., which extends to the top of the mountain.

Upon the Monroe side I have not seen the exposures for more than a mile below the summit. I have reason to believe the rock there is the Lisbon green schist; and that there are copper openings to correspond with the structure reproduced in Fig. 30. Two openings for copper have been seen about midway between the crest of the ridge and the river. Way's copper beds dip 80° S. 35° E.; Mason's, 75° S. 35° E. No rocks were observed west of these ledges near the road. The country falls off to the west, and seems to be mostly covered by drift.

Fig. 33 exhibits the position and character of the strata near the south line of Littleton, from S. Albee's house to the top of Blueberry mountain. The older clay slates make up the principal mass of the mountain. On top they dip 75° N. 20° W. A few rods north there is a local dislocation, the dips of 80° N. 33° W. and 20° S. W. adjoining each other. The slates are black, and contain crystals of pyrites. Immediately adjacent, near a school-house, there is a coarse conglomerate. From the northern slope of Blueberry hill to Mulliken brook the soil is fertile, and covers most of the ledges. Near the stream there is a mixture of Helderberg coralline limestones and easily-decomposing slates, standing upon their edges. Associated with them, towards the coarse conglomerate, are loosely-coherent sandstones resembling similar fossiliferous rocks in adjoining slates. On the west of the Helderberg there follows a half mile width of vertical strata of the Lyman group, including the "Indian rock" near the house of G. D. Shute. Between the top of the hill west and Partridge pond, the Lisbon group succeeds. About the pond we find the nearly-vertical slates, the northern prolongation of the Parker Hill range, and also the Lyman group conglomerate. The Lisbon range bordering this on the west again makes its appearance, with a greater breadth; and the copper is better developed than at some of the localities farther south, it having been worked slightly at the White Mountain or Quint mine.

The western limits of this Quint range are not well known. Near the house of Mr. Little (E. Parker's) there are cupreous schists; and the clay slate range must pass very near this site, since it occurs to the south, as before mentioned, near the copper, and to the north quite extensively about the West Littleton post-office. In climbing the hill west of Little's house, to see the principal copper mass, I do not recall this rock; but my attention had not been turned to it at that time, and it might have been passed unheeded. At this opening the dip of the strata is 60° S. 70° E., and the metalliferous schists are very abundant. Their course has been followed a considerable distance in both directions, it being the main vein of the Gardner Mountain deposit. From this opening across to the Albee mine it cannot be more than half a mile. The strata with the latter vein dip 65° S. 40° E., and nearer the house 70° S. 45° E. There is said to be another bed of copper one hundred and twenty-five feet east of the Albee mine, or nearer the Little mine. A comparison of these several figures with each other suggests that the Albee veins would probably coincide better with those nearest the ridge in Figs. 30 and 32, than with those worked in the south part of Monroe, and those opened by Way and Mason farther north. The mountain has diminished greatly in altitude between Little's and Albee's, and falls gradually from those places to Connecticut river; and the strata between the two sets of cupreous rocks do not make an obvious anticlinal with each other, as is the case in Fig. 30. There would seem to be a growing tendency to an overturn in passing from Fig. 30 to Fig. 32, which has become completed in Fig. 33, the dip upon both sides of the mountain being essentially at the same angle.

There is little to add concerning the occurrence of the Lisbon group in Monroe. Our observations have been scanty; and, so far as mapped, the green schists appear to occupy the whole township. At P. P. Mason's the dip is 60° S. 48° E. Somewhat below the middle of the town, at J. Nelson's, there is a broad band of pyritiferous granular quartz, dipping 80° S. 70° E. A fourth of a mile south, near G. Lang's, there are green schists, vertical, with the strike N. 5° E. The general character of the Monroe schists is sandy and micaceous, without much of the chloritic aspect. South of Lang's the strike is N. 15° E. At the lower Belden opening the dip is 60° N. 40° W.; at the upper it is from 70° to 75° south-easterly,—thus making a very distinct anticlinal. There is a gradual slope to Connecticut river from the summit of the ridge through the upper three fourths of the township; the other part is considerably steeper.

The western half of Littleton consists mostly of the Lisbon group. This development is characterized by the predominance of chloritic and green schists; and the cupreous layers are scarce. The Gardner Mountain and the Quint Mine ranges pass out of the state into Waterford, Vt.; while the Parker Hill range occupies a large area adjacent to Connecticut river. The Lisbon areas terminate mostly in Littleton, save one which passes through the south-west corner of Dalton on its way into Vermont. Section IX passes through the most important portion of these Huronian bands in Littleton.

In general, the rocks from J. Bowman's, near Lower Waterford bridge, to W. Redwood's, a mile and three quarters east of the upper bridge, are chloritic, usually perpendicular, with a north-east strike. At Mulliken's saw-mill the green schists are traversed by a trap dyke, and some of the rock is conglomeratic, of the Lyman group. The rocks are similar on a back road from the saw-mill to near the slate quarry. Near the town-house is the boundary between the grayish-green schists and the mixture of chlorite and feldspar. Of the former, there may be a width of two miles east of the true chloritic rock. The same outcrops at intervals between the town-house and the Wheeler Hill cemetery, where it is replaced as before by the chlorite schist. Bands of slate holding large nodules of quartzite occur east of Wheeler's. On Wheeler hill—west side—are hydro-micaceous schists. Near the summit the character is more argillaceous, and the rock carries a little copper. Some of the bands have a chocolate color. The direct road to Dalton from North Littleton is entirely covered by drift; and the same is true of the river road. The road branching off from the main road, on the south side of Cow brook, gives us a glimpse at green schists, at R. Moore's, with the strike N. 50° E. The same rocks occur abundantly farther east on the north side of the Palmer hill, near a sharp angle in it. On the north side of Morse hill, between L. B. Towne's and the slate quarry of R. Smith, there are green schists, with strike seeming to point to R. Moore's. The results of further examinations in Littleton and Lisbon will appear under the head of the Lyman group, further on.

A trip across Waterford, in 1858, may furnish a few hints concerning these rocks. At the lower village the hydro-mica schists, minutely contorted, dip 65° south-easterly. Next is a higher-dipping series of 80° in the same direction, with a multitude of the diabasic porphyritic boulders of the rock yielding *Stromatopora*, probably *in situ*. This is followed by soft schists, 80° south-easterly. The west border of the formation stands 85° south-easterly, made of harsh grits and breccias. It is succeeded at the Passumpsic river by clay slate.

Lyman Group. Early in the history of our explorations it was found needful to separate the "white schists" from the green, or the Lyman from the Lisbon group. When unweathered, the rock usually assumes a drab color, often with an olive-greenish tint, but always, after exposure, becoming grayish-white, somewhat resembling feldspathic rocks at a distance. Somewhat argillaceous and shaly layers, together with dolomitic beds, are interspersed with it, capped by the auriferous conglomerate. According to Mr. Hawes's determinations, this rock is an *argillitic mica schist*, intermediate in character between mica schist and clay slate, very like the German *Werthonschiefer*, or the first starting away from clay schists. Some of the varieties exhibit a little mica; more usually, however, the plates are wanting, and the texture reminds one of flint.

The principal range of this rock commences in the north part of Bath, crosses Smith brook in Lyman, and passes through Lyman into Littleton.

Many of the details of its distribution and stratigraphical relations have been touched upon in the descriptions of Figs. 29–33, Plate XIII.

By reference to the map exhibiting the south end of the auriferous conglomerate in Bath, it appears that the Lyman schists are enclosed by it, and the conglomerate is encompassed by clay slate, while the slates apparently dip beneath the other rocks. This does not represent the true mutual relations of these formations, as the slates overlie the others. A careful examination of the dips from the south end of the conglomerate to the neighborhood of the house of J. Clough (county map), proves the existence of singular disturbances, both dislocations and overturns. The normal dip of the slate upon the east side of the conglomerate in Bath is 30°–40° N. 42° W. The strike is the same upon the west side and to the south; but the dip varies, as will be described further along, in accordance with the synclinal disposition of the mass. In the road a little west of the brick house (M. L. Sanborn, of county map), the dip is to the north. Quite near to the conglomerate, upon the west side, the dip is N. 33° E., and N. 18° E. The slate and conglomerate are separated by a few feet thickness of the argillitic mica schist and the common shelly layers of the Lyman group. Three hundred feet west of the conglomerate the slate dips N. 72° W., or more nearly its proper position. The usual presence of the few layers of Lyman rocks with the conglomerate, not merely here, but very commonly where the conglomerate lies in close proximity to the slate, indicates the proper associations of the former rock, and that the latter has been crowded over it by lateral pressure.

Near the south end of the conglomerate upon the hill there is another illustration of this conclusion. Two masses of conglomerate run parallel to each other a few rods apart, both uniformly having a strike a little east of north. Between them lies an abundance of the slate, with the uniform north-westerly dip belonging to it, thus unconformably overlying the conglomerate.

The action of the lateral pressure is further exhibited a few rods north-easterly from Clough's house. A hummock of the Lyman dolomitic and quartzose rocks rises out of the slate; or, perhaps it should be said, rather, the rocks associated with the conglomerate extend westward more than is usual, and consequently the slate has been displaced. A portion has been entirely removed by the drift, and that remaining is forced to dip to the north. About a stone's throw distant to the west, the normal dip to the north-west appears again. If the slate dipped underneath the Lyman beds, the latter would have been eroded, instead, and made to disappear. This and other similar facts indicate that the Lyman rocks in this field constitute a hard, irregular floor, upon which the slates were placed by deposition. When lateral pressure was exerted upon this territory, the floor would be disposed more unevenly than at first, and the upper and more yielding rock be forced to accommodate itself to it. Hence the slates would be bent, broken, and thus put into proper condition to be removed largely by later erosive agencies, permitting us to see the natural limits of their distribution by imagining the scattered remnants left once joined together.

The main range of Lyman schists in Bath widens in proceeding northerly. At J. Hastings's it dips north-westerly, as usual. The most interesting feature connected with it is the branching to the east of a mass of both the white and greenish schists, so connected together as to make it difficult to decide whether both the Lisbon and Lyman groups may not be present. The road from the school-house, about a mile above the mouth of Smith brook, passing over the hill by J. Dow's, E. McAdair's, etc., crosses over a band of green schists about half a mile wide. If we pass towards the conglomerate from where these exposures appear, we find them cut off by a shelly slate, and discover beautiful examples of contorted strata. Hence a dislocation is evident, whose position is apparent upon the map, having a north-westerly course. The green schists occupy the middle portion of this area, where they cross into Lyman. The whole area is about three thousand feet wide on the town line, some four hundred feet on the west, and fifteen hundred feet on the east, being of the whiter variety. The green schists run north-easterly about three thousand feet into Lyman, and their place is taken by the whiter layers further on. But there are green schists in a band five hundred feet wide, tapering to a point, reaching from the school-house to a ledge past the Bedell mine. The latter range is covered by clay slate.

Reference should now be made to the numerous observations recorded upon the special map of four square miles' extent in the south corner of Lyman, surveyed with great pains for the purpose of elucidating the stratigraphical structure of the gold field. It was drawn upon the scale of five hundred feet to the inch, and reduced by photography to its present dimensions. Stakes were set at the corners of every block of five hundred feet, the positions being determined by theodolite and chaining. Their places are indicated by dots upon the map, together with references to town lines and other topographical features outside of the four square miles measured. For convenience of reference, the letters A, B, C, etc., designate the positions near the east line of the town next Lisbon; while upon the line next Bath figures express the several stakes in order, beginning at the south-east corner of the town. For example, C—13 denotes the stake two hundred feet northerly from the Bath line, and six thousand five hundred feet westerly from the east line of reference, which nearly coincides with the town line between Lyman and Lisbon. Figures express the catalogue numbers of the specimens obtained, and are placed as exactly as possible over the localities whence they came. Arrows show the dip of the strata; while more precise information concerning the exact angles follows in the text.

We have the following details respecting the position of the green strata in the area just mentioned, entering Lyman from Bath:

150–152—dip 85° N. 42° W.	156—dip 50° N. 22° W.
153—dip 62° N. 40° W.	289, 290—dip 55° N. 32° W.
154—dip 50° N. 42° W.	185–187—dip 70° N. 32° W.

The following are the positions of the whiter schists connected with the foregoing, extending as far north as the line J, but not embracing any that lie east of the green schists, since the latter will be described as a separate range:

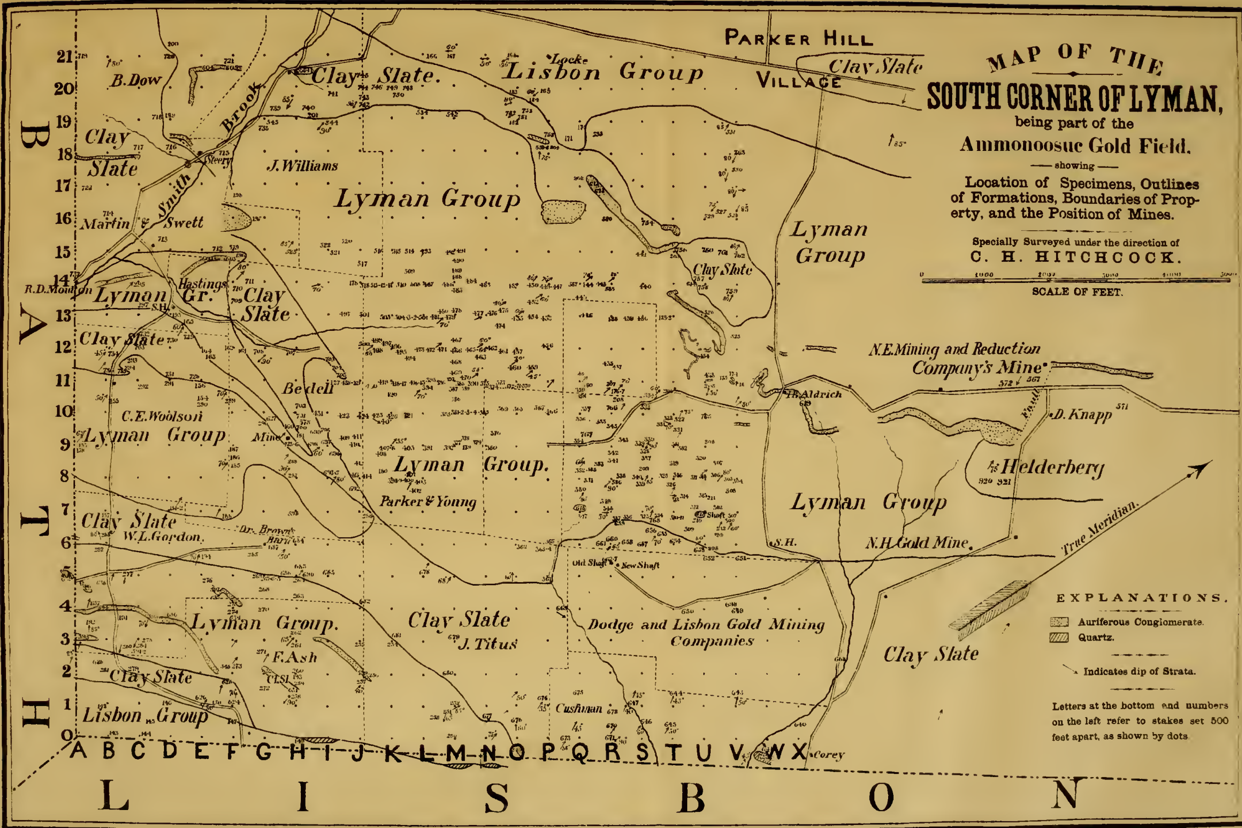
293, 294—dip N. 32° W.	296—dip 45° N. 32° E.
290—dip 55° N. 32° W.	288—dip 85° N. 32° W.
289—dip 70° N. 42° W.	287—dip vertical, strike N. 68° E.

From the range of green schists between the school-house and Bedell's, we have—

161, 162—dip 60° N. 23° E.	Near H—19, Bedell's mine, 80° N. 22° W.

Where the main range enters Lyman the rock is shaly, and is not always easy to distinguish from the clay slates. Upon the hill east from Smith brook the rock is typical of the group. The observations are quite numerous.

At B—21, vertical, strike N. 48° E.	At H—15, 85° N. 27° W.
At G—19, vertical, strike N. 58° E.	North end of a conglomerate fold near F—15. 80° N. 42° W.
At I—19, vertical.	


MAP OF THE
SOUTH CORNER OF LYMAN,
being part of the
Ammonoosuc Gold Field.
— showing —
Location of Specimens, Outlines of Formations, Boundaries of Property, and the Position of Mines.
Specially Surveyed under the direction of
C. H. HITCHCOCK.
SCALE OF FEET.
PARKER HILL
VILLAGE
Clay Slate
Lisbon Group
Lyman Group
Clay Slate.
B. Dow
Brook
Smith
J. Williams
Martin
Swett
Hastings Gr.
R.D. Moulton
Bedell
C.E. Woolson
Parker & Young
W.L. Gordon
Dr. Brown
J. Titus
F. Ash
Cushman
Corey
Old Shaft
New Shaft
N.E. Mining and Reduction Company's Mine
H. Aldrich
D. Knapp
Helderberg
N.H. Gold Mine
Dodge and Lisbon Gold Mining Companies
True Meridian
S.H.
EXPLANATIONS.
Auriferous Conglomerate.
Quartz.
Indicates dip of Strata.
Letters at the bottom and numbers on the left refer to stakes set 500 feet apart, as shown by dots
A B C D E F G H I J K L M N O P Q R S T U V W X
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
BATH
LISBON

HELIOTYPE.

Between H and I—14, 72° N. 8° E.

Near J—14, a patch of green schist stands vertical with strike N. 72° W.

Near J—11, dip 60° N. 8° E.

West of I—10, dip 55° N. 2° W.

Near I—10, dip N. 8° E.

At J—8, vertical strike N. 48° E.

At K—9, dip 55° N. 23° W.

Between J and K—10, dip 40° N. 33° E.

Between J and K—12, dip N. 12° W.

South-east of L—11, dip 70° N. 12° W.

Between K and L—10, dip 42° N. 12° W.

Between K and L—8, dip 65° N. 32° W.

At M—9, dip 42° N. 13° E.

Between M and N—10, 50° N. 12° W.

North of M—11, 58° N. 12° W.

Near N—12, dip 60° N. 12° W.

Near N—13, dip 65° N. 8° E.

At M—13, dip N. 12° W.

At M—14, dip N. 8° E.

Between M and N—14, dip 72° N. 12° W.

Large quartz bed at O—6, dip N. 42° W.

At O—5, dip N. 65° W. 60°.

Near P—6, dip 30° N. 12° W.

At P—10, dip 80° N. 32° W.

At P—11, dip 75° N. 22° W.

At O—10, dip 50° N. 12° W.

Between N and O—10, dip 64° N. 22° W.

Between O—11 and 12, dip 40° N. 8° E.

Between O—12 and P—11, dip 48° N. 32° W.

Between N and O—13, dip 40° N. 12° W.

At O—13, dip 62° N. 12° W.

At P—13, dip 70° N. 67° W.

Between O and P—14, dip 80° N. 32° W.

At P—14, dip 70° N. 12° W.

200 feet south of last, dip 62° N. 12° W.

Near P—18, dip 70° N. 22° W.

Between Q and R—14, dip 70° N. 12° W.

At R—14, dip 82° N. 12° W.

About Q—11, dip 85° N. 12° W.

200 feet east of Q—11, dip 55° N. 22° W.

At Q—9, dip 68° N. 12° W.

North-west of Q—8, dip 62° N. 12° W.

North-east of Q—8, dip 88° N. 12° W.

Near R—7, dip 50° N. 18° E.

At R—8 (argillaceous) vertical, strike N. 78° E.

At R—7, dip 66° N. 18° E.

300 feet east of R—7, dip 74° N. 18° E., adjacent to clay slate.

250 feet east of S—7, dip 70° N. 52° W.

At S—8, dip 70° N. 32° W.

Between T—7 and 8, a curve, the dip gradually passing from 65° N. 28° E., to N. 42° W. 67°.

250 feet east of T—7, dip 72° N. 12° W.

75 feet north of T—7, dip N. 42° E.

North-east of U—6, dip 85° N. 32° W., adjacent to clay slate.

200 feet south of V—7, dip 65° N. 32° W.

300 feet north of U—7, dip 73° N. 22° W.

250 feet south-west of V—8, dip 84° N. 12° W.

300 feet north of U—8, dip 88° N. 12° W.

At U—8, dip N. 12° W.

North of S—9, vertical, strike N. 48° E.

South of T—10, dip 70° N. 38° E.

East of T—10, dip 75° N. 42° W.

Between T—9 and T—10, dip 75° N. 42° W.

300 feet north of R—10, dip 90° N. 42° W. (argillaceous).

Near S—10, dip 62° N. 52° W.

200 feet north of last, dip 62° N. 12° W.

300 feet east of R—11, green schist, dip 76° N. 12° W.

Near V—11, green schist, dip 88° N. 12° W.

About R—14, dip 82° N. 12° W.

The following occur north of the conglomerate towards Parker hill:

Between U and V—16, dip 75° S. 22° E.	About V—17, dip 80° south-easterly.
Near V—16, dip 85° south-easterly.	About V—19, dip 88° N. 32° W.

These observations establish the fact of a prevalence of a dip in the direction N. 12°—25° W. over the hill region occupied by the main range of Lyman rock in the south part of the town. The variations to the east may be due to local bendings and dislocations, explained partly by the presence of newer strata. Along a line crossing the strata from J—8 to P—14 we have the following angles of inclination: 75°, 55°, 42° on top of the ridge, 70°, 60°, 65°, 40° and 80°. From these observations alone we are not warranted in concluding how many folds there may be. From general considerations there is thought to exist at least one synclinal over this main range.

The occurrence of narrow bands of dark carbonaceous argillaceous schists over this area, might, if properly worked out, illustrate the foldings. Like much of the argillitic mica schist, this rock splits up into long, narrow lenticular pieces, many of them being about the size of artificial scythe stones. There seems to be a band of this rock traceable from the Parker and Young lot across to the Dow conglomerate, F—16, and a longer one perhaps from near Jacob Williams's, G—19 to T—9; or, rather, in the north-east part of the map, there are three bands of this slate, viz., from R—8 westerly, T—9 to R—10, and quite near the twisted conglomerate, not far from Horace Aldrich's house, running towards Q and R—14.

There are also large beds of white quartz, sometimes metalliferous, which probably have a fixed stratigraphical horizon in this area. The most marked is that along the eastern border, starting on the north at the New Hampshire Gold company's mine north of the map area, cropping out west of the Dodge mine, near the western line of J. Titus, or near O—6, between M—5 and 6, at J—12. These and other outcrops are carefully laid down upon the map, as they may have economical importance.

A feature of greater stratigraphical importance than the quartz or slate is the dolomite. This may be readily distinguished by its reddish iron color, arising from decomposition, and it is unusually persistent in distribution. It seems to follow the conglomerate very closely in all its curved and fragmentary way, the best known localities being upon its north-westerly side. Of these, we have No. 196, near F—15, dipping 80° N. 42° W., away from and apparently over the conglomerate. No. 195, though disconnected with the range, probably belongs to it. A similar layer is connected with the larger development of conglomerate about F and G—16, and it seems to cross Smith brook near Steery's house, north of E—18, and to continue at D—19. Between D and E—20, on the south-west side of the conglomerate, is another exposure of the dolomite. No. 202 from Q—17 is quite interesting. It is more like a limestone than is usual in Lyman, and it makes a right angle in its course. The north-south course lies at the south-west end of a conglomerate exposure, and the bend to the west is connected with the throws of the latter rock, not fully understood. The dolomitic band is about twenty-five feet wide. There is said to be a considerable dolomite between Q—17 and J. Williams's, nearly along the line of the conglomerate. Next, there are dolomite layers at T—14 and 15. Where the conglomerate has been so terribly thrown about in the neighborhood of Aldrich's, the dolomitic outcrops are abundant, and may be seen on the map. The small conglomerate mass at U—9 is accompanied by dolomite,—Nos. 210–212.

The dolomitic masses not connected obviously with conglomerate may show where fragmentary bits of it are to be found, as at No. 206, near T—11, No. 209, near S—8, Nos. 207–208, near R—11. Those south of P—14, and near L—8, are not so clearly connected. Those from N—21 and D—21 may be associated with the Lisbon group. In the eastern Lyman range we find Nos. 191, 192, and ledges near A—5, close by conglomerates, and No. 193 by H—2, somewhat isolated. No. 194 is also in the neighborhood of conglomerate. We have also several observations showing the proximity of the dolomitic band to the conglomerate in Bath.

The following are a few positions of this dolomite band not elsewhere recorded:

193, near H—2, 75° northerly.
202, near Q—17, vertical, strike N. 72° W.
205, U—11, vertical, strike N. 48° E.
206, near T—11, dip 68 N. 12° W.
209, near S—8, dip 85° N. 12° W.
210, near V—7, dip 66° N. 52° W.
212, near U and V—7 and 8, dip 80° N. 42° W.
200 feet south of P—14, dip 62° N. 12° W.

The composition of much of the Lyman schist is indicated by specimens from between T—8 and 9 and P—10. It is a conglomerate made of long, flattened elliptical pebbles of sandstone, having the shape very nearly of whetstones used for sharpening scythes. The original rock has essentially the same mineral character with the derived strata. Usually the process of metamorphism, or rock-development, has been carried on so far that the grains and coarser pebbles have disappeared, being merged into the homogeneous argillitic mica schist. In a multitude of cases a practised eye will recognize the outlines of the pebbles in these ledges, which a stranger would not readily discover. No. 335 is an example of another variety of conglomerate, with small rounded pebbles of quartz and longer patches of a white, soft rock, the whole abundantly cemented by an argillaceous paste. This variety is not common. Whether any of these conglomerates may be the equivalent of the auriferous variety soon to be described, becomes a perplexing question after passing the known bounds of the latter.

The Lyman group may be distinctly followed beyond the limits of the special map through Lyman into Littleton. Much of it is covered by later formations. The eastern border passes uninterruptedly to Young's pond. The dip is at first about 80° north-westerly, but on the south side of the pond it is 75° S. 30° E. Figs. 31 and 32 may illustrate the course of the Lyman group in this region. The two gold mines represented in Fig. 31 are on opposite sides of a synclinal. At Young's pond the strata are monoclinal, most likely comprising only the western part of the formation, the eastern being covered unconformably by the clay slate, in agreement with the condition of things described upon page 283. Facts about the Lyman group, on Fig. 31, have been presented upon pages 288 and 289.

On taking the road to Young's pond from the Reduction Company's mine, we first pass over supposed Helderberg slates. Turning on the first road to the left, near J. E. Barber's, we find first at his house a ledge of green schists. Behind the house the rock is the well known "scythe-stone conglomerate" of the Lyman group, dipping south-east. This continues to 400 feet beyond H. Knapp's, where we find the normal argillitic mica schist standing upon edge. The Lisbon group makes its appearance by J. M. Smith's, on the turn to Young's pond, having the dip 85° N. 42° W. At A. Knapp's, half way to the pond, the argillitic mica schist dips S. 42° E. Between here and the pond there is a large development of the peculiar conglomerate seen back of Barber's, in numerous embossed ledges. At the mill above the pond this conglomerate dips 80° S. 62° E.

North of Young's pond the boundary between the slates and schist is very irregular, on account of the uneven erosion of the former resting like a blanket upon the latter. A spur of schist runs northerly from the pond into Mormon hill, all the ledges adjacent to this shore being the same. The road to H. Scales's house passes over schist nearly to G. Presby's; then it crosses the serrated boundary between the slates and argillitic conglomerate. There are at least five serratures or projections of the slate over the conglomerate, which may be seen best upon the map. On the hill west of Scales's the schistose conglomerate dips 80° N. 62° W. The slates dip north-westerly, in some cases being inverted.

The schists have not been followed across the west flank of Mormon hill, but are supposed to be continuous with the ledges seen in the stream east of G. D. Shute's, in the south part of Littleton, dipping 80° N. 42° W., and delineated upon Fig. 33. They are here flanked south-easterly by Helderberg flags, and north-westerly by the Lisbon group. They continue north-easterly from Shute's across the township, widening northerly, and crowding the Lisbon group into Vermont north of Littleton. The next road crossing them is that running directly from the slate quarry to Upper Waterford bridge. The rock is about vertical, and lies between the houses of D. Robbins and A. Eastman—half a mile. Next it crosses the roads from Littleton to this same bridge and to Lancaster. It occupies much of Wheeler hill, and perhaps it should be made to cover all the ground from Palmer hill to the Helderberg on Burnham hill. The dips on this last route are given in the first figure descriptive of the Helderberg rocks. On the south side of these hills, west of E. Farr's, greenish schists occur, dipping 78° N. 40° W. At P. S. Hatch's, north of the limestone, the white rocks dip 40° S. 42° E. On the road between Mann's hill and Mt. Misery this rock dips N. 12° W. and N. 32° W., near J. W. Dudley's. On the north side of the road excavations have been made in this for gold. The rock is completely filled with pyrites, so that small specimens even cannot be obtained free from the sulphuret. Midway between the Mt. Misery road and the one along Cow brook, the dip is from 50°–70° S. 6° W. Farther west, at M. Fisk's, in perhaps an isolated band of this rock, the dip is N. 50° W. 78°. An argillaceous schist extends from here three fourths the distance up Morse hill, where the argillitic white schist dips 56° N. 42° W. On the south side of Morse hill there are alternate bands of these two rocks, dipping 60°–80° N. 22°–32° W.

There is a curious conglomerate west of Rev. C. Corning's, in North Lyman, lying adjacent to the Lyman group, and supposed formerly to constitute a part of it. It resembles a mass of common drift, because the pebbles are so numerous and miscellaneously arranged. They consist of both the white and green schists, and dip S. 52° E. The pebbles are mostly of large size, one measuring two feet long and five inches wide. On the top of Mormon hill, nearly two miles north-east of this exposure, I found a very coarse conglomerate, with the strike N. 58° E., lying on the north-west side of clay slates dipping N. 47° W. It is probable that these two exposures belong to the same formation, which runs athwart the Lyman group, and may possibly join a very coarse supposed Helderberg conglomerate in Littleton, to be described presently. Till the very latest moment I had regarded these heterogeneous mixtures as a part of the Lyman group. There is, however, another interesting exposure of the supposed conglomerate at D. Stickney's, to the north-west of the range just mentioned. The strata are greatly contorted, the seams being filled with reticulated veins of white quartz, such as always occur at the bending of a formation in this part of the country. The dip seems to be north-westerly usually, though some incline N. 8° E.

A trip to Mt. Littleton, in 1876, adds a few items of interest. After passing the slate quarry, there is, first, the diabase range from Fitch hill, then the Lyman schists, by Robbins's and Eastman's, then a broad expanse of chloritic schists extending along Mulliken's brook from Eastman's, and connecting southerly with the Lisbon group near Partridge pond. Where the road from Mulliken's brook joins the Partridge Pond road, I found a coarse Lyman conglomerate, perhaps the continuation of that at D. Stickney's, dipping south-westerly. The same recurred north of the pond, at G. D. Lewis's, with a south-easterly dip, thus making a synclinal, holding some slates near the water. Either this or the normal Lyman rocks crop out farther south, especially above the mills at Mulliken's, near the Connecticut river, standing vertically. It appears, therefore, that there is a range of Lyman rock from Partridge pond to the Connecticut near the Upper Waterford bridge.

There is an eastern range of the Lyman group similar, as respects mineral composition, to that just described, requiring notice. It adjoins the green schists extending into Lyman from Bath, thought to be subordinate to the white schists. They are 2500 feet wide on the Lyman line, including three narrow conglomerate belts. The following are such positions of the strata as have been determined in this area:

283, dip 80° N. 82° W.
280, dip 64° S. 57° E.
At B—5, dip N. 57° W.
Half way to C—5 the dip changes to 65° S. 57° E., thus indicating the presence of an anticlinal.
Near C—3, vertical, strike north-easterly.
400 feet east of B—3, and near road, dip 67 S. 57° E.
Close by conglomerate, 300 feet east of C—4, dip 70° S. 57° E.
Dip beneath the conglomerate, on the other side, in a similar manner.

Near the south end of the conglomerate, between E—5 and F—4, are disturbances. The schists, six feet distant from the conglomerate dipping N. 42° W. 80°, and separated probably by a fault, are inclined 70° south.

At F—3, dip N. 22° W.
Same, 100 feet west of F—2.
Between G—2 and 3, dip irregularly N. 32° W.
At H—3, dip 65° N. 22° W.
East of J—2, dip 60° N. 12° W.
Between L and M—0, dip 75° N. 23° W.
Town line east of O—0, dip 55° N. 17° W.
Anticlinal about M—1, dipping 55° N. 2° W. and 65° S. 47° E.
100 feet north of N—0, dip 75° northerly.

There is dolomite near H—2 dipping 75° northerly; between E—5 and 6, dipping 70° S. 57° E., extending east of the conglomerate from Bath line 1000 feet between lines 3 and 4, dipping 85° N. 62° W., and probably on the west side of the same range. This range also contains argillaceous schists and beds or veins of quartz similar to those described as connected with the larger area.

The clay slate covers up most of this range in Lisbon, as has been explained upon page 283. There is also a fault north of Jason Titus's house, which aids in accounting for the disappearance of the Lyman group. Beyond the sandy plain it may be followed, accompanying the conglomerate as far as the saw-mill upon Mill brook, but it is quite narrow.

Auriferous Conglomerate. The last of the Huronian members to be described is usually a quartz conglomerate, with pebbles half an inch in diameter, from ten to a hundred feet in width. Owing to its hardness it has resisted disintegration better than the adjacent schists, and hence its outcrops are usually very conspicuous. It is this feature which led me to study its distribution with great care, so that it might be possible to obtain a clue to the stratigraphical structure of the whole field. The knowledge of the curves, breaks, and throws of this member illustrates finely the difficulties in the way of elucidating completely the intricacies of New Hampshire geology. The adjacent schists must be broken and curved precisely like the conglomerate. Upon the map I have delineated only the outcrops, without attempting to connect them together. Doubtless in many cases there can be no direct connection, the formation having been broken into pieces which became widely separated from one another. In other cases I have not yet been able to satisfy myself how the connecting lines should be drawn.

Besides quartz I find occasionally pebbles of jasper, chlorite, and both the green and white schists. I do not recall examples of pebbles much more than two inches in diameter. The cementing material is analogous to the composition of the adjacent schistose rocks. There may be a few cases of the distortion of the component pebbles by pressure, but they are mostly roundish or elliptical. Metamorphism has operated upon this conglomerate, so that the pebbles often seem to run into the cement by imperceptible gradations; and a piece freshly broken from a few feet depth does not readily display the fragmentary structure brought out upon the surface by weathering. I have occasionally seen the pebbles cut through by the jointed structure traversing the ledge. It is very common to see small reticulated veins of quartz traversing these ledges, especially in the neighborhood of a sharp bend or break in the continuity of the formation. Indeed, so intimate is the connection between these two phenomena, that, whenever I discover the numerous white veins, I conclude immediately this must be in the vicinity of a bend, and never fail to observe other tokens of its presence. In limestones the corresponding feature is seen in the presence of similarly disposed veins of white calcite. The designation auriferous came to be applied to this rock by way of contrast with other fragmentary accumulations. Several openings had been made in this member for the purpose of mining gold; and the mass has yielded from forty cents to two dollars per ton upon assay. Hence the name auriferous, as any one of its exposures is likely to yield a trace of the precious metal. At some of the openings pyrrhotite occurs in considerable quantity, and, in fact, it is apt to occur in any ledge of it. It is not therefore certain whether the gold discovered comes from the pyrites or the quartz; and if from the latter, whether it constitutes a part of the original conglomerate, forming pebbles like those of quartz, or whether it entered with the siliceous infiltrating matter. The constituent fragments were derived from the adjacent auriferous strata, so that the presence of gold in the pebbly condition may be looked for, though the whole of it has not been originated in that way. This conglomerate is disposed in two groups, corresponding to the main and eastern subordinate ranges of the Lyman group. Each one is double, or arranged into two parallel lines, as if repeated by undulations in the strata. I will describe the more western ranges first.

It is singular that this formation should commence so abruptly, and exhibit no traces of its existence to the north of Young's pond;—yet the enclosing material is traceable with difficulty beyond this point, because it is covered by newer slates, hence the same explanation may account for the concealment of the conglomerate.

North of the mine of the New England Mining and Reduction Company is an outcrop of the conglomerate 1600 feet long, parallel with the road and a short distance west from it. At the south end it dips 70° S. 67° E. The course of the ledge is N. 23° E., and it may be fifty feet wide. The continuity is broken at the south end of this mass, and, by proceeding S. 30° E. 1160 feet, it is found again about a hundred feet to the south of D. Knapp's house. Proceeding S. 50° W. for about 500 feet, we find an enormous expanse of this rock, attaining 335 feet in its greatest width. The strata are nearly vertical, about 80° south-easterly, rather steeper than appears upon Fig. 31. This part of the formation is flanked on the north-west by green hydro-mica schist, and by Helderberg slates upon the south-east. On account of its superior hardness it occupies the crest of a hill, the highest in the immediate vicinity. It would seem as if this mass must be folded up at least once, in order to account for its great thickness.

The next section of this range exhibits three bends, not including the right angle made by its starting opposite the very thick portion of the mass just described. We have first a bend of about 70° easterly, then of 150° to the west, and a third of over 120° to the east again. The length of the range, after leaving the very thick mass by a right angle, is about 140 feet. It then proceeds S. 35° W. after the 70° bend, for about 500 feet. Next, for about 700 feet, after bending 150°, it has the course of S. 70° W.

After bending 120° it runs S. 30° E., about 480 feet, when it sinks beneath the alluvium. The valley of a brook intervenes next. As it then crops out, having the same direction for more than 500 feet, after a short concealment, it must be continuous for the whole distance of a third of a mile. The next bend makes an angle of 110°, and the course is to the west for an eighth of a mile. At the next angle there is a subordinate bend, and the ledge courses for an eighth of a mile about S. 30° E. to the house of Horace Aldrich, situated upon the road from Lisbon to Parker hill, and at the place where a road branches to Young's pond, passing by the New England Company's mine. The width of the conglomerate, after the first quadrangular bend to Aldrich's, is from thirty to sixty feet. The delineation of the portion just described is not quite so accurate as that which follows, and I shall now rely more upon reference to the map in speaking of its continuation.

On the south-west side of the road from Aldrich's, upon an eminence and enclosed within an area of 500 feet square, is a series of twists too intricate to be described minutely. Upon looking at this and other similar bendings, one feels as if the original formation was like an elastic string in a state of strong tension, when it broke, and both ends suddenly recoiled and assumed a doubled-up appearance. The more southern part of this twist is a loop with the sides parallel to each other, the course being about north and south. The width of this rock in the road is sixty feet; the other extremity is about half as thick. The rocks bordering the curves conform to them, consisting of dolomites and slates. The probable continuation of the south end of the loop is to be found 550 feet distant, 275 feet east of V—10, it being the end of a mass 275 feet long and twenty wide, running about S. 35° W.

Next, there are numerous outcrops of conglomerate, averaging twelve or fifteen feet in width, in all respects similar to the wider bands, but when joined together continuously they more than fill out the gap between the exposures of the larger ledges. For the present, I think they belong to the same band continued southerly, or to what was originally more shallow water in the ancient sea where the rock grew. The first exposure at V—11 would connect well with those in the 500-feet square area, after the insertion of the piece that has travelled past V—10. These are doubled, and, after passing south-westerly 275 feet, another ledge is found 125 feet long. The space between is occupied by ledges of green and white schists, so that we cannot suppose the conglomerate continues beneath the soil. The next space of 250 feet S. 35° W. from V—11, is covered with earth. Then succeeds a continuous exposure of the narrow conglomerate for 1400 feet, with two acute angular bends, the extreme distance of the remotest points from each other being 740 feet. We find dolomite upon the east and south sides of this band. Between the northern end of this long crooked string and the southern end of the next development of the broader band of conglomerate, a distance of 260 feet, there are three fragments of the rock, disposed at different angles, which would neatly fill up the gap if placed in the proper position.

The next fragment in order belongs to the greater range, and lies nearly between the lines 12 and 14, the eastern end extending 100 feet beyond 12. The other limiting lines are V and S. The shortest line connecting its remotest extremities is 1300 feet long; but if we measure the length of the ledge as it lies, 300 feet must be added. There are loops at each end which bend in opposite directions from each other. The greatest width of this fragment is about eighty feet. On the west side of this fragment, near the easterly end, there goes forth a branch perhaps connecting with several narrow fragments still further away. We have first an exposure between V—12 and 13; 600 feet north-easterly, by the side of the road, is another narrow band, flanked on the east by dolomite, which is only 250 feet north from the nearest angle of the looped and twisted area near Aldrich's house. In the field north of the road are at least two other exposures of narrow dimensions, which I have followed more than fifty rods. It may extend still further: I have not traversed the region further in search of it.

There is another exposure midway between U and T—14, 200 feet north from the west end of the large fragment with the double hook, which is probably a part of the range. If we take this isolated fragment, and add to it another over 300 feet long lying between T—15 and 16, we shall have more than half enough material to fill in the 600-feet gap between the double hook range and the next one to the west. Should we straighten out this westerly fragment, and then put in these two pieces, there would be enough to join the larger fragments together by a curve. I cannot otherwise understand the existence of the mass between T—15 and 16 than by supposing it to have been forced out of the vacant space just mentioned. Accepting such a conclusion, it will be seen on inspecting the map that this piece has been thrown very singularly out of its place. The forces that should so derange the continuity of the formation are almost inconceivable.

The piece coming next in order is the largest yet encountered, lying between T—15 and Q—18, 1760 feet in length by the shortest line, and 1900 feet when measured along its centre. The general course is about east and west, but the eastern extremity, for about 500 feet distance, courses about N. 20° E. This end is 100 feet wide; the other is twice that width for 700 feet. It is this fragment that has furnished pebbles of jasper. The jasper I have seen in a ledge about a mile distant in a northerly direction, and that may have been the source whence these constituent pebbles came.

The next fragment of conglomerate illustrates clearly our theory of breaks and throws. It is a mass 700 by 400 feet, with the course N. 35° E., whose northern end is 400 feet remote from the nearest corner of the previously described fragment of conglomerate, whose course was said to be about east and west. By examining the map it may be seen that this fragment will nearly fill the vacant space existing between the east-west range and a smaller one to the west between P—18 and 19. The northern end of this fragment must have been thrown 450, and the southern end 900 feet; and its very great width suggests the accumulation of bulk by folding up the original sheet. Perhaps for the whole of the distance the mass has been pushed horizontally. The lower fragment near P—18 is only 350 feet long, running a few degrees north of east. The dip is 70° northerly. Between this and the ledge next J. Williams's house, a distance of 3650 feet, the rock is clay slate, rather more friable than usual, and is believed to cover up the conglomerate. The ledge at Williams's is 200 feet long, dipping 80° S. 35° E., rising precipitously twenty feet above the road. It is known to be auriferous, by assays.

In the valley of Smith brook the rocks have been deeply excavated and covered with sand, so that for a distance of 800 feet no ledges are discernible. We then find a large conglomeratic mass having the shape of the letter L, the upright part being 800 and the horizontal 550 feet long. The upright part is in the same line with the two previously mentioned exposures, and the other runs S. 35° E. The country is wooded, and hence the ledge cannot readily exhibit its shape, as it does elsewhere, rising like a rampart above the adjacent land, not forming the crest of the hill, however. The western and northern walls are the most prominent, rising perpendicularly twenty-five feet for several rods. The northern slope is covered by enormous blocks of stone separated by frost from the ledges, and then fallen a short distance down hill.

The connection between the next conglomerate masses is not understood. We have first a fragment 500 feet from the end of the L running N. 35° E., save that the northern end is bent towards the greater mass to the east. It is 400 feet long. The larger fragment is conical in shape, when viewed horizontally, or as projected upon the map, the longer diameter being 500 feet and the base 400. The base is at the foot of a precipice, say 150 feet high. Near the upper part excavations have been made into the ledge in search of gold, and it was known formerly as the "Dow mine." The aspect of the fragment oftentimes seems like that of an anticlinal plunging beneath the hill, with a cap of dolomite. There is certainly an accumulation by shoving of an unusually large mass on this hillside. In favor of a synclinal structure we have the apparent starting out of two conglomerate lines from the Dow ledge, spreading out 2000 feet before reaching the south town line, and uniting again in the northern part of Bath. To the east of the Dow ledge, 400 feet, there is another fragment whose northern end touches the hill in the same way with the last, and capped by dolomite. The fragment is 800 feet long, at first N. 35° E., and then with a more nearly north-south course. It nearly reaches the road from Lisbon village over the hill to Smith brook. A hill between this road and R. D. Moulton's house on the Bath line has the same general course, and appears to be underlaid by conglomerates, 800 feet long. On the opposite side of the valley there is a ledge of the conglomerate running 1000 feet S. 35° W. up the hill before reaching the Bath line. A line of boulders running easterly from the north end of this last named fragment, between B—17 and 18, is suggestive of a bend towards the Dow ledge. This ledge on the west side of the valley rises to the top of the hill, and then passes by the house of H. Ash in Bath, and continues uninterruptedly nearly to the brick house occupied by M. L. Sanborn in Bath, a distance of one mile and seven eighths in a right line. I have protracted carefully upon the map, measured with chain and compass, the various bends of this formation in Bath, and will not particularize the details here. There are about thirty angles made in its course, which might be mentioned in detail. There is frequently a high wall upon the western side, as in the south part of Lyman. Dolomite beds cling to it continuously on the west side. At the lower end the course reminds one of escalloped embroidery. Concerning the relation of the slates, Lyman schist, and conglomerate at this lower end, sufficient mention has already been made (page 293).

While the western side of the *basin*, if it may be so called, is continuous, the eastern has been badly shattered. Near the town line there is a fragment a third of a mile long, roughly parallel to the western belt, about the same distance apart as before, above R. D. Moulton's. Farther south we find only remnants, five pieces scattered for half a mile, beginning five sixths of a mile south of the town line, and terminating fifty rods east of the western belt, where it bends sharply to the east for about forty rods. No other fragments occur save for the last half mile before reaching the southern end of the basin. The junction there is not regular, but through a fault. The irregularities on the eastern side may be due to the elevation of a considerable band of Lyman schists, starting near the line and extending north-easterly towards the Dodge gold mine.

A few isolated patches of this conglomerate occur south of Aldrich's in Lyman. One has been known as the gold mine of Tute & Co., at U—7. The ledge is one hundred feet long, running north and south. There is a smaller patch of it at Q—7, with the strike N. 80° W. The relations of these isolated patches to the great ranges have not been conjectured.

The phenomena of the occurrence of auriferous conglomerate along the eastern range of the Lyman group are similar to those just enumerated upon the western belt. The most northerly fragments occur from half to a quarter of a mile south-west from Mill brook in Lisbon, on the road from a saw-mill to C. E. Woolson's (county map). These ledges run N. 63° E., dipping 75° N. 27° W., and are fifty feet wide. Like the conglomerate mass on the hill east of the New England Reduction Works mine, it is flanked on the east by Helderberg limestone, though in very limited quantity. The next conglomerate ledge occurs in Lyman, nearly two miles to the south-west, and reaches from near J—2 to H—3, a distance of 1100 feet. The dip is 75° south-easterly. This fragment is often one hundred feet wide, flanked by Lyman schist. Its continuation is 1200 feet further in the same direction, with a slight easterly dip. The fragment is straight for about five hundred feet, when it is bent southerly at a right angle, and disappears. Large boulders of it may show its continuance for over a hundred feet; and there are a great many pieces of it for 1000 feet between B and C—5, which are suggestive of the occurrence of ledges there. Two fragments, near A—5 on the town line, may belong to this band, each two hundred feet long, and the nearest one three hundred feet from the eastern belt.

The eastern belt is continuous from a swamp midway between E and F—2 to a point one hundred and fifty feet into Bath, below A—4, 2850 feet in length. At the north-western end it runs east and north, and at the Bath terminus its course is from N. 30°–40° E. It is usually seventy feet wide. At the Gordon mine, between C—4 and D—3, the dip is 60° S. 32° E. Five hundred feet farther north the dip is in the opposite direction. At A—3 there is a mass one hundred feet wide, vertical, running north-east, and seen for five hundred feet distance. The two bands probably make a synclinal axis with each other, as in the main range. All the phenomena in the two ranges are identical.

Topographically speaking, the conglomerate ledges always occupy the highest ground. The eastern bands just mentioned in Lyman average about a thousand feet altitude above the sea, falling off after entering Bath, where the whole country slopes towards the Ammonoosuc. While the western band is usually greatly elevated, it does not follow the crest of the hill beyond the vicinity of Aldrich's. From about V—12 to J. Williams's, there is a uniform descent of nearly seven hundred feet. The great depression along Smith brook I have thought may indicate a sinking of the strata, rather than the complete result of erosion. Such a supposition may aid us in elucidating the marvellous changes in the surface of the country since Huronian times. To the south of Smith brook the country rises, but not so greatly as at Aldrich's, and it falls off to about the level of Smith brook at its southern termination. The topography of the eastern belt of the conglomerate agrees essentially with that of the western.

Cambrian Clay Slate.

From northern Massachusetts to Fairlee pond, Vt., there is a nearly continuous band of clay slate believed to be of Cambrian age. As may be seen upon the map, it lies to the west of the Huronian. Occasionally, as at Norwich, there seem to be limited bands of this formation left in the synclinal axes, as relics of its former extent, covering over the green schists. If we continue the line of outcrop northerly, it strikes across Bath and Lyman exactly in the course of an extensive development of the same rock, occupying the centre of the Ammonoosuc gold field, and isolated from all connection with similar layers elsewhere. For this and other reasons it is probable that the Ammonoosuc slates belong to the same range with those farther south in the Connecticut valley, and that all of them are to be regarded as Cambrian, or of the same age with the auriferous slates of Nova Scotia, called the representatives of the English Lingula flags, by Selwyn. Nevertheless, it is true that there is also a range of this slate west of the Huronian, above the mouth of the Passumpsic river in Vermont.

Viewed in a general way, the slates appear as a single basin, with a normal synclinal dip evident at the south end. Older rocks have protruded themselves into the midst of the slates, having been pushed up from below through lateral pressure, thus punching holes, as it were, through the more yielding material. As a whole, the dips along the borders have not been affected, though there are many local exceptions. Often, where limited patches of the slate remain, their dips conform to the synclinal disposition. If the underlying rocks have been thrust through the slates near the eastern border, the remnants preserve their proper north-westerly dip; or, if the disturbance has been upon the western side, we discover the normal south-westerly dip remaining. At the south end of the formation in Bath, the pressure has been so great that the strata stand nearly upon their edges. The general attitude is anticlinal, dipping 80° south-easterly by S. M. Lang's near the eastern border, and north-westerly near the junction with the western schists near B. C. Child's. Yet the underlying schists conform to the proper basin structure, dipping north-westerly at the town-house, and south-easterly at W. Lang's, west of B. C. Child's. The altitudes of the lower and upper series are portrayed upon Fig. 29, Plate XIII.

The lithological aspect of the slate is uniform all over the basin. Analyses by Prof. Seely indicate a close similarity between these slates and the argillitic mica schists of the Lyman group in their ultimate constituents, so I have suggested the derivation of the former from the degradation of the latter. The slate at the Dodge mine gave,—silica, 72.98; peroxide of iron, 6.35; alumina, 5.99; magnesia, 0.36; potash, 5.61; soda, 9.92=101.21. Veins of auriferous quartz and an occasional thin bed of quartz conglomerate are the chief foreign rocks present. It is likely that careful analyses of the slates from different parts of the basin would show a considerable variation in composition, especially in the amount of silica. The constancy of mineral composition may be a useful guide to us in distinguishing between the Cambrian and Helderberg slates, where they come into close contact with each other.

Excursions along the eastern border of the slate in Bath show a uniform north-westerly dip between the Lyman line and the nearest road crossing it to Bath village. At the tunnel, or ancient mining excavation for coal opposite the south end of the auriferous conglomerate, the dip is 30° N. 42° W., the rock being black and carbonaceous.

Nearer the eastern edge the dip takes the direction of N. 62° W. The variations in the dip, caused by the elevation of the Lyman group near its southern end and at J. Clough's, have already been specified. The normal dip of N. 72° W. is apparent 300 feet west of the conglomerate. It is the same a little further on at the brook crossing the road just west of J. Clough's. The western side of the basin is reached at G. A. Wood's, the dip being 80° S. 55° E. Near the west border we have several positions noted: West of Wood's, S. E.; at W. S. Wood's, 85° N. 87° E.; half a mile north, south-easterly; at A. Wood's, 75° S. 47° E., and also at other places along the same north-east road. Occasionally along this route are a few feet thickness of schists inter-stratified with the slates; and a vein of auriferous quartz in the shelly strata near A. Wood's.

As soon as we cross the Bath line into Lyman the slates greatly diminish in amount, owing to the elevation of the underlying strata. Continuing north-east from the house of A. Wood, we find at J. M. Moulton's (county map) a shelly mass about 85° S. 50° E. Just west of L. Whiting's there is a remnant of the slate with a north-east strike, separated from the main mass. Bands of it weather dark, and carry crystals of pyrites. At A—20 and A—21, on the town line, the position varies from 85° S. 42° E. to 90°. The position is much like this all over the western corner of the specially-surveyed area west of the conglomerate, and it is on high land. The slates cover much ground between J. Williams's and the great throw above P—18. East of Williams's the dip is 85° S. 42° E. (See Fig. 30.) For a space 1500 feet long and 1000 wide the dip is much the same, often inclining to vertical, and occasionally leaning south-easterly, slightly. The strike is N. 38° E., with vertical dip at J—20. Between O—19 and 20 the vertical slates strike east and west. At O—19 the dip is 77° southerly. The rocks here are quite ferruginous. Between the conglomerate ranges at B—16, and largely over an area 2000 by 2500 feet, the position is 70° N. 32° W. The slate at V—18 dips 80° south-easterly. The slate area of perhaps 1500 by 2000 feet, near the Parker Hill road from Lisbon and north of the line T, averages 82° northerly.

Passing to the lower part of Lyman we find three slaty bands, all divisions of the eastern part of the basin. The first extends beyond the line F, and the strata are often much corrugated and broken. Near C—2, at a quartz opening, the dip is 50° S. 37° E. Between A—2 and 3, just over the Bath line, the dip is 25° N. 37°-40° W. Between B—4 and 5 a small fault may be seen at the junction of the slate and conglomerate. The former has the strike N. 38° E., and the latter N. 68° E. The course of this fault is N. 28° E. Both rocks are inclined about eighty degrees. At E—1, by the roadside, the average dip of the crumpled slates is 50° N. At F—1 the dip is 70° N. 50° W. It stands vertically five hundred feet west. Between G—2 and H—1 there is an isolated slaty fragment caught in the Lyman schist, about six hundred feet long and one hundred wide, standing on edge and running about N. 80° E. On the band of slate from 12 on the town line to the Bedell gold mine we find, near B—11, the dip 50° N. 17° W.; east of B—12, 45° N. 27° W.; west of D—12, 50° N. 32° W.; three hundred feet farther north, 60° N. 42° W. These slates split readily into large slabs. At E—11 the dip is 50° N. 27° W. At G—10 the dip is 68° N. 20° W. to N. 12° W., five hundred feet farther to the north-east. At the Bedell mine the dip is 80° N. 22° W. On the next range to the north-west, between F—13 and 14, the dip is 80° N. 32° W.; at F—14, the same; on the road near H—12, 70° N. 12° E.; below G—12, 90°, with strike of N. 78° E.; near H—10, 58° N. 13° E.; four hundred feet farther east, 67° N. 12° W.; between H and I—9, 60° N. 8° E.; near I—8, 80° N. 32° W.

Returning to the main range, we find immense slate ledges near Dr. Brown's barn, at the end of a road about G—6, dipping north. On the crest of the hill north-west the slates have the same strike, but stand vertically. East of the barn the dip is 50° north. The position is the same north of H—5. At L—5 the dip is about 20° west of north. It is 68° N. 20° W. at M—5. Between N and N—1 the dip is 65° N. 37° W., the strata being much contorted. The same fact is true of the boundary line from here for 3000 feet westerly. The Lyman schists on the south-east usually form a low hill or precipice immediately adjacent to the extremely bent slates. It is likely there is more or less of a fault all along the line. About a third of this boundary is obscured by a swamp. The presence of the fault is further confirmed by the high Lyman schist hill, near Titus's house, which is full of contortions. Where the color for slate is spread out to the north (P—5), I find evidence of a bending of the rock. Opposite the angle between P and Q—4 the dip is N. 48° E., and that is the common position in the neighborhood. It gradually works around to the normal position of N. 35° W. at the Dodge mine. The same change is apparent in proceeding south-westerly from the N. 48° E. dip. Some of the ledges near the angle show marks of disturbance. I suppose the strata have been bent here especially, because of the projection of the underlying Lyman rock. These facts do not militate against our theory of the unconformable covering of the Lyman rocks by the clay slates.

Other dips are the following:

200 feet south of O—1, dip 44° N.
200 feet west of O—1, dip 50° N. 8° W.
Between O and O—1, 60° N. 62° W.
200 feet west of P—1, dip 85° N. 14° W.
Between P and Q, dip 85° N. 12° W.
Between Q and Q—1, 45° N. 37° W.
At R, vertical, strike E. and W.
Between R and R—1, dip 62° N. 12° W.
Between R and S—1, dip 41° N. 47° W.
300 feet north of last, dip 40° N. 22° W.
Brook between S and S—1, dip 60° N. 32° W.
Between T and T—1, dip 50° N. 22° W.
100 feet N. W. from T—1, dip 48° N. 47° W.
Between V—1 and 2, dip 56° N. 42° W.
200 feet N. W. of X, dip 28° N. 17° W.
At R—6, dip 65° N. 12° W.
Near S—6, dip 72° N. 32° W.
Near U—6, dip 87° N. 12° W.

The relations of the slates to the knobs of white quartz in the Lisbon group, showing unconformity, have already been treated of (p. 282). The dip of the slates is very high north-westerly across the formation half a mile north of the line V, as exhibited upon Fig. 31. On the north side of the outlet of Young's pond the slates dip 78° S. 32° E. At the town line below, the dip is 60° N. 52° W. North of the pond, on the south flank of Mormon hill, the dip is usually high north-westerly. As before stated, the west boundary of the slates is roughly serrated. Near the top of the hill, adjacent to the curious conglomerate, are ledges of slate, holding veins of quartz eight feet wide, cutting across the stratification. The dip is N. 47° W. This seems to be the end of the clay slates proper in this direction. There is slate by the saw-mill on Mill brook, below Young's pond, also at S. Wetherby's, on the hill west, both with the usual dip noted farther south-west. On the west side of Perch pond the dip is 70° N. 32° W. On top of Bald hill the same slates dip 40°–60° N. 42° W. Beyond this they occur at Ela's, where there has been a quarry, the last house in Lisbon on the Blueberry Hill road. The whole of the Blueberry Mountain slates, with their argillaceous schists and sandstones, seem now, after further study, to belong to the Cambrian group and not the Helderberg, contrary to the delineation of the map (Fig. 27) and published papers. For convenience, we will describe them further on in connection with the several sections crossing the Helderberg strata.

We have very little to say concerning the considerable development of clay slate from Parker hill to Partridge pond. The dip in the south-west part is thought to be south-easterly. There are irregularities in it two miles before reaching the north line of Lyman, on the road to West Littleton. South from Partridge pond the slates stand nearly vertical, with a north-east strike. There is a narrow band of clay slate dipping south of east, conforming with the Lisbon schist at the east base of Gardner mountain. We have notes of it, also, at E. C. Stevens's, a mile north, and in West Littleton at the north base of Gardner mountain. It is rather more micaceous and ferruginous than is common in the larger areas. It points towards the tapering end of the Lyman group across the Connecticut river in Vermont. There are two or three very small patches of slate in the north-west part of Littleton. One of them has a quarry in it, at R. Smith's.

Coös Group.

Two areas referable to the Coös group constitute much of the eastern boundary of the tract now being described. The first enters Littleton from Dalton, crosses the Ammonoosuc near Littleton depot, and rises into Eustis hill. The north end is about two and a half miles north-east from the Littleton line, dipping near J. Quimby's in a westerly direction. There is a considerable hornblende schist between the mica schist and the gneiss. The band is about a mile wide where it enters Littleton upon Mann's hill. The common or Lake gneiss borders it on the east in Dalton, but in Littleton it comes in contact with porphyritic gneiss, and on the west at first the Huronian. Further along it may touch the Helderberg, but for two or three miles it borders gneiss, especially on Oak hill and at the village of Littleton. At A. Annis's the dip of the mica schist is 70° N. 37° W. Part of these ledges north of Mann's hill are calcareous, reminding one of the calciferous mica schists of Vermont. Towards the crest of the hill and the western border of the formation, the dip is 70° N. 52° W. Beds of hornblende occur in it, also. On the hill west the dip is 70° N. 70° W. of mica and hornblende schists. Another dip is 30° in the same direction, in ledges containing many staurolites and garnets. There are a few feet thickness of granite associated with the staurolite beds near Annis's. A mile farther south, near the road turning to Smith's slate quarry from Mann's hill, the mica schists dip 80° N. 55° W., and also west. Where the formation crosses the road near P. C. Wilkins's, the strike of it is N. 22° W. It was noticed that the layers were somewhat twisted, and contained large hornblendic nodules. It seems therefore to run athwart the underlying Lake and porphyritic gneisses in an unusual direction, and, of course, unconformably. The mica schist then proceeds southerly to Scythe Factory Village. It outcrops in two or three places along the railroad on the east bank of the Ammonoosuc. One ledge of it, by a mill-dam, exhibits the dip 75°–80° N. 22° W. Three fourths of a mile east on the railroad there is an isolated outlier of it. Opposite the new scythe factory the micaceous quartzite dips 80° N. 37° W. With it are interstratified argillaceous bands, sometimes wrinkled. The gneiss crops out at the second dam at Scythe Village. Perhaps a fourth of a mile above, on the railroad, the micaceous quartzite reäppears, carrying staurolite. The dip is 65° westerly. The actual junction of the quartzite and gneiss may be seen on the Ammonoosuc, near where the railroad has cut a passage through a ledge of gneiss. Certain layers here and in the village of Littleton are properly micaceous quartzites, of a type that is characteristic of the Coös group in Stewartstown, Vershire and Thetford, Vt., and at various other localities. In the river, near the Littleton depot, the dip is 80° northerly. On Eustis hill it is 57° N. 27° W. This formation is the same with that coming from Whitefield, east of the Boston, Concord & Montreal Railroad, on Kimball hill, and extending nearly to the Wing Road junction. Both these ranges may once have been united near Littleton, and crossed over the hill of Bethlehem gneiss to join the Lisbon area about to be described.

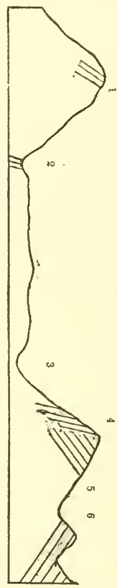


Fig. 34.—SECTION IN DALTON AND WHITEFIELD.

1, Gneiss, dipping westerly, in south-east part of Dalton; 2, Gneiss, on the west side of Round pond, dipping 60° N. 42° W.; 3, B., C. & M. R. R.; 4, Coös mica schists of Kimball Hill range; 5, Lake gneiss; 6, Bethlehem gneiss in Whitefield, south part.

The Kimball Hill range of these Coös mica schists is represented upon Fig. 34, which is partly the same with Fig. 11, Pl. VIII. The latter figure shows the unconformable superposition of the mica schists upon the Lake or Atlantic gneiss, which is not separated here from the Bethlehem series. Some part of the valley between 2 and 3 is occupied by porphyritic gneiss. As the country is swampy and wooded, it is difficult to trace the limits of the several formations within it. Farther north there are patches of mica schist outcropping in it.

The rocks of East Lisbon abound in staurolite, the ledges about Mink pond having been long known to mineralogists. This area, the second of our description, was separated from all other rocks in our first report, in 1869, under the designation of "staurolite schists;" and there is very little change to be made from that representation of its topographical distribution, save that the argillaceous division west of it is now incorporated with the grayish mica schists. The three leading varieties of this formation in Lisbon are (1) quartzite, (2) staurolite mica schist, (3) stauroliferous and garnetiferous clay slates.

Of these the quartzites occur chiefly in a narrow strip colored as gneiss on some of our maps, extending from the South Branch half way through the township. They follow a road parallel to the Ammonoosuc between the South Branch and Salmon Hole brook. Near the South Branch we have in order, proceeding northerly, gneiss, slaty layers, perhaps slightly calcareous, dipping 80° north-westerly, quartzite, with a dip of 75° S. E., limestone, and quartz. This series is only a few rods wide. Quartz and limestone, with gneiss, are found along this road nearly to Salmon Hole brook (near J. Hildreth's) in a very narrow band. The quartzite is evidently older than the adjacent staurolite schists, and the structure may be anticlinal. The limestones are connected with the gneiss, being of the same age with the bed at Bronson's kiln. The quartzites are represented in the Ammonoosuc collection, in Nos. 783–788. See, also, the Map, Pl. XII.

The Coös area east of the Ammonoosuc naturally divides itself into two parts mineralogically, the western consisting of clay slates, with many garnets and a few staurolites, and the eastern part being a mica schist, everywhere stauroliferous, and often holding magnificent crystals. The slates at the upper end occupy about half the space between the quartzite range and the Huronian. At the south-west end of Streeter pond the dip is N. 27° W. at a high angle. A mile west the position is the same. Near the mouth of the South Branch, at a bend in the stream, these slates dip 60° N. 29° W., and are exposed for a width of thirty rods. The relations of the slates to the adjacent Huronian and Helderberg strata are given further on, in a section under the description of the latter rocks. On Salmon Hole brook these slates dip 85° W. The section in Fig. 28 crosses this and the schistose band farther south along Mink brook. The thickness of the clay slates here is given at 3000 feet, with an average dip of 58°, and that of the schist at 3300 feet. Beginning at the Atwood gold mine on this section, the following were the dips observed across the slates: 48° N. 62° W., 50° N. 67° W., 64° N. 57° W., 68° N. 62° W., and 65° N. 32° W. The distance is about fifteen sixteenths of a mile. These slates terminate on the west side of Pond hill in Landaff, with the dip 58° N. 32° W.

The mica schists begin in the edge of Bethlehem, south of W. Burleigh's, on the road from Littleton to Franconia, with the dip 20° N. 57° W. The valley continues to Baker's hollow in Bethlehem; and it would not be surprising if the staurolite rock extended further in that direction, as the ledges there are all covered by drift. There is a beautiful display of large staurolites on the road from the furnace, a little north of west over a hill towards the north-west line of quartz, passing by the names D. A. Oakes, J. Bowles, etc., of the county map. On Salmon Hole brook the staurolite mica schist agrees with the slate in position, viz., 85° W. Recorded observations are meagre north of Mink pond; but the usual dip is north-westerly to westerly. A hornblende schist occurs near H. N. Page's, on the west side of the gneiss and quartz ridge. Near Mink pond the dips are 65° N. 57° W., N. 42° W., and N. 72° W. (See Fig. 28.) The formation narrows in proceeding southerly into Landaff. It seems to cross Mill brook three fourths of a mile below the village, the garnetiferous ledge dipping 80° N. 52° W. It may possibly be represented in argillaceous schist layers near the schoolhouse at the west base of Green mountain; though we have not yet fully established in this neighborhood the boundary between the Coös and Swift Water series. We find quartzite by the Baptist church, about a mile from the north line of Landaff, dipping at a low angle north-westerly, and a larger conglomerate exposure west of W. Hunt's. Our notes speak of quartzites also following the limestone of the Bronson range in Lisbon. These are on the same strike with the outcrops at the Baptist church and at Hunt's. The range is parallel with that on the north-east road between Jesseman's and Hildreth's, and may occupy a synclinal fold of the same stratigraphical horizon with that. The latter line of outcrop may divide the mica schists stratigraphically, as it does territorially. There is no evidence to prove that the slates on the west of the schists have been folded. The quartz is beautifully developed farther south through Landaff, Benton, Haverhill, etc., passing into the mountainous masses referred to the Coös group. These will be described further on, in the next division of the Connecticut Valley rocks.

There is considerable variation in the aspect of the staurolite rocks. We have fine-grained homogeneous clay slates, with slender staurolites. Then there are coarsely-crystalized ledges of mica, staurolite, and garnet. Perhaps the most characteristic is an argillaceous schist, with numerous stems of staurolite about three inches long, of a reddish-brown color, cutting through the rock in various directions. The staurolite is also found in a gray micaceous rock, and in the western edge of the gneiss by Mink pond. Some of our specimens suggest the existence of the Coös slates to a limited amount upon Walker hill and its neighborhood, the continuation of the Eustis Hill range from Littleton lying between the Bethlehem and Swift Water series. The last that can be depended upon is at P. H. Padelford's, at the south line of Littleton.

Swift Water Series.

While occupied in studying the geology of the gold field, I found a set of specimens which could not be readily referred to any of the series that have been mentioned. They approximate nearest to the Lisbon group, and occupy the territory east of that formation. Its whole extent from Haverhill to North Lisbon (Fig. 28, p. 278) shows the position of this series in the typical section, crossing the east part of the field at Lisbon village. The combined thickness of the quartzites, sandstones, hornblende schist, and slates amounts to 4400 feet.

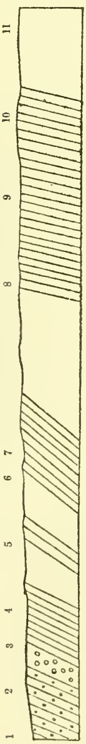


Fig. 35.—Section through Swift Water Village.

1, Starch mill; 2, Lisbon group; 3, Micaceous conglomerate; 4, Slate; 5, Gneissic; 6, Mica schist; 7, Swift Water Village—chlorite; 8, Mica schist; 9, Hornblende schist; 10, Micaceous quartzite; 11, Gneiss.

Our attention was directed to this group partly by the slate bands, and partly by a nondescript conglomerate adjoining it, particularly noticeable a mile and a half north from Lisbon, west of Mrs. A. Bishop's, on the north-west side of the river. The pebbles are not discernible till the rock has been weathered nearly white, and even then it is difficult to understand their character. This band is not more than fifty feet thick.

Following up the Wild Ammonoosuc river in Bath, there is a characteristic representation of this series of strata; and our name is derived from that of a small village on its banks. The facts given are chiefly from the notes of Mr. J. H. Huntington. The Lisbon group seems to extend up this stream for more than a mile above its mouth, judging from its general distribution. A little above a starch factory (Fig. 35) there are strata of micaceous conglomerate, of gneissoid aspect, dipping 40° N. 65° W. The slate, or the continuation of the Lisbon band, is half a mile above the factory, and it dips 65° N. 82° W. Less than half a mile above is a more distinctly gneissic band, dipping 56° N. 62° W. About the village of Swift Water are various exposures of a whitish mica schist, from 40° to 55° dip in the same general direction. There seems in many cases to be feldspar present; certainly a hasty look would make the ledges to be gneiss. On the north side of the river one ledge dips 50° N. 2° W. There is a band near a cemetery, in the south-west outskirts of the village, containing crystals of chlorite. Passing above the village the dip rises to 80° and more, or, in order, 83° N. 54° W., and 82° N. 74° W. The last is the most remote exposure seen. The rocks are micaceous friable quartzites, decomposing so as to appear ferruginous. There are thin, glossy black micaceous bands, of a few inches in thickness, interstratified with the quartzites. This is at a bridge a mile and a half above the village. A wide band of hornblende schist below the bridge should not be forgotten. The gneiss above has a high dip. It is possible that an anticlinal axis may be indicated by the divergence in the steepness of the dips. There seems to be a prolongation of a spur from the gneiss of Haverhill directly to this point of dip-divergence. There is considerable lithological similarity between the rocks along the Lisbon and Swift Water sections.

The slate band (No. 4) of the section is quite interesting, as it can be traced to Lisbon village, and perhaps Littleton, bounding the series on the west. A conspicuous locality of it is at I. Clark's, about two miles east of Bath village. Going south-east from J. M. Nutter's, for a mile, the following three dips were noticed: 80° N. 50° W., 68° N. 52° W., 60° N. 42° W. The rocks are mica schists, also, at W. Bass's. Ninety rods south of W. Waddell's, the rock adjoining the mica schists is chloritic. A quarter of a mile south-west of the Hon. A. S. Wood's we have mica schist and hornblende rock somewhat calcareous. Next I. Clark's slate there is mica schist, and a slightly chloritic rock sixty rods north. Micaceous quartzites occur half a mile south-west of S. Clark's, on the Bath line, at L. Elliot's, and at J. Chandler's in Landaff. At S. Clark's there is a mica schist, with acicular hornblende. By J. Chandler's we find a little of the Coös group, also. West of Mrs. Bishop's, in connection with the conglomerate referred to above, the dip is N. 40°–58° W. Across the section, in Fig. 28, we have the following dips proceeding east: Slate, 60° N. 60° W.; hornblende, 50° N. E., 50° N. 67° W. on hill-top, also quartzite with smaller dip; sandstone, 70° N. 66° W.; hornblende layer, 70° N. 62° W.; and rock at Atwood's gold mine, 50° N. 72° W.

As at present advised, the rocks north of Lisbon village may be thus classified. At the railroad crossing is the Swift Water slate, continued northerly from I. Clark's, which seems to point across the river to join the ledges associated with the conglomerate west of Mrs. A. Bishop's. Nearly two miles of exposure next are concealed by the meadows. A little white quartzite, once thought to resemble Bethlehem gneiss, appears by M. Kimball's; then the Lisbon group as far as W. (not S.) K. Chase's up the Ammonoosuc. These dip high north-westerly. As mentioned on page 284, this area of Lisbon rocks seems to be disconnected with both the other ranges. The hornblende band succeeding dips N. 82° W. beyond Chase's, and may be seen upon both sides of the river for some distance. It occurs again at G. H. Buel's, upon Walker hill. I think that is the branch proceeding towards Fitch hill, while that on the east side of the river directs towards Streeter pond. (Compare with statement on p. 284.) This hornblende band is thought to be Huronian. Next are supposed Helderberg slates, dipping N. 50° W. just before reaching the Whipple Brook road. Beyond that turn a short distance are calcareous rocks 75° N. 42° W., followed by fossiliferous Helderberg strata 75° N. 32° W. Then there comes, by J. Dexter's, 2d., and D. S. Richardson's, a series of micaceous limestones, green rocks, and conglomerates, having the aspect of the Swift Water series, dipping N. 32° W. This brings us nearly to North Lisbon, and the peculiar conglomerates and limestones of the Helderberg group.

These Swift Water rocks seem to be continued at eighty rods south of W. Morse's house,—a white, soapy rock with quartz pebbles, the slate of Walker hill used for whetstones, a ledge adjoining the Bethlehem group west of D. Dexter's, and in general from this ledge across to the road from Walker hill past W. Jackman's and Col. H. Richardson's into the south part of Littleton. The ledges along this road dip 55° N. 32° W. There is a fine development of them on a private road up to P. K. Corey's in Littleton. Near his house the sandstone rock dips 70° N. 52° W. South of the house the schistose rocks dip 75° N. 52° W., and there are a large number of ledges. These Swift Water rocks are not seen farther north-east, being covered by the alluvium. The Cambrian joins them on the west.

Our general impression of the age of this new series is, that it is allied to the Helderberg. The Coös group disappeared finally about two miles below the Lisbon section, so that the Swift Water series lies contiguous to gneiss of a very ancient period for five or six miles. Were the presence of chlorite an index to its age, it would be ranked with the Lisbon group. No one need be troubled by the apparent dip both of the Coös and Swift Water groups, as well as of the Helderberg strata beneath the Lisbon series; for the lateral force has been exerted so forcibly in New Hampshire that inversion is the rule rather than the exception.

Postscript. With the view of finally settling the relations of the Swift Water series to the Huronian and adjacent rocks, I have reëxamined the Ammonoosuc valley between Lisbon and Littleton while the foregoing pages were being set up, and think evidence is afforded to prove them to be a part of the Huronian, perhaps the equivalent of the strata developed along the Upper Ammonoosuc river in Stark and Milan (p. 52). This will enable us to color the area between the clay slates and the Coös group in Lisbon as Huronian. The Bethlehem group at North Lisbon may extend a little farther south-west than appears on Fig. 27, and the small area of it by M. Kimball's may be eliminated. I also think that the slate band, spoken of as extending from Swift Water river past I. Clark's to the north part of Lisbon village, should not cross the Ammonoosuc to join the rock near Mrs. Bishop's, but continue to North Lisbon, perhaps dividing above the saw-mill near the mouth of Whipple brook, and the western branch continuing over Walker hill, constituting the whetstone quarries there, and outcropping at Paddleford's just in the limits of Littleton. If there is to remain any relic of the Swift Water series in our classification, it will be this band of slate. I cannot fully satisfy myself whether it belongs to the Huronian, Coös, or Helderberg series. Future explorers of this district may well commence by fixing the age of this slate. A hornblende band lies adjacent to this slate on the west, traceable perhaps from Lisbon village, certainly from about the mouth of the Salmon Hole brook to W. K. Chase's and the adjacent saw-mill, G. H. Buel's, J. Clark's, and so on into Littleton at or near Fitch Hill summit. I suppose the same, or a closely-related hornblende band, courses to Streeter pond from the Whipple Brook saw-mill. This is the band spoken of on page 284, and it is to be regarded as Huronian.

A few details additional to what has been already given will now be in order. The greenish sandstones crop out on the hill south of the Atwood mine, dipping 70° W. By S. C. Simonds's, next the town line, there are hard greenstones, not conglomerate, dipping 65° N. 70° W. There are bands of a white quartzite a little west of the Atwood mine, believed to be the same with the white ledges by M. Kimball's, and near the mouth of Salmon Hole brook. In following up this latter stream we find the following order:—First, there are the usual hard dioritic schists of the Huronian, much like those in the railroad cut, being the same layers in fact, dipping 65° north-westerly. These layers contain interesting iron ore nodules, consisting of the specular variety, enclosing hematite, the latter verging into limonite as it decomposes. The ledge is full of holes, caused by the washing out of these iron ore nodules. Close to the railroad crossing of the stream are micaceous quartzites underlaid by the white rocks. About a fourth of mile back are large blocks of hornblende rock, which are supposed to represent this rock as it continues south from the saw-mill called above "near W. K. Chase's" and the "Whipple Brook" establishment. It must be in place very near. Next comes the slate band, occurring at a bend in the stream quite conspicuously. The remainder of the distance to the display of the Coös slates is mostly covered by drift; but two or three exposures of conglomerate are visible, dipping 60° north-westerly like all the strata upon this brook. This is believed to connect with the coarser "egg" conglomerate at North Lisbon, but here it closely resembles the auriferous variety so common in Lyman. A micaceous schist occurs with it. No other rock intervenes between this fragmental one and the Coös staurolite slates, which begin to show themselves three fourths of a mile above the Ammonoosuc. It is the place for a narrow band of Huronian to occur between this conglomerate and the staurolite slates, as appears from the order of succession at North Lisbon.

Following up the Ammonoosuc, the next outcrop is the massive hornblende at the saw-mill, coursing in the direction of G. H. Buel's. The first ledge above it is a black slate, with many small veins of quartz, much contorted, and with a strike carrying it squarely across the river. This is thought to be the continuation of the slate just mentioned, and the contortions are due to local compression. It appears distinctly on the west side, near the house of P. Ash. Helderberg rocks may appear next, which I will notice hereafter. The following is the order of rocks seen from D. Richardson's house, up a deserted road towards Sugar hill: At the house, Helderberg limestone; measures concealed across the railroad and field; at the base of the hill, conglomerates, one variety holding stones of the size of a hen's egg, and the other indurated and composed of small fragments, together with mica schist, both the same with the rock exposures in the South Branch. Bands of quartzite accompany the schist, and all dip 85° north-westerly. Close by these schists, and next in order, are ledges of the hard Huronian diorites. On climbing the hill for half a mile, no other ledges were seen. This order of rocks agrees with that figured in one of the Helderberg North Lisbon sections.

Taking the west side of the river, the following are the rocks seen, beginning with Chase's hornblende. It appears on the river bank opposite a curious sheep-house, shaped like an old-fashioned straw beehive, near the house of P. Ash. Then we find the slate band. Between J. Dexter's, 2d., and D. S. Richardson's, are schists referred heretofore to the Swift Water series. Near a school-house is a hard quartzite, like some Huronian varieties. There is nothing else till we reach the conglomerate under the bridge crossing to the station.

On the road from Walker hill over to the south part of Littleton are numerous greenish schists, with large, pebbly grains of quartz. The same occur in large amounts to the north-west towards the house of P. K. Corey. There is quite a broad band,—say a mile wide between the slates and the gneiss in the north part of Lisbon,—which belongs to the Swift Water member of the Huronian. In South Littleton this mostly disappears beneath the alluvium of the Ammonoosuc, and may connect with the narrow Huronian band east of the Helderberg by Parker's river. By such a reference of these strata it is easy to understand the relations of the several formations along the Ammonoosuc valley. There will be further reference to them in the description of the sections crossing Blueberry hill under the next topic.

Helderberg.

There are three divisions of the Helderberg rocks of Littleton. The lowest member is quartzite or buhrstone; the middle is a limestone;

and the upper a few slates. We have several sections crossing this area, on which one can see many other rocks besides the Helderberg delineated, and described here for convenience. The first (Fig. 36) is near the north-east extremity, extending from Palmer to Burnham hill, nearly a mile and three fourths. Palmer hill is composed of Lyman schist, dipping 78° N. 48° W. In passing to the depression, which is in reality a water-shed for streams flowing northerly and southerly,—Cow and Parker brooks,—the strata, first, are vertical, then they dip north-westerly; and, finally, several measurements in a distance of thirty rods gave 80° S. 54° E., S. 30° E., and 85° S. 45° E. The rock here, near C. Closson's house, is an indurated slate, chiefly siliceous. Next we pass up a hill over the Lisbon schist, perhaps dipping 80° S. 25° E. On top of the hill there are good exposures of the Lyman argillitic quartzites, dipping 80° S. 37° E. Immediately to the east succeeds a siliceous rock, which, from different observers, has received the names of sandstone and buhrstone. It dips sometimes north-west, but perhaps oftener to the south-east. On the north slope of the hill the sandstone varies in position from about 80° S. 18° E. to S. 2° E. This rock can be followed a mile north-easterly across the road going eastward to Mann's hill, or nearly to W. I. Heyer's, and then is supposed to turn and follow up the hill to the south-east of Burnham's house, and to continue south-west to Parker river. It has its maximum development on the east side of the basin, and probably connects with the buhrstone of Fig. 38.

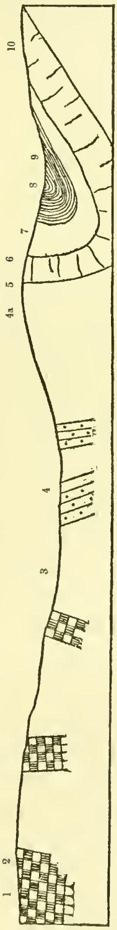


Fig. 36.—SECTION FROM PALMER HILL THROUGH BURNHAM'S LIME QUARRY.

1, Lyman group; 2, Palmer hill; 3, Closson's house; 4, Lisbon group; 4a, Lyman group; 5, Farr hill; 6, Quartz; 7, Helderberg limestone; 8, Slate; 9, Burnham's house; 10, Quartz.

Overlying the sandstone, as I suppose, is the fossiliferous limestone. It has been excavated at several places quite extensively, and burnt in a contiguous kiln. It is usually of a light-drab color, somewhat brecciated; and the fossils are not conspicuous, but upon search they prove to be considerably abundant. The thickness varies from ten to sixty feet. On the north side the limestone forms a precipice of twenty feet, in consequence of excavations. It is an excellent locality for large crinoidal stem fragments. In contact with it, on the section line, is a slate dipping 80° S. 30° E. I understand this dip, as it involves the limestone, also, to be an inversion. The Lyman schist and Helderberg here adjoin each other without the intervention of the quartzite. I find it also stated in my note-book, that a chloritic rock and a rough mixture of quartz and feldspar occur with the limestone at the kiln, perhaps as *horses*, to use a mining term; and also the fact of a change of a quadrant in the strike, in a few rods' distance. The overlying slate is seen to best advantage in descending the hill toward Littleton. It is rather dark, soft, splits readily, and contains fucoids and markings like *Chondrites*, and dips south-east. The top of this hill is an excellent place to observe contorted strata; and, on account of their variation in position, it is difficult to be satisfied with any interpretation of them.

I do not suppose that all the facts are indicated by so even a synclinal as appears in the figure. There may be hummocks of underlying rocks to disturb the continuity; and the strata are certainly contorted. The limestone was not observed to the east of Mr. Burnham's house; but, as the sandstone beyond has a small reverse dip, we may presume that the limestone changes with it. Still farther to the south-east gneiss occurs. The country is wooded, and slopes rapidly, and would not be likely to afford good ledge exposures.*

A mile to the south-west a more satisfactory section may be obtained (Fig. 37), so far as the position of the strata is concerned; but the limestone has not been observed. The west end lies in a valley, a tributary of Parker brook; and the rock is chiefly the chloritic rock of the Lisbon group, dipping a few degrees, S. 20° to 30° E. The ground is cleared, and the ledges common. The junction between this rock and the slates can be seen to the best advantage near A. Mills's house. At the house the slates dip 85° N. 20° W., and a short distance south-east 70° S. 30° E., showing a small synclinal, where the rock was crowded hard. The

* Fig. 36 was constructed from fragmentary observations obtained at two different visits, and was based partly upon theory. It was drawn several years since. Having had an opportunity to examine the rocks again, though not sufficiently to thoroughly understand them, I will add in Fig. 36a, to be placed upon some plate further on, a new delineation of the order and position of the strata east of Closson's house. The slates will there appear to underlie the Helderberg series, as I found them in the hill south of the house to dip 70° S. 70° W. and, on top, N. 38° E. The sandstone may be five hundred feet thick.

schists, including calcareous limestone, a drusy rock, and diabase, dip 85° N. 80° W. At A. P. Hubbard's, exactly upon the section line, the dip is 85° S. 30° E. The soft clay slate is thin-bedded, jointed but not contorted. The same position continues two thirds of the way to the house of J. Shute. The last third of the way the slate resumes the dip of N. 30° W., and disturbances are common. The cleavage planes can also be distinguished from the strata in a few ledges. The quartzite is a rough-looking rock, somewhat like buhrstone, dipping even as low as 35° N. 30° W. The band of chlorite schist dips 75°–80° N. W., and corresponds to a similar rock in the next section holding the same position. Last of all is the gneiss, dipping at a moderate angle in the same direction, and probably underlying unconformably the whole series described. This section is four hundred and twenty rods long. The slate is estimated to be 1490 feet in thickness.

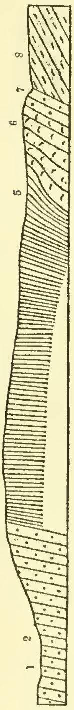


Fig. 37.—SECTION FROM CROUCH'S TO SHUTE'S.

1, Crouch's house; 2, Lisbon group; 3, A. P. Hubbard's; 4, Clay slate; 5, Shute's house; 6, Quartzite; 7, Chlorite band of Huronian; 8, Gneiss.

The slate is continuous from Fig. 37 to Fig. 38, gradually narrowing, and disappearing before reaching the section in Fig. 39. That which appears on the latter occupies a slightly different line. Fig. 38 crosses the best locality of buhrstone, from E. P. Miner's, on a tributary of Parker brook, and an eighth of a mile north of the Littleton cemetery. It is one hundred and sixty rods long. The western edge of the gneiss appears at Miner's. The chloritic layer is mostly concealed by drift. The buhrstone crops out on the hillside: it is quartz, massive and brecciated, sometimes jaspery and opaline, with a multitude of seams covered by quartz crystals. About forty feet in thickness of it are exposed. Following up the hill, we find next the slates, the limestone being concealed by drift. It appears in a place only a few rods to the south of the section. The slate is bent everywhere, and shows a tendency to contain drusy quartz. Two measured dips are 70° N. 70° W., and 85° N. 80° W. Other strikes are more easterly. The section, if

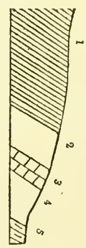


Fig. 38.—SECTION THROUGH BUHRSTONE.

1, Slate; 2, Limestone (?); 3, Buhrstone; 4, Place of the Lisbon group; 5, Gneiss, near E. P. Miner's.

continued, would pass down a precipitous hill and across Parker brook into a swampy forest.

The next (Fig. 39) is the most important of all the sections, partly because it is near the travelled road to the Connecticut river west from Littleton village, and partly because it comes from Section IX. It is a mile and three eighths long. The gneiss is the Oak Hill deposit, and is in place an eighth of a mile north of the section, with a dip of 35°–40° N. 30° W. The chloritic rock appears next. It is close by the road, opposite the last house before reaching the Parker brook, and can be traced along the ridge extending north-east for one fourth of a mile. The dip is 60° N. 60° W., with a somewhat higher dip down the slope. The fossiliferous limestone follows immediately. The first layer seems to conform with the wall rock. At the kiln, which is not fifty feet from the base, it dips 60° N. 85° E., and also westerly. Hence there is a small anticlinal axis. The same fact was also observed farther north, near Fig. 38. Directly at the kiln no fossils were obtained: they came from a dark layer, with a westerly dip, near the brook. The *Zaphrentis* and the *Favosites*, with small crinoidal fragments, are found here. Geologists have searched for fossils at the kiln, and, finding none, have concluded that our story about them is a myth; but they should look in the right place. Dr. C. T. Jackson visited this kiln in 1841. He says,—"The bed is included in mica slate, embraced on both sides by granite, which crowded the limestone in such a manner as to produce contortions of the strata. The course of the limestone, as indicated by strata marks, is N. 20° E., S. 20° W., and its dip is to the north-west." He figures the bed as enclosed between two masses of granite, but does not exhibit any contortions in the strata.*

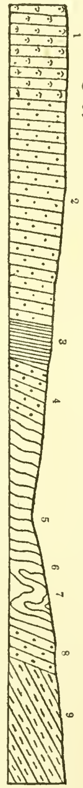


Fig. 39.—SECTION ALONG CARRIAGE-ROAD WESTERLY FROM LITTLETON VILLAGE.

1, Green schists; 2, Chlorite rock; 3, Helderberg slate; 4, Chlorite rock; 5, Parker brook; 6, Helderberg fossils; 7, Lime quarry; 8, Chloritic rock; 9, Gneiss (supposed).

The alluvium of Parker brook intervenes, and conceals the rock for an eighth of a mile, perhaps. On the south-west side there are several out-

* *Geol. Report*, p. 108.

crops of limestone, some of them containing coral masses. A slaty mass with no cleavage is mixed with it. The limestone near the first house on the west side of Parker brook is bluish, and was at first supposed to belong to the Lisbon series, as it is not fossiliferous. It has been excavated for a kiln in years gone by. Recent researches indicate that the whole of this hillside, perhaps into Lisbon, is of Helderberg age. The strata have somewhat of a zigzag arrangement, which need not be described in detail.

Directly beyond the brick-kiln we find the chloritic rock in its perfection, dipping in the same direction with that already noted, but at a steeper angle, and the range is only thirty rods wide. At a turn in the road, slate of less width, seemingly vertical, appears; and we discovered imbedded in it two feet thickness of compact crinoidal limestone. This identifies the slate with the deposit upon Fitch hill, a quarter of a mile to the south-west, where the *Pentamerus* is found. The mingled slate and limestone extend up the hill, and then across the ridge.

The chloritic rock reäppears on the section at a fork in the road, and continues uninterruptedly for three eighths of a mile, dipping 75°–80° north-westerly. This would give a thickness of about 1900 feet of strata. This is undoubtedly continuous to the west end of Fig. 36 in one direction, and to the ledge under the slate quarry in the other, a distance of about three miles.

The Fitch Hill locality was discovered September 22, 1873. Mr. J. H. Huntington and A. S. Bachelor, of Littleton, and myself composed the exploring party; and Mr. Huntington first detected the presence of the *Pentamerus*. Our attention was called to the spot by Mr. A. R. Burton, of the village, who had seen limestone there. It is about fifty rods southerly from E. Fitch's house, in an open pasture, near the forest and above an orchard. The first rock seen above Mr. Fitch's is the chloritic feldspathic layer of the Lisbon group, running N. 55°–60° E., and containing a layer of white quartz. In the pasture the strike changes to nearly east and west; and this fact is made certain by the position there of the white quartz, which curves with the Lisbon rock, but may be a little nearer the Helderberg after the bend is passed than before. This is confirmed by examining the rocks east of the Helderberg range. On Fig. 39, below, there are thirty rods of chloritic rock east of the slate range, but on

Fitch hill, in consequence of the transverse course of the latter, it is wanting, as shown in Fig. 40. To the south-west there is another outcrop of this older range, and the Helderberg is cut off by it; but the fossiliferous seam again covers it when the low ground is reached, and the hard rock is seen no more.

Furthermore, the contact between the Helderberg and the diabase or chloritic strata on Fitch hill is not a direct succession or interstratification, since there has been a sliding of one rock over the other. The removal of the turf revealed a slickenside between them. As expressed by Prof. W. B. Rogers, who examined the locality with us a few days later, it "looks as if the limestone had backed up on to the green rock." These facts are mentioned to show our reasons for believing that the Helderberg rocks on Fitch hill and the neighborhood overlie the Lisbon group unconformably.

The order of the rocks from Fitch's house to the very summit of the hill is well shown in Fig. 40. What I have called the top of the hill thus far, signifies the highest part of the cleared land. This section reaches the very summit, which is wooded. Above the Lisbon series come about fifty feet of Lower Helderberg limestone, holding the chain coral, *Pentamerus*, and a gasteropod, with the others mentioned by Mr. Billings. This is followed by forty or fifty feet of coralline slate; thirty or forty feet of friable conglomerate, white, when weathered, like the Oriskany sandstone of New York, the quartz pebbles being of the size of kernels of Indian corn. Next is a bluish, compact feldspar, somewhat resembling siliceous limestone; then follows considerable tough, massive hornblende rock, with no signs of stratification, which, with the felsite, is supposed to be a repetition of the underlying Huronian. On the very apex of the hill is a sandstone weathering white, but gray in the interior. It dips apparently fifty degrees east of north. The section is about half a mile long.

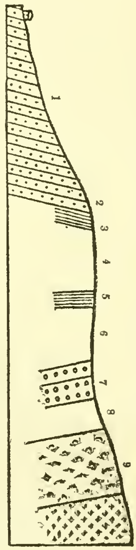


Fig. 40.—SECTION SOUTHERLY FROM FITCH'S HOUSE.

1, Chlorite rock; 2, Quartz; 3, Slates; 4, Fossils in limestone; 5, Slates; 6, Limestone; 7, Conglomerate; 8, Compact feldspar; 9, Hornblende; 10, Sandstone.

Following the limestone south-west, perhaps a fourth of a mile, we find the purest carbonate of lime yet seen. This is interrupted by chloritic rock,—to be succeeded by fossiliferous slate and limestone,—which passes west of the slate quarry and lower down the hill, if its strike does not alter. Commencing near the fork in the road turning to the slate quarry, there is, first, the chlorite rock on Fig. 41, with its usual position; second, the Helderberg rocks just mentioned. The slates predominate, and decompose readily and unequally. High up the hill is the gray sandstone, decomposing white, continued from Fig. 40. The hornblende rock on the crest of the hill is one massive stratum, with no indication of divisional planes. The slates were at first thought to be the continuation of the quarry ledge on Fig. 42. Both have the pyrites in abundance, and the same general aspect; but, by comparing the several figures together, it seems as if the sandstone would properly correspond with the conglomerate back of the quarry; and the hornblende rocks agree with the green schist. That would make the slates just mentioned correspond with each other, as well as the harder dark slates in which a synclinal appears.

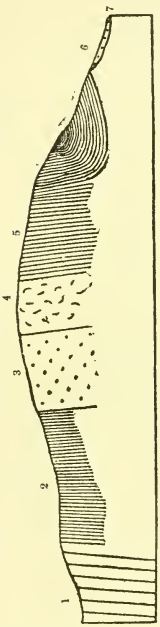


Fig. 41.—SECTION FROM QUARRY ROAD TO L. A. PARKER'S.

1, Chloritic rock; 2, Fossiliferous slates; 3, Sandstone; 4, Hornblende; 5, Dark slates; 6, Sand; 7, L. A. Parker's.

The latter slate is a hard, black, even-bedded rock, which also shows itself continuously nearly to Parker brook. The east part of the synclinal is wanting in Fig. 41, its supposed place being covered by the alluvium of the Ammonoosuc. The strike varies to the north-west near L. A. Parker's house, at the east end of the section; and the rock makes a part of the zigzag arrangement before alluded to.

The next section (Fig. 42) passes from the slate quarry to the Ammonoosuc river, near the south line of Littleton, a mile and seven eighths long, and seven eighths of a mile south-west from Fig. 41. The same hill is traversed as before, but the upper slates are better displayed. They are covered by two grades of argillaceous sandstones, the lower portion being more argillaceous and of a darker color; the upper grayish, and of a different texture from the sandstones on Figs. 40 and 41. The hill was crossed transversely as far as indicated; the eastern slope remains unexplored. The strike varies N. 65° E. to N. 70° E. There seems to be an outcrop of the Lisbon group dipping toward Bluberry hill in the valley east.

The slate quarry is a location known to residents, on account of extensive excavations once made there. The slate is of excellent quality, and, were it not for a profusion of cubical crystals of pyrites, would be worth quarrying. It dips about 80° south-easterly. Above it on the hill is an interesting conglomerate, with pebbles averaging the size of a hen's egg. This is what we have familiarly called the "egg" conglomerate. The paste is the slate of the quarry. One pebble is a foot long. Siliceous fragments of a dark color predominate, which seem to have been derived from the Lisbon group, as also have been a few greenish chloritic bits. Others, and possibly the greater portion, show resemblances to the compact feldspars of the Porphyry group. There are small bits of black slate like that occurring near the east end of Fig 41.

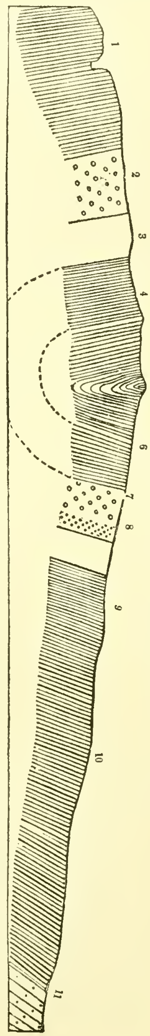


Fig. 42.—SECTION FROM SLATE QUARRY TO THE AMMONOOSUC RIVER.

1, Slate quarry; 2, Conglomerate; 3, Greenish schist; 4, Dark slates; 5, Light-colored sandstones; 6, Dark slates; 7, 8, Helderberg conglomerate and limestone, resting on Huronian, not shown here; 9, J. K. Corey's house; 10, Swift Water division of Huronian; 11, Green schists.

Two recent visits to the east end of the above section give the following information respecting it. Starting from S. Hastings's, Jr., in Littleton, the Huronian rocks were not seen, because covered by drift. The slates have somewhat of a sandstone aspect, dipping north-westerly up the side of the mountain. On top the layers exhibit contortion, and have a more easterly course. The east slope is very precipitous for three hundred feet; and the strike is fairly east and west, or running with the section line for a considerable distance, with vertical strata, or 80° southerly. At the base of the precipice are numerous large Huronian loose blocks. The first ledges seen are of the same character, dipping 70° N. 52° W. Upon them are some narrow ranges of conglomerate like that seen above the slate quarry. On examining the fields back of J. K. Corey's house, we find some of these ledges isolated, and others resting upon the Huronian, with the same dip as the underlying strata. Next there occurs a large ledge of Helderberg limestone, full of coralline and crinoidal remains. Some of the limestone bunches contain irregularly shaped masses of chlorite, evidently of later origin than Helderberg, or, more precisely, of the age of the elevation of the fossiliferous sediment. Still farther east is a mass of white quartz, full of reticulated veins. Then there succeed a great many ledges of green schists, full of fragmental grains, belonging to our Swift Water series, dipping like the foregoing. Near J. K. Corey's house some of the layers have the aspect of calcareous decomposition. On the height of land to the south there is a great abundance of embossed schistose layers, like those near the house, dipping 75° N. 52° W. Below Corey's house the greenish, sandy schists dip 70° N. 52° W.

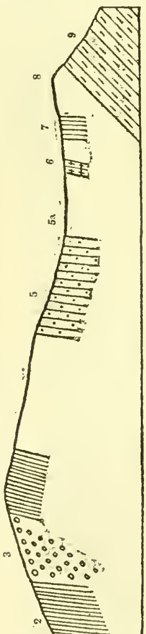


Fig. 43.—Section from Mulliken's Brook to North Lisbon.

1, Lyman group, near G. D. Shute's; 2, Helderberg slates; 3, Conglomerate; 4, Dark slates; 5, Lisbon group; 5a, Hornblende; 6, Mica schists; 7, Hornblende rock; 8, Conglomerate—Swift Water (?); 9, Gneiss.

Another trip was made from the slate quarry to Corey's farm. The conditions of Fig. 42 were found up to the slate. On the ridge I found argillaceous schists, with the high north-westerly dip. The eastern slope is gradual, but so covered by earth that no ledges appeared. The blocks of Huronian hornblendes and diabases suggested the possible presence of ledges to connect the Corey schists with those on the wooded summit of Fitch hill. North from Corey's is a spur from the main Blueberry range, running south-easterly. This proved to be the same greenish, sandy schists with those before described, dipping to the north-west.

The next section in Fig. 43 is three and three eighths miles long, and passes over more strata. It begins high up the early course of Mulliken's brook, crosses Blueberry hill, and terminates a short distance north of North Lisbon, reaching the gneiss. At the beginning is the Lyman instead of the Lisbon group, though the latter would appear if the section had been elongated half a mile. Near G. D. Shute's house and "Indian Rock" these schists dip 85° N. 30° W. The east border of this group dips 80° N. 40° W. It weathers whitish, presenting a chalky aspect at a little distance. Along the carriage-road succeeding is an extensive range of Helderberg slates and limestones, containing *Favosites*. The strata stand perpendicular, running north-east. On a tributary stream, near C. Hastings's house, is a fine exposure of grit, slates, and calcareous beds, greatly resembling fossiliferous strata in Maine and New York, but they yielded no relics of life, in a half-hour's search. This series of strata forms a steep cliff seventy or eighty feet high, which can be followed a mile and a half to the slate quarry. The country at the base of the cliff is everywhere a swampy forest not intersected by roads, so that its exploration is not inviting.

Passing up the hill there are so many boulders of conglomerate, that we must believe this to be the rock in place. Near a school-house it dips S. 68° E. Its character does not vary from that seen in Fig. 42. This view will make the fossiliferous slates correspond with the slates at the quarry. Near the top of Blueberry hill are slates with the course N. 55° E.; and others dip 20° south-westerly, which may be explained by supposing cleavage planes to be present having a different strike from the strata, or by a local sliding. On the crest of the hill the slates dip 70° N. 35° W. This continues about half a mile on the line of section, or as far as I was able to travel upon it. There is room enough for the double thickness of slate seen in Fig. 42.

The slates extend on the eastern slope of the hill to the ridge east of C. Ela's in Lisbon, where there is an excavation in them made for some mining object. The greenish Huronian schists adjoin them, followed by a hornblendic band, seen at J. Clark's, dipping north-westerly. Specimens of the mica schist come next, probably the whetstone slate layer, followed by more hornblende and the Swift Water sandstone, a rock with whitish cement and pebbles of the size of buckshot, with vertical dip. The locality of the last is on top of the hill, next the Ammonoosuc river. The hornblende first spoken of is that connecting the Whipple Brook saw-mill and perhaps Fitch hill. The other strata belong to the Swift Water division of the Huronian. There is a resemblance between the mica schist spoken of and the rock of Eustis hill. The gneiss following belongs to the Bethlehem group, dipping 30° northerly, and is a part of the range mentioned upon page 274, running into Bethlehem, and terminating less than two miles south-west from the section line. Whatever may be the stratigraphical character of this group in Bethlehem, it is practically an inverted anticlinal at North Lisbon, since it is flanked on both sides by newer rocks, all dipping in the same general direction, unless the discordance in strike of the gneiss and Huronian is of enough consequence to be styled an unconformity.

Fig. 43, if protracted, would cross another interesting Helderberg area; but, for the sake of clearness, I will add a small section (Fig. 44), with greater horizontal scale, situated about a quarter of a mile to the south-west, crossing the Ammonoosuc nearly at North Lisbon railroad station, and passing up its south branch. The gneiss dips 36° N. 47° W. at the lead mine. Next is a coarse conglomerate, seen in the field and under the bridge, dipping 65°–70° N. 22° W. As there is a general resemblance between this and the conglomerate of the Lisbon group, it was not till the recent discovery of extensive Helderberg strata that these ledges at North Lisbon appeared to belong to the Paleozoic series. The materials of the pebbles are white and blue quartz, hydro-mica schist or Lisbon group, two or three gneisses, Coös slates, and calcareous masses, with an argillo-micaceous paste. Some pebbles are a foot long. They are usually slaty, but not contorted.

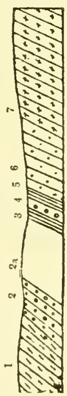


Fig. 44.—SECTION UP SOUTH BRANCH, NORTH LISBON.

1, Gneiss; 2, Conglomerate; 2a, Place for Helderberg limestone; 3, Slates; 4, Conglomerate; 5, Slates; 6, Lisbon group; 7, Coös group—staurolite slates.

Crossing the river and walking over twenty rods of gravel, we came next to a more interesting locality in the South Branch valley. The first ledge, back of the last house on the road, is micaceous slate, with calcareous layers, cut by an obscure igneous dyke. The strata dip 45° N. 32° W. Beneath are fifty feet of coarse conglomerate, containing, in addition to the pebbles under the bridge, pieces of the mica schist of the Coös group, without staurolite. The slates next observed have a higher dip. They are followed by indurated slates dipping 50° N. 22° W. They are traversed by beautiful ribbons of banded trap, from half an inch to three inches in width, which jump and curve in a fanciful way.

The next series evidently belongs to the Lisbon group, having essentially the same strike and dip with the last mentioned beds. It extends for about twenty-five rods along the stream. The rock is a labradorite-diorite, according to Mr. Hawes's careful determination. Probably this is the place for a coarse hornblende aggregate or diorite rock, which is seen on the west side of Streeter pond *in situ*, and in enormous boulders between North Lisbon and the pond. These hard rocks terminate just as the stream bends and passes through a narrow, rocky gorge of clay slates, containing staurolite and garnet, dipping 60° N. 29° W. The same dip is manifest higher up. The ledges extend for twenty-five or thirty rods; after which the rocks are covered with earth for a great distance. The banks are made up of boulder clay, which is undermined by high freshets; and the road has been torn away so many times that the town authorities have been compelled to discontinue the carriage-road, thus necessitating pedestrian explorations in this interesting spot. A slate similar to that just described crops out on the new road from the station to Streeter pond, about a mile north-easterly. The course is nearly east and west, and the strata are more nearly vertical; but the ledges must be continuous between these points. It is shown, also, by the presence of enormous blocks of diorite, whose source must be to the north of the slates, and not far distant. The map shows the distribution of all the parts of this section. The width of the coarse conglomerates is about forty rods, which implies a thickness of at least five hundred feet. The clay slates correspond perfectly to portions of the Coös group in the Lyme and Lisbon sections, as well as to the interesting staurolite slate seen at Purple's quarry in Bernardston, Mass., described by Prof. Dana.*

When I first made this section (Fig. 44) I believed the coarse "egg" conglomerate of Blueberry mountain and the accompanying sandstones and slates belonged to the Helderberg. Hence the discovery of isolated beds at North Lisbon led to the supposition of the existence of a Helderberg area there. The chief evidence of this Helderberg age, however, I

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* *Amer. Jour. Sci.*, III, vol. vi, p. 348.

have not stated. The vacant space in Fig. 44, between 2 and 3, is on the line of strike of a limestone containing Helderberg crinoids. Therefore the rocks associated with it are to be regarded as of the same age. The readier decomposition of the limestone has left the space vacant on the section, being covered by a thick deposit of gravel. It is now an unanswered question whether these conglomerates are to be ranked with the adjacent fossiliferous limestones, or with the coarser conglomerates associated with the Cambrian slates. In the absence of definite knowledge, I shall consider these conglomerates at North Lisbon as Helderberg, and the other as probably Cambrian. It must not be forgotten that there are sandstones and fine-grained conglomerates on the west side of the Blueberry Hill range readily referable to the Helderberg. Such are those on Fitch hill, near C. Hastings's, Littleton, and numerous loose blocks scattered along the unfrequented road back of Bald hill in the north-west corner of Lisbon.

I have a little further information about the Helderberg limestones below North Lisbon. At D. Richardson's house, and in the river bank adjacent, are several ledges of white limestone, some of them quite pure carbonate of lime, standing nearly vertical. About one hundred rods below, or nearly opposite J. Dexter's, 2d, the limestone appears on the same side of the river, holding fragments of the large crinoids characterizing this formation, both at Littleton and Bernardston, Mass. The limestone is here only twenty-five feet wide, traversed by veins of pyrites and quartz. Bunches and large masses of hornblende are associated with it in such a way as to suggest the possibility of their belonging to the underlying floor, as the Helderberg limestones and accompanying mica schists have been subjected to a violent pressure. Nearly opposite are similar slates and limestones at the water's edge, dipping 75° N. 22° W. Lastly, there are calcareous beds exposed a short distance above the turn of the carriage-road up Whipple brook, dipping 75° N. 42° W. All these ledges, of unquestionable Helderberg age, may be embraced in an area of a mile and a quarter in length, and having a thickness of strata rudely estimated at five hundred feet.

It is a matter of interest to know whether the Helderberg rocks could not be traced continuously from Fitch hill south-westerly along the western border of the Cambrian in Lyman. We have on this line of exposure an area of slates and limestones, the latter very scanty in amount, upon the top of the hill east of the Reduction Works Company's mine, near the house of D. Knapp. The limestone contains many small crinoidal fragments. The slate is friable, dipping 75° north-westerly, and is eight hundred feet wide. This area has been preserved from denudation by the presence on the exposed side of a thick mass of conglomerate, described upon page 305. On passing northerly the slates expand so as to adjoin the conglomerate above the fault, and seem to extend nearly to Young's pond. In this area are several veins of white cavernous quartz, full of iron rust, which have been opened to a slight extent for gold, though evidence that gold is present is meagre. It occurred to me, when examining them, that these Helderberg veins might be distinguished from the Cambrian auriferous quartz by a very fetid odor and the absence of ankerite. The very cavernous feature would hardly be distinctive, since it may have arisen from a more perfect atmospheric disintegration. North of Young's pond are some irregular slates, which may perhaps represent the Helderberg.

Still another possible locality of this formation exists about half a mile from Mill brook in Lisbon, on the road running south-west from a saw-mill. Loose blocks of crinoidal limestones were seen adjacent to an outcrop of the auriferous conglomerate, which seem to have been derived from a ledge. Without doubt other similar patches will be found in different parts of the Ammonoosuc gold field after further search.

In my article upon the Helderberg of New Hampshire, published in the *American Journal of Science*, I remarked upon the probability that the Dalton Mountain slates are of Helderberg age. Much of the rock there is a fine argillaceous sandstone. Since the later reference of the argillaceous rocks of Blueberry hill to the Cambrian area, this opinion is greatly weakened. The possibility of the Helderberg slates back of the Crawford house is set aside by further investigation.

Fossils. We have found quite a number of fossils. The circumstances of their original discovery have been noted in Volume I, page 48. Two parcels of these organisms were forwarded to the late distinguished paleontologist of Canada, E. Billings, who had special familiarity with the fossils of about this period in the extension of the series northward. At first he found *Favosites basaltica* and a *Zaphrentis*, with small crinoidal fragments. There was nothing in them that would enable us to localize the horizon more definitely than the general term of Helderberg, which is partly Upper Silurian and partly Lower Devonian; but the fact of the existence of the upper part of the series only at Lake Memphremagog, fifty-five miles distant, led to the opinion that the newly-discovered area was of the same age. Of the second parcel sent, from Fitch hill, Mr. Billings wrote as follows:

"The fossils came last night. They are *Favosites Gothlandica*, a large crinoidal column, a *Pentamerus* closely allied to if not identical with *P. Knightii*, and a gasteropod. The first two prove nothing. The *Pentamerus* goes far to show that the rock is about the top of the Upper Silurian—say Lower Helderberg. The gasteropod is just like some that occur in the same horizon. I do not consider the fossils sufficient to decide the age of the rock very closely, but only that it is either Upper Silurian or Lower Devonian. I have specimens of the Bernardston encrinites, and will endeavor to determine whether they are identical with yours or not."

Since then we have obtained large masses of the chain coral, *Halysites*, and probably fragments of the tribolite *Lichas*. This last discovery seems to be sufficient, coupled with the presence of the *Pentamerus*, to identify our New Hampshire deposits with the Lower instead of the Upper Helderberg. The chain coral has been considered characteristic of the Niagara limestone, a formation lower than the Helderberg. Its extreme range is from the Trenton to the Lower Helderberg, culminating in the Niagara. Possibly we shall be able to search further for fossils in our Helderberg and other fossiliferous strata, and thus obtain material for a chapter upon paleontology. In that case there may be presented hereafter full descriptions and figures of the genera enumerated above.

Relations of the New Hampshire and Massachusetts Helderberg. An allied rock has long been known at Bernardston, Mass. It was first described by my father in the Massachusetts report of 1833, with a drawing of the crinoidal stems. Quite recently Prof. Dana has described the locality and the adjacent strata,* deducing important generalizations from his observations. The Memphremagog and Bernardston deposits lie on the opposite sides of the same formation,—the calciferous mica schist

* *Amer. Jour. Sci.*, III, vol. vi, p. 339.

group of the Vermont report, and Upper Silurian (supposed Niagara) of Sir W. E. Logan's report,—and separated by a distance of one hundred and sixty-five miles. The mica schist is probably an older formation than the Helderberg, lying in a trough of clay slates, the latter constituting the floor of the fossiliferous beds. These slates may be Cambrian, judging from general considerations. No fossils yet appear in them. The calcareous schists carry a few obscure crinoidal fragments at Derby, Vt., which are of no value in the identification of strata.

At first sight, one would declare that there is no similarity between the Littleton and Bernardston rocks. After considerable study of both localities, I find a few points of resemblance, perhaps as much as we have a right to expect in synchronous deposits more than a hundred miles apart. In our studies we often look for exact resemblances in remote localities. Perhaps it is better that the connecting tie be discovered with difficulty, in which case the conclusions may be more surely established. The surroundings at Littleton are different from those at Bernardston. The series rests on diorites and diabases, close by gneiss and argillitic quartzites at Littleton. At Bernardston, the underlying as well as the overlying rock is quartzite; and in the neighborhood are the mica and staurolite schists denominated in my report as the "Coös group." Prof. Dana thinks it clear that the Massachusetts Helderberg and the Coös group, as defined by me in reports of 1869 and 1870, are, "if correctly traced out," identical.

Inasmuch as the limestones in all these localities are characterized by a similar large crinoid, those at Bernardston and North Lisbon containing no other form whatever, and occur in the same open valley of the Connecticut, it is presumable they are of the same age, and that is the Silurian Helderberg, as made known by the presence of *Halysites* and *Pentamerus*. The opinion of Prof. James Hall, to the effect that the crinoids in the Bernardston limestone are like those of the Onondaga or Upper Helderberg limestone of New York, has been quoted.* Since that time I understand that similar fossils have been found much lower down, so that they were not necessarily confined to the Onondaga. The correlation of the Massachusetts and New Hampshire limestones is better, using the same fossil for our guide, since the localities are contiguous

* *Proc. Amer. Ass. Adv. Sci.*, vol. vi, p. 300.

to each other, and situated in the same ancient valley of depression. The animals, when living, occupied the same arm of the sea, and were separated from New York by the long Green Mountain ridge.

Extent of the Helderberg Sea. The many localities of Helderberg rocks scattered over the middle Atlantic region indicate the presence of the ocean in very many parts of it. At Littleton some of these rocks now rise at least 1800 feet above tide-water. If the region rose and sank in close correspondence with its present surface, it would be comparatively easy to map out the limits of the land and water. The impression gains upon me that this depression occupied certain great valleys, leaving, as hills between, the areas that are now in many places lower than the uplifted Helderberg. The Connecticut would have been one of these areas of submergence, the Memphremagog a second, nearly parallel, supposing that the first named followed the course of the Upper Ammonoosuc and the Androscoggin lakes into Maine. Littleton village must have been at least 2000 feet lower than now. The low region of the Merrimack basin has not yet afforded any evidence of a Helderberg submergence. More likely it constituted an elevated island at the time of the growth of the Grafton county coral reefs.

Until recently I had supposed the Blueberry mountain range consisted of rocks even newer than the Silurian, anticipating future paleontological discoveries of Devonian life. For reasons given above, it is probable that these slates, sandstones, and conglomerates should be placed with the Cambrian, a much older formation. That mountain range may have been a submarine ridge, with the coralline growth upon both sides, as is proved by the occurrence of the fossiliferous structures along the two diverging lines. There is a very marked want of conformity between the coralline and Huronian layers, while there is not so much difference between the Helderberg and Cambrian. The former, closely pressing the latter, would naturally exhibit the same line of strike; and the near verticality and inversion of the strata, the force of elevation having been greater in some areas than others, render it difficult to distinguish an unconformability through the dip.

Catalogue of the Ammonoosuc Collection.

The same general remarks will apply to this catalogue and the accompanying maps, that have been made heretofore respecting the similar illustrations descriptive of the Coös and White Mountain areas. In particular, it may be said that these numbers appear on two distinct maps, the one of the entire field, and of the limited area in Lyman specially surveyed with reference to the mining interests. A few of these numbers have been placed upon Plate XII.

PORPHYRITIC GNEISS.

Bethlehem.

1, Porphyritic gneiss.

Littleton.

2–7, Porphyritic gneiss.

BETHLEHEM GNEISS.

Lisbon.

17–20, 22, Gneiss, with much black mica.

Littleton.

21, Gneiss, with much black mica.
22 a, Gneiss, slightly epidotic.

ATLANTIC GNEISS.

Littleton.

8–11, 13–16, Gneiss.
9 a, Diorite dyke in 9.
12, Hornblende schist.

Lisbon.

25, 46, Hornblende rock.
26–28, 30, 32, 33, 40–42, 44, Limestone.
29, 45 a, 45 b, Mica schist.
31, 34, 35, 55, Calcareous schists.
36, Conglomerate.
37–39, Gneiss.
43, Junction of limestone and granite.
45, Magnetite.
45 c, Ferruginous mica schist.
47, Hornblende and chlorite.
54, Trap.

Landaff.

48, Gneiss, with garnets.
49, Mica schist.
50–53, 56, Gneiss.
57, Granitic gneiss.

LISBON GROUP.

Littleton.

59–65, 67, 68, Green schists.
66, 72, 73, Sandstones.
69, 70, 75, 77, Diabase.
71, 74, 76, 78–81, Green schists.
82, Hornblende dyke.
83, Galena and copper pyrites.
84, Gossan—Albee mine.
85, Talcose gangue of copper vein.
86–89, Greenstones.
89 a, 89 c, 89 e, f, g, Argillitic mica schists.
89 b, Diorite.
89 d, Green schist.
89 h, Protogene.
89 i, Mica schist.
868, Compact feldspar.
869, Hornblende schist.

Lisbon.

23, 24, 90, 91, 96, Hornblende schist.
58, 99, g-i, l, 622, Quartzite.
92–95, Labradorite diorite.
97, 99, 99 b-d, 99 n, Dioritic schists.
99 a, Iron ore nodule.

99 e, f, j, m, Hornblende schist.

99 k, Gray micaceous conglomerate.

SECTION FROM BRONSON'S QUARRY TO DODGE GOLD MINE (Fig. 28). NOS. 100–141.

Gneiss.

100, Limestone—Bronson's quarry.

101, Trap.

102, Staurolite gneiss.

103, Hornblende rock.

Coös Group.

104–106, Staurolite mica schists—Mink pond.

107–108, Staurolite slates.

109, Garnetiferous slate.

110, Slate, with staurolite and garnet.

111, Garnetiferous slate.

112, Pyritiferous slate.

113, 114, Garnetiferous slates.

Swift Water Series.

115, Slate—Atwood gold mine.

116, Quartzite.

117, Sandstone, with white cement.

118, Actinolite schist. S. M.

119, Hornblende schist.

120, White mica schist.

121, 122, Sandstones.

123, 124, Hornblende schists.

125, Argillo-mica slate—railroad crossing at Lisbon village.

Lisbon Group.

126, 127, Light-colored hydro-mica schist.

128, Conglomerate.

129, Hydro-mica schist.

130, Diorite schist.

131, Diorite schist—decomposing.

132, Galenite in schist.

134, Diorite schist.

135, Gray schist.

136, Quartz, near J. Titus's house.

Lyman Group.

137, Argillitic mica schist.

Cambrian.

138, Clay slate.

139, Quartz vein.

140, Clay slate—Dodge mine.

Lyman Group.

141, Argillitic mica schist, back of mine.

South-east Corner of Lyman.

142–147, 149, Protogene.

148, Hornblende rock.

Range passing Gordon's house.

150–152, Argillaceous sandstone.

153–155, Diorite schists.

156, Hornblende schist.

157–163, 165, Green schists.

164, 623, Quartz vein.

590, Conglomerate.

Parker Hill Range.

166–171, 173–180, Green schists.

172, Light-colored schist.

181–184, 189, 190, 248, 278, Green schists.

185–188, Argillaceous schists.

563, Conglomerate.

Landaff.

939, 940, Chlorite schist.

LYMAN GROUP.

Lyman.

191–212, Dolomites.

Littleton.

213–216, 218, 220–222, 224–234, 849, 850, 852, Argillitic quartzites.

217, 223, Slates.

Landaff.

235, Argillitic quartzite.

236, Slate.

237, 238, Quartz veins.

Bath.

239–242, 245–247, Argillitic quartzites.

243, Dolomite.

244, Copper vein.

Lyman.

249–264, 266–268, 270–273, 275–278, 282, 283, Argillitic quartzite.

265, Quartz vein.

269, 274, 279, 281, Slaty layers.

RANGE FROM J—6 TO NEAR B—12.

286, 287, 293, 294, 297, Green schists.

288–292, 295, 296, Argillitic quartzites.

MAIN RANGE—DIVIDED INTO SMALL AREAS.

BETWEEN LINES U AND V, EAST OF 11.

298, 301, 302, 304–307, 309–318, 320–322, Argillitic quartzite.

299, 300, Slaty layers.

303, Greenish schist.

308, Ferruginous slate.

319, Ferruginous sandstone.

BETWEEN LINES S AND T.

323–333, Argillitic quartzite.

334, Slate.

BETWEEN S AND R.

335, Conglomerate, argillitic quartzite pebbles in argillaceous paste.

336–339, 342–346, Argillitic quartzite.

340, 341, Dolomitic slate.

BETWEEN LINES R AND Q.

347, 348, 350–361, 363–376, Argillitic quartzite.

349, Conglomerate like 335.

362, Quartz vein.

BETWEEN N AND M.

377, 380–390, Argillitic quartzite.

378, 379, Greenish schist.

BETWEEN M AND L.

391–395, 398–400, 402, 404, 406–416, 418–421, 423–431, Argillitic quartzite.

396, 405, Argillitic quartzite—ferruginous.

397, 401, 432, Grayish schist.

403, Slate.

417, Grit, with ferruginous spots.

WEST OF LINE 11 AND EAST OF AURIFEROUS CONGLOMERATE RANGES.

BETWEEN V AND O.

433, 436, Greenish schists.

434, 435, 437, 438, 444–447, 449–457, 459, 460, Argillitic quartzites.

439, 458, Quartz vein.

440, 441, 448, Slate.

442, 443, Dolomitic slate.

BETWEEN O AND L.

461, 463, 464, 465–474, 476–486, 488–493, Argillitic quartzite.

462, 475, 487, Schists somewhat ferruginous.

BETWEEN L AND G.

494–499, 501–506, 508, 509, 512–523, Argillitic quartzite.

500, Quartz vein.

507, Schist, with calcareous incrustation.

510, 511, Schists—ferruginous.

524, Dolomitic slate.

WEST OF CONGLOMERATE RANGES.

525–529, 536, 539, Slates.

530–533, 535, 538, 540–544, 546, 547, Argillitic quartzite.

534, 537, Dolomite.

545, Greenish schist, with ferruginous spots.

MISCELLANEOUS LOCALITIES.

548, 550–554, 557–561, Argillitic quartzite.

549, Dolomite.

555, Drab conglomerate.

556, 562, Shale.

OTHER LOCALITIES IN LYMAN.

564, "Stevens's fertilizer."

565, 567–570, 573–575, 577, Argillitic quartzites.

566, 571, Dolomite.

572, 576, Conglomerate.

NARROW BANDS OF SLATE INCLOSED IN LYMAN GROUP.

578–588, Slate.

Bath.

589, Argillitic quartzite.

AURIFEROUS CONGLOMERATE.

Lyman.

591–594, 596–603, 605–609, 614, 617–620, Conglomerate of quartz pebbles.

595, 604, 615, Conglomerate containing greenish pebbles.

610–613, Pebbles from conglomerate.

616, Conglomerate, with greenish layers.

Bath.

621, Conglomerate, with chlorite.

CAMBRIAN.

Lyman. South-east Range.

624–626, 628, 630, Clay slate.

627, 629, Quartz veins.

Fragmentary masses, possibly beds in the Lyman Group.

631–639, Clay slate.

Main Range.

640–662, 669–691, Clay slate.

663, Pyritiferous slate.

664, 665, Auriferous quartz.

666, Quartz, with pyrites.

667, 668, Quartz, with ankerite.

Bedell Branch—West.

692–722, Clay slate.

Bedell Branch—East.

723—737, Clay slate.

Area north of J. Williams's.

738–750, Friable clay slate.

Areas in north-west part of special map.

751–764, Clay slate.

Beds in Lyman Group.

765–768, Argillaceous schist.

Littleton.

769–771, Clay slate.

854, 855, 855 a, 856, Argillaceous schists.

851, 853, Sandstones.

872–874, 877 b, 877 f, 878–882, Clay slate.

873 a, 876, 877 c, 877 d, Argillaceous sandstones.

875, 877 a, 877 e, Argillaceous schists.

877 g, 883–892, 892 a, Conglomerates.

Lisbon.

772, Bent slate.

772 a-b, 772 e-f, 772 h-k, 916, 917, Clay slate.

772 c, 772 l-m, Sandy slates.

772 d, Quartz.

772 g, Trap—loose.

772 h, Large pebble from conglomerate.

Lyman.

773, 916, Clay slates.

Bath.

774, Schist in slate.

775, 777, Clay slate.

776, 778–781, Quartz veins.

782, Galena.

COÖS GROUP.

Lisbon.

783–788, Quartzite.

Landaff.

789–799, Quartzite.

941, Mica schist.

Littleton.

800, 801, 804–811, 812 a, 812 b, Mica schist.

802, 812, Staurolite mica schist.

803, Hornblende schist.

Lisbon.

813, Whetstone mica schist.

814, 815, 821–823, 832, 835, 836, 816, 819, 837, Garnetiferous slate.

817, 820, 824, 825, 831, 833, 834, Staurolite schist.

818, Clay slate.

826–829, Trap.

830, Hornblende rock.

HELDERBERG.

Littleton Buhrstone and Quartzite.

838, 840–848, Buhrstone.

839, 839 a-c, Sandstone.

Littleton Limestone.

857, "Horse" in limestone.

858-865, 865 a, Limestone.

865 b, Chlorite in limestone.

Other Rocks.

866, Conglomerate.

867, 871, Sandstone.

North Lisbon Series of Rocks.

893, 898, 902, 914, Limestone.

894, 895, 897, Mica schist.

896, 903–907, 909–913, Conglomerate.

899, 901, 908, Slates.

900, Calcareous mica and hornblende schist.

900 a, Argillaceous mica schist.

900 b, Conglomerate.

900 c, Mica schist in 900 b.

900 d, Quartzite.

915, Siliceous dyke.

SPECIMENS BETWEEN D. S. RICHARDSON'S AND D. RICHARDSON'S.

915 a, Micaceous quartzite. D. S. Richardson's.

915 b, Mica and hornblende schist. Near D. S. Richardson's.

915 c, White limestone. Between D. S. Richardson's and J. Dexter's, Jr.

915 d, Micaceous quartzite. Same as the above.

915 e, Conglomerate. Same as the above.

915 f, Quartz vein. D. Richardson's.

915 g, White limestone. D. Richardson's.

915 h, Gray micaceous limestone. D. Richardson's.

Lisbon.

915 i, Sandstone—loose.

915 j-k, Limestone.

Lyman.

917, Slate.

918, 919, Quartzite.

920, 921, Limestone.

SWIFT WATER SERIES (*Huronian*).

SECTION FROM A BRIDGE ABOVE SWIFT WATER TO NEAR STARCH-MILL (Fig. 35).

923, Micaceous quartzite.

924, Decomposing quartzite.

925, Glossy mica schist.

926, 927, Hornblende schist.

928, 929, Mica schist.

930, Micaceous quartzite.

931, 932, Mica schist.

933, Chlorite schist.

934, Gneiss.

935, Slate.

976, Micaceous conglomerate—at starch-mill.

Lisbon.

937, Conglomerate.

938, Slate.

Landaff.

942, 943, 947, 954–956, Micaceous quartz.

944, 945, Quartzite.

946, Mica schist, with acicular hornblende.

948, 953, Chlorite schist.

949, 951, 952–960, Mica schist.

950, Slate.

952, 962, Hornblende schist.

961, Mica schist conglomerates.

THE CONNECTICUT VALLEY BETWEEN HAVERHILL AND CLAREMONT.

The second section of the Connecticut valley occupies the country between the north part of Haverhill and Claremont, the limits being designed to cover the territory south of the Ammonoosuc gold field as far as to include the rocks of Mt. Ascutney. The following are the rock formations in this area, arranged in the supposed order of their age: 1, Bethlehem gneiss; 2, Huronian, with three or four subdivisions; 3, Cambrian clay slate; 4, Coös quartzite; 5, Coös slates and schists; 6, Calciferous mica schist; 7, Eruptive granites, including the Mt. Ascutney area, which is partly composed of rocks older than Huronian. This territory is about fifty-eight miles long and fifteen wide, including all of Vermont that appears upon the map. That which lies in New Hampshire is usually five or six miles wide.

Bethlehem Gneiss.

Regarding the narrow quartzite areas as the eastern border of our field, it is clear that we have three isolated fields of Bethlehem gneiss on the east side of the Connecticut, and perhaps the representative of another among the foundations of the Ascutney formations. First, is the one in Haverhill; second, in Orford and Lyme; third, in Hanover and Lebanon. These all have certain features in common, and each has its peculiarities. They are all repeated east of the quartzite areas in the Merrimack district.

Haverhill Area. This is confined to the town of Haverhill, with a length of about eight miles and a width of three. Three sections crossing it are represented. (Fig. 45 to Fig. 47.) In the most northern there appear to be an anticlinal and a synclinal; in the second, nearly vertical strata throughout, which may therefore include one or more inverted axes; and in the third, a synclinal. We have noted the following varieties of rock in this area: Protogene; common gneiss; the same, with an excess of black mica; granitic beds; hornblende schist; soapstone; and limestone. The first ledges of gneiss seen south-east from Woodsville are inclined 40° N. 82° W. at a less angle than those farther east, as at the soapstone quarry, dipping as much as 75° north-westerly. The soapstone is from twelve to fifteen feet wide, with some pyrites scattered through it. The rock south from the quarry is quite granitic. The strike runs about east and west, changing abruptly from the north-east curve in a quarter of a mile. There is a large quarry of granite at H. Eastman's, about a mile north-easterly from North Haverhill, with other smaller openings in the neighborhood, and a similar stone upon the high hill-top north of French pond. By F. C. Handford's the granitic blocks are so numerous as to suggest the close proximity of the ledge. Other exposures of gneiss, dipping 70° north-easterly, appear at the south-east of a hamlet north of North Haverhill. The enormous area of alluvium along the valley of Demming Pond brook conceals the ledges over much of this formation.

On the road from North Haverhill to Swift Water Village are other interesting gneissic outcrops. Hornblende schist and protogene gneiss, dipping 65° S. 43° W., occur by W. C. Marston's and a school-house. By R. M. Sly's, half a mile from the town line, we find ordinary gneiss dipping 68° S. 77° E. There are important irregularities in the course of the strata, in the north part of Haverhill, not yet worked out. Close to the Bath line, on the road passing French pond, the dip is 40° N. 72° W. I observed along this road, also, a considerable hornblende schist. There is protogene on the east side of Brier hill. There is an extension of the Swift Water division of the Huronian, nearly as far as French pond, of at least a mile and a half width along the town line, and a smaller projection up the valley of the tributary streams to the west. Between these projections is a similar point of gneiss, to which allusion has been made heretofore, as it seems to underlie the Swift Water rocks (Fig. 35). It is the north-easterly continuation of the Brier Hill range.

Another region of interest is afforded by the limestone and its surroundings. There are numerous ledges of the gneiss, holding an excess of black mica, on the road from Swift Water to the limestone quarry. By E. Meader's the dip is N. 26° E.; by H. & H. S. Carr's, and to the south, the dip is about 70° N. 60° W.; by M. Mann's the dip is 70° N. 50° W. By S. Hartwell's the gneiss dips 85° N. 34° W., and the layers seem to run to Black mountain in the north part of Benton. The limestone dips N. 20° W. as much as 70° W. Of this rock there is an immense supply. It occupies the valley of the north branch of Oliverian brook, and may be several hundred feet wide. We have been unable to explore it, but it may be followed north-easterly a considerable distance. It has been quarried largely here (at Mason's) for burning. It should also extend westerly. South of the quartz towards East Haverhill the gneiss dips 40° N. 20° E. The limestone crops out near the quartzite, but is connected unmistakably with the gneiss. On Knight's hill the gneiss dips 70° N. 30° W., holding a large trap dyke. The high land to the south-west of Knight's is probably composed of a later formation, overlying the gneiss unconformably. The village of East Haverhill lies upon a drift plain. Many large blocks are of gneiss, so as to give one the impression at first that this rock underlies the village, especially as it constitutes Iron Ore hill to the south. An outcrop of the Bethlehem gneiss by J. Blake's, a mile and a half north of the railroad station, has the dip of 40° N. 32° W. Between this and the limestone quarry is the westerly extension of the Sugar Loaf Mountain quartzite. The latter may form a synclinal resting upon the gneiss, Sugar Loaf showing strata dipping south, and Hogsback mountain having the north dip of the quartzite. The gneiss crops out upon Blueberry and Owl's Head mountains in Benton; but I have no data to show whether the synclinal structure pertains to the lower as well as the upper series in that town. There is evidence of its existence in the east part of Haverhill, as shown in Fig. 47. Gneiss exists near Haverhill town-house and in the valley of Cold Spring brook, but I have no facts to present in reference to its position.

As the conclusion to be drawn from these statements, we have, first, the anticlinal ridge from North Haverhill village to Swift Water, flanked westerly by obscure Huronian rocks at one time thought to represent the Montalban series; second, an anticlinal line from near Knight's hill north-easterly; third, there is the synclinal between these anticlinals; and, fourth, the more important basin underlying the Sugar Loaf quartzite. These axial lines all have a general north-easterly course. I have not described the whole of this area, as a portion of it passes out of the Connecticut into the Merrimack district, and it will be alluded to again in a subsequent chapter.

The Orford-Lyme Area. This extends from near Indian pond in the north part of Orford, to include Bear hill in the south part of Lyme, a distance of ten miles. It may possibly represent the continuation of the Haverhill area, the intervening space of about ten miles being covered by Coös rocks. The predominant varieties of rock are the same here as before, the limestone occurring in a longer range, and the protogene existing in larger amount. Pine hill may be the north end of the outcrop of this formation. It appears along the road over its northern flank. On the north and south road, west of Pine hill, none of these ledges occur north of the North Branch. Just to the south of this stream is a great profusion of its boulders, suggestive of accumulation by glacial agency. East of Sunday mountain, at the fork in the road, and by J. and A. Marston's, half a mile east, the protogene gneiss dips 80° N. 42° W. South of L. Hancock's and the blacksmith's shop, the same rock dips the same way. On the road north-east from J. Howard's the ledges are concealed mostly, but it occurs both west, at J. M. Learned's, and east, at Mrs. R. Hall's. On the north slope of Cuba mountain a hornblendic variety crops out three or four hundred feet above the road, dipping 85° S. 17° E. The rock seems to form a floor, on which the slates and quartzites of Cuba rest, the latter series being probably isolated, so that in "Davistown" this area of gneiss connects directly with that of Wentworth and Warren.

There is a large development of protogene in the valley of Jacob's brook. On the north side, near its western limit, it dips 80° N. 54° W. The dip is essentially the same at its eastern limit. On the south side of this brook, at the north base of Bass hill, a north-easterly dip of 85° is recorded. The same rock extends to the summit of Bass hill, where it holds a vein of quartz, with titanic iron and massive hornblende crystals. East of A. English's, near the south Orford line, the dip is 70° N. 62° W. On the same line, east of Lime hill, the dip is 60° N. 54° W., and half a mile west, on the east side of Davison hill, the dip is 15° east. The hill is composed entirely of the same material.

An interesting feature of this area is the occurrence of a long line of limestone. We have it first at the west base of Cuba mountain, near B. Sanders's; then it appears towards Lime hill. Just in Lyme, by D. F. Tillotson's, it dips 40° N. 74° W.; at J. Smith's it dips 50° westerly. At the fork of the road from Lyme turning to Dorchester and Canaan, there is a long exposure of limestone dipping 60° N. 82° W. As one follows the Canaan road, the limestone shows for a considerable distance. This limestone can be traced continuously, therefore, for a distance of about eight miles. In my second annual report I ranked this layer with the Coös group, as well as the band of Bethlehem gneiss accompanying it to the west. That reference is an error. The gneiss here is obviously the rising up of an older formation in the midst of slaty rocks, separating the mica schists from the quartzite believed to be of the same series, since they are not separated from each other farther south.

West of Post pond in Lyme this gneiss crops out, dipping N. 52° W. To the south, along Grant brook, the outcrops constitute massive bosses, rounded by ice, in which I find it difficult to identify the planes of deposition. I suppose they must agree essentially with the inclination of the slates to the west, and the limestones to the east. At A. B. Dimick's, near the western border, I have an observation of a dip in it of 25° N. 50° W. By I. P. Stark's the dip is 30° N. 17° W. Hornblendic and epidotic varieties occur half a mile south of Stark's, on another road, dipping 15° N. 28° E. This is probably a local irregularity in the position. Near J. P. Dimick's, at the north foot of Bear hill, the recorded observation indicates the position of 20° N. 24° W. Along the Canaan road, between Bear and Holt's hills, are fine exposures of gneiss. Bear hill rises precipitously on the west for two or three hundred feet. It is probably composed of gneiss at the base and quartzite at the summit, both with a very low north-westerly inclination. There should be further details of the position and character of these rocks in the south-east part of Lyme, in the following chapter. The south end of Bear hill is precipitous; and the gneiss terminates as abruptly as the hill.

The dip of this gneissic area seems to be essentially monoclinal, with slight indications of a synclinal under Mt. Cuba, and at the east base of Davison hill. The structure will probably prove to be like that of the Hanover area, which has been examined with greater care. Some further light as to its relations to the adjoining rocks will be gained by referring to the several sections crossing the rocks in Orford and Lyme (Figs. 50–54).

The Hanover-Lebanon Area. This extends from the north part of Hanover to the south part of Lebanon, about ten miles long and three miles wide at its maximum. The north end is narrow, commencing in Woodward's and Spencer hills, rising into Lord's and Prospect or Pinneo hills, which are the culmination of the range as respects height; it continues into Corey hill, is cut deeply by the valley of Mink brook, but rises into large hills in the north part of Lebanon. These are again cut by the Mascomy river; and the country rises into considerable eminences, but falls off before terminating in the south part of the town. As rocks, we have, first, the typical variety of protogene; second, common gneiss, or that which contains a considerable black mica; third, schists, considerably ferruginous, passing into mica schists; fourth, quartz beds; fifth, hornblende schist, at the borders, which may belong to the Huronian system. The most northern of the hills referred to this series is deeply covered by drift, with a strongly ferruginous soil. Next, the Spencer hill has ledges of gritty pyritiferous mica schist. About L. Hall's the rock is similar, dipping as much as 55° N. W. South of O. Pinneo's we have a mixture of ferruginous, micaceous, and gneissic strata, dipping 45°–50° N. 32° W. With them is a quartz bed ten or twelve feet wide, extending for several rods. About on the top of Prospect hill the rocks are similar, dipping 20° N. 26° E. They are the same on the summit. North of Lord's hill, where a road turns to O. Pinneo's and to the south, are ledges of micaceous and ferruginous rocks dipping 50° N. At J. C. Child's the same schists, less siliceous, dip 50° N. W. At H. S. Davis's there is gneiss dipping 65° N. 32° W. Lord's hill is composed apparently of the same materials with Prospect. Perhaps the schists as far south as the bases of Prospect and Lord's hills should not be ranked with the Bethlehem. I put them here provisionally, chiefly to render unnecessary the making of another division of the strata.

The unequivocal strata show themselves to the south of these high hills. At A. Wright's the gneiss dips N. 13° E.; at J. J. Mason's the dip is 25° N. 2° W., with a band of white quartz twelve or fifteen feet wide, and like that mentioned on the north side of Prospect hill. The ledges on the south side of the last-named hill are numerous, dipping 20° northerly. It is 18° N. 12° W. at T. W. Durkee's. By C. C. Foster's the dip of gneiss is 30° north-westerly. The gneiss may be followed a short distance down the ravine towards C. Houston's till it adjoins hornblende schist, dipping in the same general direction. Near W. Hall's, on top of Balch hill, is a gneiss dipping 20° N. 37° W. The rock contains a large part of black mica, and this seems to characterize all the layers on the west side of the area, others occurring in Lebanon. The same is true of the broader eastern belt at J. Hough's and at Mill Village. At the former place hornblende is present, the strata inclining 75° N. 55° E. The following is the order of rocks from west to east across this micaceous band along Mink brook and through Mill Village: Mica schist, near Hon. I. Ross's, on road turning to Lebanon, dipping 65° easterly; schist, 65° E.; decomposing mica schist, 45° N. 63° E.; epidotic mica schist or gneiss at Mill Village store, 65° N. 30° E. There is an abundance of similar ledges to the Baptist church. East, the same rocks extend about a quarter of a mile. A few rods north of the church there is a massive micaceous schist, resembling hornblende rock. A real hornblende schist by Mrs. Kinne's, about a mile north, dips 80° N. 70° E. On the hill east of Mill Village there are light-colored soft schists, showing the presence of pyrites abundantly, on exposure to the air, dipping 55° N. 65° E. Passing southerly on a road to East Lebanon, schists appear more like those upon Prospect hill. At W. Knight's there is gneiss dipping 70° S. 50° E. Over the ridge, about on the town line, the schist has a greenish tint, dipping S. 45° E. Near A. Freeman's, ferruginous schists dip 80° S. 23° E. Between this hill and the high land west of the road from Mill Village to Lebanon is a deep and gradually broadening valley, in which the ledges are concealed; and those which we should expect to find there are of the same character with the schists under consideration. In passing to the south of the village we seem to meet better defined mica schists, referable to the Coös group, occupying the place of much of the rock running south from Mill Village; but the outside vein of the Bethlehem area from Lebanon village to its extreme southern end, and thence on the west side through Lebanon and Hanover, is clearly composed of this feldspathic mica schist. Among other localities I may cite the school-house north of F. Peabody's, and the north edge of the Colburn hill in Lebanon (70° N. 80° W.); the valley of Mink brook, and the west base of Corey hill in Hanover (50° N. 80° W.).

The dark schists just spoken of surround a massive protogene gneiss, which is the characteristic Bethlehem rock. Its northern end is the top of the hill back of A. P. Balch's stone house. On Corey hill, near the summit and by H. H. Marshall's, it has been quarried for building. The foundations of Culver Hall came from the latter; and those of the Episcopal church in Hanover from the former quarry. Other openings are on the Sand hill, south-east of the college, in the valley of Mink brook, near J. Wright's, and near S. Tenney's on the road to Mill Village. The following are the positions of the strata proceeding east from the Sand hill along the line of Section VI: Top of hill, 32° N. 55° W.; spotted gneiss, 33° N. 55° W. and 25° N. 40° W.; thick bedded, with large crystals of flesh-colored feldspar, 58° S. 50° E. north-westerly, the last rock holding small bits of epidote and tourmaline. These strata are nearly all monoclinal, the exceptional case being a little east of the centre, and being evidently a relic of what once represented the position of the whole eastern half, and what is still retained by the micaceous upper layer. In other words, this is an example of an inverted anticlinal, not extending sufficiently far to include the upper division, or else there is a fault at the east border of the massive heavier member. Essentially a similar inversion may be seen wherever the area is crossed to the south, as along Mascomy river and the south part of Lebanon. In the latter locality not only the gneiss and micaceous layers, but also the green, soft Coös schists adjacent upon both sides, all dip westerly and not at a very high angle. These facts show the thoroughness of the overturn.

There is a band of gneiss of superior character for quarrying, the counterpart of that on Corey hill, extending southerly from near S. Tenney's in Hanover, through the high hill south to the west part of the village of Lebanon. The white ledges east of the school-house, near Freeman's quarry, seem to belong to this layer. It is quarried extensively at Freeman's and Walling's openings, on the road from Hanover to Lebanon. The quarries are arranged in two lines, on the two sides of the anticlinal. Near the scythe factory are huge blocks of sienite, which are probably in place near at hand, and may follow the river into the village. Between J. Ela's and F. Peabody's the gneiss dips north-west. Other facts about these rocks may be seen upon the small sections crossing them, presented in Figs. 55–58. The whole series of rocks near the Connecticut river is repeated in Moose mountain. (See delineation of Section VI.)

2. Huronian.

These rocks extend the entire length of the tract under description; and we may trace the three divisions of them mentioned in the preceding sketch, viz., Lisbon, Lyman, and Swift Water groups. The first is the most constant; the last is recognized only in Haverhill; the second has been separated from the first only recently, as I had supposed it did not extend out of the gold district. Hence I may not be able to separate it entirely from the first. I will describe the three divisions in the order of convenience.

Swift Water Schists. These are properly a part of the preceding field, extending no farther south than North Haverhill, and being the extension of those exposed along the Wild Ammonoosuc river. There are three prongs reaching into the gneissic area. Two have been spoken of already, in the east part of the Bethlehem gneiss area. Rising from the modified drift south-east from Woodsville we find a long, gently-sloping hill, allowing the ledges to appear only on its summit, as about F. D. Kimball's, the strata dipping 60° N. 60° W. The rock has this strike in the ledges at Kimball's house, but on the north side of the road the dip is more westerly. The rock is a micaceous, arenaceous schist. Garnets are said to be abundant in this neighborhood. Following the road into Bath, around the north side of the hill, the only ledges seen are near A. Johnson's,—greenish arenaceous beds,—dipping 40° N. 80° W. The strike of the rock would carry it to the village just south of Howard's island. On the most eastern extension of this group there are hornblende and argillaceous schists, dipping north-westerly. Near D. B. Blodgett's, on the town line, slates dip 40° E., with a large mass of white quartz.

Lyman Group. These strata are not abundant, save in the north part of Newbury. They occupy most of the section line from Woodsville across to Boltonville, Vt. (Fig. 45), and they stand upright at Woodsville. In Wells River village, ledges are abundant. There seems to be a ridge of the lower division in the village, perhaps explaining the existence of the anticlinal. At the first cut in the Montpelier Railroad the rock is greenish, with many nodular veins of quartz carrying chlorite, ankerite, iron, and copper pyrites. There is, also, what seemed to me to be a dyke, about two feet wide, of diabase. Others who have since examined the locality do not esteem it an injection. Opposite the railroad, in the anticlinal portion, are layers of dolomite. All these rocks are suggestive of the Lisbon group. If it is present, it is only in small amount, since the argillitic layers predominate to the west and south.

After passing the green rocks the argillitic schist succeeds in great profusion, beginning at a steam mill and extending to Boltonville. It is soft, occurs in thin, slaty layers, and is in this respect different from the more common variety as seen in Lyman. It weathers white, staining the rock an inch deep. When fresh there are two shades of green, a bluish and a drab. Thin layers of a darker variety, and hard, green sandstones, are interstratified. The first strikes are almost east and west; near the railroad bridge over the river the strike is N. 20 E., dipping N. 70° W. at a very high angle. After reaching the railroad flag station the ledges are mostly concealed by sand. Half a mile before reaching Boltonville there is a greater proportion of the hard, green schists. Those by A. Sly's house dip 55° north-west, while at Boltonville dam they dip 85°. The formation probably extends a mile farther up the river, but everything is concealed. Farther south in Newbury, down nearly the whole valley of Hall's brook, the Lisbon schists predominate, so that ground is afforded for believing the lower group comes up west of Boltonville.

The county map represents a conspicuous range of hills from Wells River village to Mt. Pulaski, below Newbury village. This seems to be mainly composed of the argillitic strata, which continue into Bradford. At the railroad cut below Wells river they dip 70° N. 55° W., and are finely exposed. Further on they dip 75° N. 65° W. They are the same by C. J. Scott's, or where the railroad nearly touches the river. In the south part of Newbury village, where crossed by Section VIII, there is an anticlinal, as if the lower rock came very near to the surface. At the railroad cut south of Newbury station, close to the Connecticut, the dip is 85° south-easterly. Where the road turns to cross the bridge, the dip is 75° S. 80° E. The position is exactly the same thirty rods west, while on the continuation of the Pulaski schists the dip is 85° N. 80° W.; and this rock does not extend more than a mile to the west. There are several ledges of this rock near South Newbury station. All the Huronian seen in Bradford belongs to this division. It is prominently exposed by road cuttings opposite the "Ledge," dipping 70° east. The road from J. Clark's, back of the "Ledge" down to the fair-ground, runs over Cambrian slates, showing that the Lyman slates pass southerly under the sand; but there is a repetition of the latter upon the hill back of Bradford village, whose presence can be explained only by the action of elevation with faults. It runs from the hill at least to the bridge over Wait's river south-west from the village. At the bridge over this river in the village the rock is Cambrian. In the south-east part of Bradford we find a range of the same rock from a school-house near Piermont station to the east side of the north end of Fairlee pond. It dips 85° easterly at the school-house; 80° S. 60° E. opposite the turn of the Connecticut easterly north of Shaw's mountain, and it may be the same by the lake. This band has not been recognized as yet farther south. To the east the protogene comes in, composing Shaw's, Sawyer's, and Morey's mountains, crowding out the slates. Further observations will probably show the existence of this member farther south, since it is only recently that the Pulaski range has been separated from the lower group.

Lisbon Group. Two divisions of this formation may be followed along the Connecticut river,—first, hard greenstones of various shades of composition; second, protogene. The first are the prevailing varieties; the latter occur occasionally. All that appears in Haverhill and Newbury, so far as observed, is of this kind. Along the section (Fig. 45) very little appears, and that in Wells River village and west of Boltonville. It may exist beneath the sand of Woodsville, since it is known to crop out opposite Howard's island. Along the section (Fig. 47) it is more abundant. There is a conical hill near the north Newbury bridge, composed of diabases resembling those that yield fossils. The dip is obscure, most probably easterly. The rocks have been much shattered by the action of frost. Between the river and Wood's pond is a great development of these ledges. They are so abundant that the land is mostly uncultivated. By the Haverhill depot the hard schists dip 75° S. 35° E. Half a mile north-easterly, on the road to the town-house, the dips are irregular and westerly, making a synclinal axis. West of Wood's pond green micaceous schists dip north. About half a mile north of the pond the schists occur for the last time, with north-westerly dips. The ledges are concealed by alluvium, and they are probably Bethlehem gneiss beyond D. H. Hale's.

At and above the bridge over Oliverian brook, by Haverhill Corner, argillaceous quartzites appear, very much contorted. The best observation of the dip is to the east 70°. Others dip north. A fourth of a mile

—SECTIONS ILLUSTRATING THE HURONIAN.—

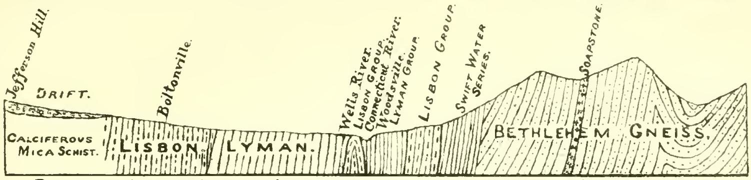

FIG. 45. NEAR NORTH LINES OF NEWBURY AND HAVERHILL.

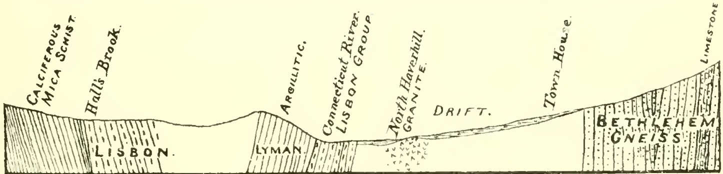

FIG. 46. FROM HALL'S BROOK, NEWBURY, TO LIMESTONE IN HAVERHILL.

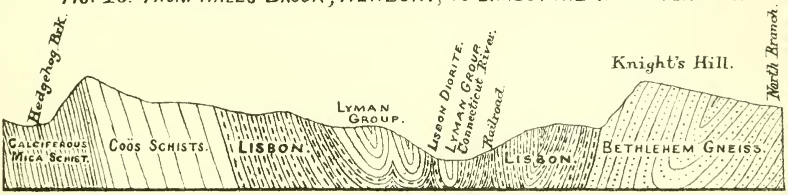

FIG. 47. FROM HEDGEHOG BROOK, NEWBURY, TO EAST HAVERHILL.

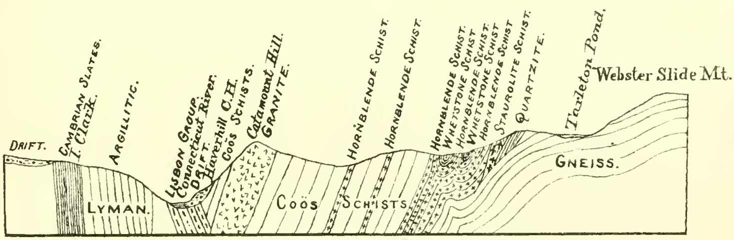

FIG. 48. FROM N. E. BRADFORD TO WEBSTER SLIDE MOUNTAIN.

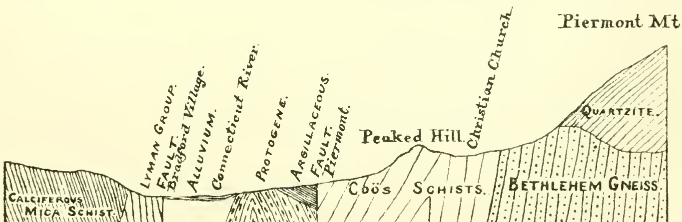

FIG. 49. FROM BRADFORD TO PIERMONT MOUNTAIN.

VERTICAL SCALE, 2000 FEET TO AN INCH.
HORIZONTAL " , $2\frac{1}{2}$ MILES " " "

HELIOTYPE

above the bridge the dip is south-east. The rock bears some resemblance to that in Stark. East of D. Randall's a fine-grained mica schist, resembling hornblende when water worn, succeeds, dipping 70° W. This may belong to the Coös group. In Newbury this greenstone range occupies the ox-bow north of the village. At its northern end the ledges are prominently exposed, large bosses extending to the water's edge, which, by their superior hardness, have turned the course of the Connecticut. They dip 75° N. 70° W. The mineral spring near the village comes from these schists. The valley of Hall's brook in central Newbury is underlaid by these greenstones. On the water-shed between this and Wells River, I found large boulders of serpentine, which probably came from a ledge not far off. The range is broadest about the middle of the town. It appears on the east side of Ticklenaked pond in Ryegate, dipping 80° N. 80° W., but disappears entirely after reaching the Bradford line, that last seen having an easterly dip. In Piermont a few ledges appear in the north-west part of the town, next the Connecticut river.

An important range of protogene commences in a large hill north of Piermont village, crosses the river at a great bend, rises first into the isolated Shaw's mountain, and then into Sawyer's and Morey's mountains, terminating with them in Fairlee. East of Piermont hill the protogene and mica schists are separated by a fault about N. 25° E. The protogene dips east of south, and the mica schists west of south. Near Gully brook, west of Mrs. E. Bixby's, there is an anticlinal, the dips being 75° N. 30° W. and 70° S. 35° E. On the Vermont side the strata are usually about vertical. The mountains named have inaccessible precipices on their eastern sides, with *débris* at their bases, and, as seen from Orford village, are very conspicuous. One of them was colored as granite in the geological map of Vermont. The same error occurred there in the delineation of the similar rock in Northumberland and Lancaster; and in a statement descriptive of Section X the diabase of Littleton was called porphyritic granite. The error is an easy one to make on a superficial examination. Without a very thorough study of the relations of the protogene to the other Huronian members, I have thought it to occupy a high place in the Lisbon group below the interesting quartz bosses of Lyman. It does not occur in the valley, as I remember, above Claremont and south of Vershire.

In Orford the Huronian is wanting, unless it is connected with the soapstones of Sunday mountain and the quarry of Mr. Strong in Orfordville. In Lyme a narrow strip occurs above Gilbert's bridge, close to the river. Large ledges by E. P. Snow's, in the north-west corner of the town, dip easterly about 70°, and the same at the North Thetford bridge. Dolomite occurs between these two localities, Fig. 53 showing the relations of the Huronian and Coös groups in North Lyme. None of the greenstones crop out in Hanover or Lebanon, but they cross in great force from Hartland into Plainfield.

The range is continuous from Fairlee southward in Vermont through Thetford, Norwich, and Hartford. I have not separated the two groups below Fairlee as yet upon the map. On the first hill north of North Thetford, hard siliceous schists dip S. 60° E. at their contact with slate. A mile east of Thetford hill the green schists dip 80° N. 30° W. At a school-house still farther east, perhaps two thirds of the way to the station from the hill, is a quartzite dipping north-westerly 50°. This may indicate the eastern limit of the Huronian. Following these rocks to Union Village we find them making an anticlinal, with a strike to the north-east, where cut down deeply by Pomponoosuc river. The ledges of this rock extend through Norwich, are abundant, and have been determined with much pains. The ledges in the north part of the town are allied to the greenstones holding fossils. A range of argillaceous schist lies in the Huronian, extending from a little north of the station for two or three miles. It undoubtedly shows the place of a synclinal line. By a windmill, half a mile above Hanover bridge, the hornblende comes in contact with greenstones; and in a railroad cut adjacent there is a large, unconformable mass of serpentine. Somewhat similar schists make the cliff for half a mile above. A similar junction appears in railroad cuts south of the depot, as near the paper-mill. On that line we have, going west, hornblende schist (the Observatory range) dipping 46° N. 85° W.; serpentinous mass above it; soft slaty layers, dipping 70° N. 57° W., separated from the last by a quarter of a mile of earth covering; green schists, with dolomitic layers, vertical, having a strike of N. 5° W.; schists dipping N. 30° E.; on the ridge, both hard and soft vertical schists; and, lastly, in the road, half a mile from the depot, dioritic rock dipping 50° N. 70° W. The Meeting House hill, a mile north of Norwich village, is composed of greenstones mostly, with a bed of steatite and cupriferous schists, once worked for copper. The steatite continues through the town northerly into Thetford. The ledges north of the village of Norwich are the same diorites. The boundary on the west side appears about a mile above the village, at a bridge over the stream called Bloody brook. At Kibling's old mill the schists dip 65° W. The stream exposes other ledges of the same rock, all of the Lisbon group. In the valley to the right of the road from the depot to Norwich village are dolomites and thin-bedded schists, holding many small crystals of magnetite. The eastern base of the hill south-west from Norwich village is composed of greenstones, cropping out at the tannery and on a back road farther south. Section VI crosses this range in Norwich and Hartford; and the dips upon it are uniformly high westerly.

A few allusions to Huronian rocks upon Figs. 51, 53, and 55 may be found in the descriptions of them under the head of *Coös Group*. The ledges at Snow's (p. 360) are argillitic.

In Fig. 58 we have the delineation afforded by the facts descriptive of Section VI. There is an excellent development of green dioritic schists by the grist-mill on Bloody brook, near the railroad, dipping 65° westerly. By S. Godard's, gritty schists dip 50°; and west of J. Newton's in Hartford, at the base of the hill, softer layers appear, dipping 80° N. 80° W. These facts afford data for perceiving the existence of two or three folds.

The slate range is of considerable width at the north-west angle of school-district No. 14, Norwich, and appears on both the roads running west from the Connecticut before coming to the depot. It is an open question whether this is an equivalent of the Cambrian, or a part of the Huronian. Turning on to the Thetford road, at the school-house No. 14, we leave a friable slate, and pass diabases and breccias on the right, which make up the cliff alongside of the railroad. After passing the slate range at the angle of the district, we find hard, green sandstones, accompanied by dolomite, at school-house No. 5. Similar dioritic schists appear on the road at W. Johnson's, and on the line between districts 6 and 7. About half a mile north of Norwich village is a narrow band of cupriferous schist; and east of the old meeting-house hill, near Deacon Coleman's house, is a bed of soapstone, where excellent specimens of green talc may be obtained.

From J. K. Edgerton's, near the south line of Norwich to the river, we have the following order of Huronian rocks: Greenish sandy schist; east of S. Godard's, grit, dipping 50° N. 70° W.; soft green schists; hard and slaty layers on top of the ridge, vertical, strike N. 30° E.; green schists, 78° N. 60° W.; dolomitic seams, vertical, strike N. 5° W.; and, lastly, soft argillitic schists, dip 70° N. 57° W. The last ledge does not reach the railroad, where the hornblende rock makes its appearance, with the inverted westerly dip.

An interesting section is that from Craft's hill in Lebanon to a little north of White River village or Hartford post-office, as delineated in Fig. 59.

On the south side of White river, by the Hartford post-office, the clay slates appear in a railroad cut, standing vertical, and full of small faults. This position seems to be the result of enormous lateral pressure. Great disturbances appear in the slates, because, being weaker than the hard Huronian schists adjacent, they yield more easily to the force exerted. The Huronian schists immediately contiguous to the slates are thin-bedded, and dip 70° S. E. On the north side of the river, in a tributary north-south valley, the greenstones properly begin, and extend nearly to the railroad. At the eastern side of the valley the diorites dip 50° E. 5° S., and this position is continuous to the top of the hill overlooking the road to Norwich from White River village. Here the dip of 80° west commences; and we find narrow hornblendic layers, diorites, sandy grits, and diabases, like those holding fossils. Midway to the road from the hill-top are twenty-five or thirty feet thickness of finely-bedded, white siliceous rocks. Other layers are of green chlorite schists, with white, ragged spots of quartz. These may be twelve hundred feet west of the road. Next come fossiliferous diabase, fine-grained schists, white feldspathic sandstone, fossiliferous diabase, and diorites. East of the road the strata are similar to those described, there being no established order between the sandstones, diabases, diorites, and siliceous layers. Evidence is afforded of the existence of two anticlinals and a synclinal in this distance of nearly a mile. The whole section, therefore (Fig. 59), would indicate five axes,—first, at the east end, an overturn anticlinal; and lastly, at the west end, a closely pressed anticlinal. Thus the aspect of the Huronian is that of an older underlying formation, the slates at the west end being supposed to be the same with those in the synclinal between the road to Norwich and the railroad. The latter are not certainly seen, but are believed to continue from the line of exposure farther north in the east part of Norwich. The thickness of the Huronian here may be estimated at about 2500 feet, allowing for five duplications.

On reaching the railroad, a band of hornblende schist crops out, dipping only 45° N. 85° W. This is the range appearing on Observatory hill in Hanover. The angle of the dip is the same at the lower falls, on the east bank of the Connecticut river. This is an interesting place to observe the course of narrow quartz veins, sometimes cutting the strata, and then running between the planes of deposition. On reaching the carriage-road, the strata dip 70° W., thus suggesting the presence of an inverted anticlinal. Passing from the house at the foot of Craft's hill easterly, loose materials conceal the ledges for 2000 or 3000 feet; and then crumbling mica schists, sometimes calcareous, appear in the hillside, standing about vertical. These belong to the Coös group, and may overlie the hornblende schist, which appears higher up and extends nearly to the summit. The latter dip 75° W., and are certainly four hundred and fifty feet wide on the surface. Craft's hill has two summits; and upon the west side of each the hornblende rock appears, continuous from one to the other, besides extending down the south slope to cross the Mascomy river a mile east of the Connecticut. On the summit ridge, in several places, are mica schists dipping from 60°–80° W., and occasionally holding staurolite. In a few places quartzite occupies beds in these schists, closely resembling the Coös quartzite of Moose mountain. It may not be more than a fathom thick upon Craft's hill, but it is thicker upon Colburn's hill to the north, and is still more abundant in Hanover, it having been followed through that township into Lyme. Hence it is believed this small development upon Craft's hill represents the horizon of the Coös quartzite. The country falls off east of the summit of this hill; and the next rocks are the two members of the Bethlehem group in the Hanover-Lebanon area described on a previous page. The great value of the eastern part of this section is the development of the whole Coös group, though in greatly reduced dimensions. Samples of every part of its representation upon the west side of Moose mountain appear here. Hence it is plain that the formation is repeated upon Craft's hill;

and the materials are afforded for an understanding of the structure of the rocks in Hanover and Lebanon.

The Huronian rocks range through Hartford south of White river, and then pass through the north-east corner of Hartland, before crossing the Connecticut into New Hampshire. They are mostly hard, green diorites. Along White river the strata are nearly vertical,—both diorites and dark hornblendic varieties. About a mile below the junction there is a railroad cut through the hard greenstones. Towards the agricultural society grounds the yellowish-green hard schists are vertical, with the course N. 13° E. The formation extends to the school-house No. 14 at the crossroads. In the south-east corner of Hartford the ledges are mostly concealed by sand. At the falls, North Hartland, the hard green schists form an island. A mile north they dip 85° N. 70° E.

The Huronian, in crossing the Connecticut below Quechee falls, has left several high ledges resembling the piers of a bridge. Seams dipping 85° westerly traverse them, and are believed to represent the stratification both of the diorites and the adjacent hornblende schist. The Huronian schists now leave the river, and form the foundations of Willard's ledge. Numerous embossed ledges of greenstone show themselves over this hill as far as Beaver brook; the dips are a little north of west. Newer rocks and alluvium conceal the Huronian schists to the south of Beaver brook. There is evidence of the presence of these underlying ledges about a mile north of the Windsor bridge, in the production of a westerly dip and an anticlinal in the calciferous schists. Dingleton hill must have these greenstones within it, since they crop out in a single ledge along Section V, at its southern end.

The rocks supposed to underlie Dingleton hill appear again in the ridge south of Walker's brook, in the north-west part of Claremont. The country between has not been explored. At the school-house No. 19 there are hard, green sandstones, dipping S. 30° W. This reaches for a mile or more, when the valley of Sugar river intervenes, occupied by Calciferous mica schist. The continuation of the Huronian is to be seen in Barber's mountain, in the angle of a large curve in Connecticut river. The near proximity of the Ascutney granite suggests a reason why the bosses in the north-west part of the town should be thrust out so far east of the continuation of Barber's mountain. The summit of this eminence consists of dioritic and dolomitic schists, cut by large veins of quartz. The dip is quite variable, perhaps the most prominent being 12° S. 10° W. Others dip due south, and also easterly. On the west side of the summit there is a south-east dip. To the north of the summit the rock is more slaty, and inclined southerly. On the south-west side of the mountain, at J. Woodill's, the rock is somewhat argillitic, dipping 48° S. 55° E.

Crossing Connecticut river, we find a north-westerly dip of 75° to the Huronian schists at the south-west angle of the stream, and between the mouths of two brooks. A similar position seems to pertain to the ledges on the Claremont side, as seen from Vermont. A little north of Weathersfield Bow post-office the rock is an indurated slate, dipping 80° N. 60° E. From these observations we conclude, first, that disturbances of continuity are more common than usual; second, that the structure is anticlinal; third, that the group is the Lisbon rather than the Lyman.

Hornblende Schist. A band of hornblende schist, forming as it were the "connecting link" between the Huronian and Coös groups in this district, may properly be described here. It seems to extend continuously from Orford to Plainfield. Back of Orford street, on the hill, it dips 65° N. 60° W. Another development of it is near the south-west corner of the town, on Section VII. A mile and a half east of the north bridge in Lyme (Fig. 53) this range appears, dipping 50° N. 70° W. It passes southerly to the west side of Post pond. A similar rock, half a mile south of Gilbert's bridge, probably dips 60° N. 30° W. This is somewhat associated with the soft, green talcy schists of the Coös group. This range should properly strike across into the south-east corner of Thetford, where immense accumulations of soil conceal the ledges. On the south side of the Pompanoosuc river this rock makes the eminence known as Blood mountain, on which is a copper mine, the cupreous schists dipping N. 70° W. There is a similar dip at T. Tilden's house, at the south end of the same mountain. The range crosses into Hanover at a bend of the river below Pompanoosuc station, and crops out near the mouth of Slate brook. There are ledges of hornblende dipping 40° S. W. near the outlets of the stream from the town farm and the small brook north of it. Where the stream follows a ravine, above C. Houston's, this rock dips about 30° N. W. adjoining the gneiss. Next is the large outcrop of the

Observatory hill, from 32°–41° N. 50° W. The western border of this band touches Norwich about a quarter of a mile above the depot. Along Connecticut river the rock appears abundantly below the Ledyard bridge, as at Negro island, Granny's island, and at both the upper (Olcott's) and the lower falls. The hill east of these localities shows the same rock rising above the alluvium. (See plate opposite p. 302, vol. i.) At the upper falls, east side, the dip is 52° N. 80° W. On the west side of the river the dip is 44° N. 85° W., and at the railroad nearly 46° N. 85° W. This is at the extreme western edge of the formation, where it comes in contact with the Huronian grits. The positions at the lower falls are indicated upon Fig. 59. Below the lower falls the ledges are frequent as far as the railroad bridge by White River Junction. A mile or so south of the junction the hornblende dips 65° W., nearly in contact with the Huronian. Opposite this point is a small hummock of the same rock, rising out of the meadow south of Mascomy river. The formation now increases in width very much, and lies entirely on the east side of the Connecticut. West of S. Waterman's a large hill is made of hornblende, dipping 50° S. 65° W. Blood's or Hinckley brook cuts through this hill near the line of Lebanon and Plainfield, making a deep, narrow gorge seventy-five feet deep for a distance of half a mile. In this chasm the dip is 50° S. 70° W. In this neighborhood there are several ledges dipping in the opposite direction, so that two foldings of the strata are inferred. They may not be of large extent. The noticeable change in the strike is due to the disappearance of the Bethlehem gneiss to the east, as the hornblende rock is forced to conform in disposition to the older area. In the north-west part of Plainfield this ridge is continuous in Governor's and Black hills. Beyond, our observations are scanty, but we seem to be authorized to affirm that the hornblende rock ceases to crop out on the surface in the neighborhood of Mud pond. Ledges of it are marked adjacent to Connecticut river, in the north-west corner of the town, towards Willard's ledge, and by Governor's hill. Near W. H. Daniels's the dip is north-westerly, and the rock is somewhat gneissic.

The range appearing on Craft's hill crosses the Mascomy river with the railroad, dipping 42° N. 63° W. We are unable to trace this band to a direct connection with the main mass farther south. The ledges by S. Woods's, extending half a mile south to the school-house and dipping

80° S. 70° W., also standing on edge, seem to be a repetition of this band,—perhaps the eastern border of the principal area. (See Fig. 61.)

In agreement with our theory of the relative ages of the rocks about Hanover, we have the repetition of the hornblende rock on the east side of the Bethlehem gneiss, in the central parts of the town, midway between Hanover centre and Mill Village. The general situation of the formation along the river is in the line between the Bethlehem group and the Huronian, with a westerly dip. Inasmuch as a rock of similar mineral character is associated with the Coös slates, the first supposition placed the two together as a part of the newer group. Reflection suggests that it should be regarded as an older member than the Coös, possibly even underlying the Huronian. Further descriptions will set forth interesting ranges of hornblende overlying other areas of the Bethlehem group in Grafton and Cheshire counties, which stand related to the anticlinal ridge extending from West Brattleborough to Leyden, Mass., at Shelburne Falls, Mass., and elsewhere in southern Vermont. They seem to be more nearly allied to the Huronian than any other system of strata. It is probable that these schists in Piermont should be referred to the same age, though for convenience described with the Coös slates farther along. A limited outlier of the same rock in Cornish will be noticed in the description of Section V.

Cambrian.

Allusion has been made (p. 311) to the existence of three ranges of clay slate along the Connecticut valley,—first, the more northern one from Kirby to Barnet in Vermont; second, the series of basins in the Ammonoosuc gold field; and third, the larger area from Fairlee to Hartland in Vermont, repeated again below Ascutney from Rockingham to Massachusetts. Extensive argillaceous and slaty rocks occur on the east side of the river, and upon previous maps I have colored them the same with these Vermont ranges. With the exception of the one extending from Plainfield to Charlestown, upon the east side of the calciferous mica schist, I think the latter should be placed with the Coös group, since they often contain staurolite, and especially a multitude of garnets. It is very uncommon to find these minerals in the former set of ranges, so that for the present I think it desirable to separate these argillaceous developments from each other, calling the one Cambrian and the other Coös.

Upon our earlier unpublished maps we distinguished a band of contorted clay slate, commencing in West Stewartstown and passing northerly into Quebec along Hall's stream. The structure of this band on Sections XIII, XIV, and Fig. 2, Plate VI, is anticlinal. It joins the Calciferous mica schist, just like the Cambrian in Vermont; and further facts about it have been given upon pages 40–42. I think it best to give this band prominence upon the map, and refer it to the Cambrian series. It often carries minute pebbles, and is full of ferruginous spots, caused, probably, by the decomposition of ankerite or bitter spar. With these minerals gold is also found, thus allying the rock to that in Lyman.

The Vermont observations represent the Kirby-Waterford range, with easterly dips, mostly from 70°–80°. The notch near its northern end is caused by the existence there of a bunch of granite. There is an abundance of material suitable for building purposes in this area, and the rock is quarried at two places in Waterford for slates.

Concerning the range properly lying within our present field of description, we may say that all along the eastern border of the Calciferous mica schist there are many argillaceous bands, so much so that our Vermont official observations led us to connect together the Waterford and Fairlee *termini*. At Barnet, Newbury, and Bradford the argillaceous bands are prominent. Between the Union church, Newbury (Section VIII), and Bradford village there may be a fault, which has displaced the slates and concealed them from sight. At the north-east end of Fairlee pond these slates are at least two hundred and fifty feet wide, with a high easterly dip. There has been a quarry in this vicinity, upon the land of Amos Waterman, and the slate is said by good judges to be excellent. I have not seen any outcrops on this range, though they undoubtedly exist, till we come to the turn of the road over the hill to Fairlee lake, near Ely station. Both here and in the new road following up the brook, the slates dip about 80° N. 75°–80° W., and they may be a mile wide. Nearer the station (Ely) the strata are vertical. In the north-east part of Thetford there is a westerly dip, while at the old Howard quarry the dip is 70°–80° E. A mile north of the academy the dip is 80° S. 50° E. At the "lead mine" we have also the south-easterly dip. The slate ledges are abundant between the mine and Potato hill. Between the academy and Union Village, on the Pompanoosuc river, numerous slate outcrops have been observed, many of them showing contortions. Veins of quartz are abundant all through this formation in Thetford. Just above Union Village the slates are well developed, most of them vertical, and others nearest the Huronian dipping 80° easterly in consequence of an overturn. The Union Village Huronian anticlinal has been the older rock, whose northwesterly pushing has produced this overturn. I have followed the range from the Pompanoosuc to Norwich village, and find it standing vertical for the most part. At G. W. Simmonds's it dips 85° S. 65° E., and it is about the same at E. Johnson's. A valley has been excavated by the east branch of Bloody brook between Meeting-House hill on the east, and an equally lofty eminence to the west. The east edge of the slates is well shown at the crossing of Bloody brook at S. Wright's. It also crops out in the valley of this brook in school-districts Nos. 17 and 11, not extending above school-house No. 11. The hill west of Norwich village is entirely composed of this same clay slate. The rock shows itself, also, in the valley of the stream descending from school-house No. 2. To reach these last-named localities, the slate bends considerably southerly. In the edge of Hartford, along the valley of a stream, the slate dips 80° N. 80° W. Between this and White River valley no observations have been made. In the last-named region, near Hartford post-office, a railroad cut exhibits vertical and disturbed slates, and there is a greater breadth of measures. Not far to the west of school-house No. 14, the slates dip 70° N. 70° W., and the country rises. At a bend in the road farther west, the slates dip 70° S. 70° E., thus making a synclinal axis. The slates continue to the foot of a higher range of hills forming the dividing ridge between the Quechee and Connecticut rivers. Along this line, parallel with White river, the formation is twice as wide as it is farther south. It diminishes towards North Hartland. At the south end of this village the slate dips 75° E. If the range follows the adjacent Huronian, it should cross the Connecticut here; but there are no clay slates of consequence opposite in Plainfield. Hence, for the present, we must believe the formation terminates at North Hartland, and it is so represented upon the map.

Our studies of this range have been fragmentary; but we seem to have evidence of an anticlinal in Fairlee, an overturn synclinal at Union Village, a synclinal, with enough measures to supply other axes, in Hartford, etc. I suppose the formation marks a horizon between the Huronian and Calciferous mica schist.

The quartz veins of Thetford are auriferous, and resemble those of Lyman. The galena is more abundant in the former locality; and the other characteristic minerals, as ankerite, blende, and mispickel, are present. Quartz veins occur also in Norwich and Hartford; and in the latter town there is said to be a gold-mining location.

There is another range of clay slate connecting our two areas of description, to the east of the Connecticut and the Calciferous, from southern Plainfield to North Charlestown. It bears the same relation to the Cornish and Plainfield area of Calciferous mica schist that the Thetford range just described does to the great Calciferous range to the west. In Plainfield the ledges lie a short distance east of the school-house No. 16. Many of the exposures in the east part of Cornish resemble this series; and on the west slope of Croydon mountain, opposite Parsonage hill, there is a quarry of slate, the flags dipping 60° S. 80° E. Their extension southward is noted as argillaceous in the deep valley of a small stream between N. Lear's and Mrs. Huggins's, and their position is similar to that just noted. In Claremont the slates are much better developed. There is a small quarry on Redwater brook, in the north edge of the town; and Bald mountain is mainly composed of this rock, with intercalated sandstones and quartzites. Between Bald and Green mountains, on the "cat hole road," there are clay slates dipping 40° E. They occur at intervals on the road following around the west and south flanks of Green mountain, dipping S. 87° E. very near the junction of the slate with quartzite. In the valley of Sugar river, towards the village of Claremont, the ledges show evident marks of distortion, with average dips of 70° S. 85°–87° E. They are also permeated by many fissures, produced in comparatively modern times, since they are not filled by veins. At Mrs. O. Walker's there is a dip of 67° N. 70° W., which may be of limited extent. Farther east there is another small synclinal, the basin being not more than fifty feet wide. Of this the westerly dip on the east side is very steep, while the easterly dip on the west side is not over thirty degrees. At the end of this side road, by S. Nott's, the dips are mostly to the east, with the strike N. 30° E. Nearly opposite, on the main river road, we find a strike N. 7° W., and easterly dip. Near H. Hubbard's the dip is 80° S. 62° E. For half a mile north of Hubbard's the slate becomes micaceous, dipping 60° N. 77° W. A section of the rocks along Sugar river is given farther on. The slate does not underlie the principal village, though it touches its south-east extension, approaching the railroad station. The west line runs over the westerly slope of Bible hill, the hill itself and the Flat Top near the village being composed of slate. At a reservoir on the northern slope of Flat Top hill the strike is N. 27° E., the strata being vertical or leaning slightly to the east. On the east side the westerly dip is strongly marked. On top, the irregularities in dip prevail, on the east side dipping 75° N. W., and on the very apex 34°–50° S. E. On the summit of Bible hill, the highest part of the rock mass of which Flat Top is the northern spur, the dip is about 85° S. E., with north-westerly variations. In descending south-westerly, we observe a large vein of white quartz. Near R. Cassady's there is a bed, ten feet thick, of quartzite, full of minute undulations. Near N. Stone's house the strike is north-east, and the dip is vertical. This house marks the west edge of the formation. The mica schists adjacent dip towards the slate.

I had occasion to examine Bible hill more carefully than usual, and was impressed strongly by two classes of facts: First, the great diversity in the position of the strata. As indicated above, north-westerly and south-easterly dips are mixed together confusedly. It may be explained by the second class, viz., the existence of numerous fissures of modern origin, say post-glacial. I have never observed such fissures elsewhere so abundant as here, either because attention was not specially directed to them, or they do not exist. The fissures have probably been made since the ice period, because the hill-top is covered by striæ. Had the cracks been as abundant when the glacier pummeled the hill, the ledge could hardly have resisted its blows. It would have been carried away, and the Sugar River valley been much widened. These fractures have probably been caused by the lateral pressure, which shows itself oftentimes in quarrying. When the strain is taken off by the removal of large blocks, the tension will relieve itself by a spreading or moving of the rock.

To the south the slates diminish. They occur at North Charlestown, on Calavant hill, with nodular masses of quartz thought to be auriferous. A hornblendic rock—possibly gneiss—from the east point of this hill, together with the slate itself, is a little suggestive of Huronian. Towards the village of North Charlestown I have an observation of a dip of 80° S. E. In Springfield, Vt., near school-house No. 1, the slates crop out strongly, dipping 50° S. E., and holding auriferous quartz veins. There is also an observation of slaty rocks at N. Spaulding's, in the north part of district No. 6. These outcrops are the last seen of this range, and it is believed to be cut off by the rising up of the quartzite and Huronian in Springfield, about Skitchawang mountain. The line of slate outcrop is therefore situated between two Huronian masses,—Barber's mountain to the north in Claremont, and near Skitchawang to the south in Springfield. It is possible that the Huronian hills existed before the mud of the Cambrian period was deposited beneath the quiet waters. Beginning in Plainfield, this band of slate has Coös schists upon the east; next, are quartzites in Claremont; Coös schists in North Charlestown; and, finally, the Huronian and Coös quartzite in Springfield. On the west side the border is uniformly the Calciferous mica schist. It will be quite desirable, in order that these formations be thoroughly understood, to investigate further the south-west end of this slate range.

COÖS QUARTZITE.

There are fifteen or twenty areas of quartzite near the eastern border of the Connecticut Valley district, between Lisbon and Claremont, which are grouped with the Coös slates on account of their proximity and intimate association. Some of them repose upon gneiss, entirely isolated from all connection with the staurolitic schists. They also extend to Bernardston, Mass., and may have some connection with the quartzites connected with the Helderberg limestone there. For these reasons, they are described by themselves, and are distinguished from all other formations upon the map.

Mr. Huntington has examined most of these areas, and will describe them in the next section. I will only speak of a few things which he has not seen.

Starting at Landaff, there are one or two isolated patches of sandstone; and then commences the range which is so curiously developed among the mountains in the west part of Benton and eastern Haverhill. After passing the gap of the Oliverian stream in East Haverhill, there succeeds the beautiful quartzite culminating in Piermont mountain, and terminating in the north part of Orford. Then there follow, possibly connected directly with the preceding, the mass of Mt. Cuba, and several isolated patches in Wentworth and Dorchester. Next, there is a Lyme range; then comes the Moose Mountain mass in Hanover, terminating obscurely in the east part of Lebanon. Several insignificant outliers occur in the gap ensuing before the quartzite gathers itself together to form the Croydon Mountain mass. In Claremont and Newport there is another development, seemingly curving round an area of Bethlehem gneiss. Towards the river there is an interesting bed of quartzite, quite narrow, but discernible through Lyme, Hanover, and Lebanon. A few others will be mentioned presently.

Mt. Cuba. A hasty climb of Mt. Cuba in Orford will show the relations of this quartzite to the accompanying schist. Starting from "Halltown" on the west side, and passing thence up the north edge of the mountain, we leave Bethlehem gneiss standing on edge, and come to exceedingly twisted thin layers of rusty staurolite mica schist, with strike N. 3° W. Another ledge standing vertically has the strike N. 5° E. Still farther east, about one third of the distance up the mountain, the same rock dips 85° S. 85° E. From a third to half the distance up, we find quartzite dipping 70°, 75°, and 80° S. 20° E. After reaching the first eminence, or outlying spur of the mountain, we again discover the hard mica schist,—another mass,—but it is not extensive. The apex of the mountain is composed of the quartzite, hyaline, and dipping N. 65° W. I had no time to explore the woods to the south. In order to properly understand the relation of the mica schist and quartzite, we need a model of the mountain carefully constructed from a perambulation of the entire surface. Judging from all the data at command, it would appear that this quartzite is of an oval shape, unconformably reposing upon gneiss, with some intermixture of mica schist. Fig. 51 shows its situation, in relation to the other rocks, as well as we can judge. The shape of Cuba and Smart's mountains is such that, from a distance, one would think the rock was continuous from one to the other; but I believe observation does not verify this anticipation. It is not impossible, however, that the Cuba Mountain mass should join the continuation of the Piermont range. Between the two the ledges are concealed by soil; and their directions seem to correspond, save that the first quartzite seen in our ascent dips to the south, overlying mica schist and gneiss. If, however, there were an upthrow of the mountain, the facts would be consistent with a former union of the two.

The Western Range. Quite recently the facts establishing the existence of a narrow but persistent range of quartzite in the west part of Orford, Lyme, Hanover, and Lebanon have been observed. It seems to follow the western border of the Hanover-Lebanon area of Bethlehem gneiss. Commencing in the south part of Lebanon, we find large blocks, and, I believe, ledges of a conglomeratic quartz, east of A. Hall's and sons. They occupy a hill-top, extending nearly a mile northerly past the two Stearns houses. This layer cannot be large. Upon Craft's hill a stratum of it, perhaps three feet thick, may be seen in two places. There is another outcrop of quartzite on the south side of the top of Colburn hill, and there are some appearances of it on the long north slope towards Hanover plain. In the valley of Mink brook, and through much of Hanover, this rock is concealed. Back of C. Houston's, there is an outcrop conspicuous for a long distance. We begin to find many ledges of this rock on a large brook opposite Pompanoosuc. Near F. Merrill's it is a sandstone, dipping 40° N. 48° W. It may be followed for a mile along the hill road to Lyme with certainty, cropping out in several places. In Lyme, in the bend of Fairfield brook, it appears again, also at Lyme church; and the hill west shows a white rock like it, but it has not been visited. It is equally plain to the east of the road to Post pond. It is unusually thick at the fork of the road north-east of Post pond, dipping north-westerly. High up the west side of Acorn hill, as you take the north-east road from Post pond, the same rock appears. At J. Hall's the quartzite dips 75° N. 50° W. There is a mass of quartzite, on the south-west side of Indian pond in the north part of Orford, eight miles distant, which may belong to the same band; for that traced northerly from Lebanon skirts the west line of the Bethlehem gneiss, and this in Orford occupies the same stratigraphical horizon. Future search may detect occasional ledges of quartzite through Orford, connecting the two remote points. It is worthy of note, however, that the quartzite immediately adjacent to the gneiss is much more limited than that connecting the two Bethlehem areas together, from Merrill's in Hanover to Hall's in the north part of Lyme. The Moose Mountain and other ranges border the Bethlehem gneiss as well as the longer range near the Connecticut river. Both areas lie upon the west flanks of the gneiss, and none occur upon the eastern. Both occur in staurolite mica schists, while the western comes very close to hornblende rock all the way, though probably not connected with it. These ranges are undoubtedly of the same age, and originally constituted beaches upon the shores of Bethlehem islands.

Moose Mountain Range. The gap between Bear hill, Lyme, which is the southern end of a quartzite area, and Moose mountain, Hanover, is one thousand feet above the sea. The valley is covered by drift, and might conceal this rock, save that the south end of Bear hill is so completely occupied by other rocks that there is no place for it. Moose mountain rises very rapidly 1300 feet above the valley; and it is easy to see, from the hills north, the gradual thickening of the white quartzite from below upwards. This range, as conspicuous as Cuba, Piermont, and other similar mountains to the north, owes its existence, like the others named, to the presence of quartzite. On the road over this mountain the quartzite dips 50° N. W. Nearly three miles farther south the dip is 72° W., and it is somewhat interstratified with mica schist. Less than a mile farther, the observed dip is 80° W., and the rock occupies the very crest of the mountain. The course, which has been south, now changes to a few degrees east of south. Almost at the south-east corner of the town, it doubles back westerly so as to run S. 33° W., and abruptly disappears beneath the slates as if it were broken off, while its thickness is not great. A considerable search in the neighborhood, in East Lebanon and the north-west part of Enfield, fails to find any trace of the continuation of this particular type of quartzite. The boundary between the slates and gneiss has been carefully examined; and nothing is met with north of Lily ponds, where it is largely developed, and probably dips westerly. It lies in the proper stratigraphical position, between the slates and the gneiss; and it is likely that the material is wanting in the Mascomy valley, just as it was along Fairfield brook in Lyme, at the north end of the range. I have never explored Mt. Tug—1700 feet—(980 above the lake), which is in a direct line between the last exposure seen upon Moose mountain and another locality about to be mentioned. The rocks have a south-westerly strike, as if the two quartzites might be continuous.

Much of the mountain is bare, and, as seen from the road, looks altogether like slate. There are large boulders of an interesting conglomerate of quartz pebbles in a brook crossed by the road east of Mt. Tug, which must have come from this range.

East Lebanon Areas. I regret never to have worked out the relations of several small quartzite areas in the east part of Lebanon, etc., the first of which is in the line of the Moose Mountain rock, after its westerly bend. It is probable it is a repetition of the same band, by folding, perhaps, under the synclinal which is observable between the sides of the valley by Walker's slate quarry in Hanover. A friable sandstone, from fifteen to twenty feet thick, known in the neighborhood as the "Sandhill," is a landmark on the sloping ridge west of the slate quarry. On the south side of the valley, back of J. W. Cleveland's, is a hard quartz, often showing constituent pebbles, twenty-five feet wide, and carrying mispickel. At one place it has been broken, and one end shifted about twenty-five feet. The dip is 75° N. 75° E. On climbing the hill, it is again seen before coming to I. Eastman's. The argillaceous schists about it are much twisted. A quarter of a mile south of Eastman's is a short piece of quartzite, which looks as if it had broken out of the long reach of this rock, continuous for three or four miles S. 8° E. from the sand-hill. This fragment dips 60° N. 20° E. West of A. P. Hoyt's, the range is continuous for more than a mile to the Enfield line. Two other outcrops, apparently belonging to the same range, are just south of Stony brook and near a church in the south-west corner of Enfield. This would seem to be continued in the area west of school-house No. 14 in Plainfield, on the course of Ring brook, if extended. An outcrop west of Leavitt pond, in the edge of Grantham, appears to be the continuation of the Lily Pond (Enfield) exposures. That at the Grantham Lily pond is obviously connected with the Croydon Mountain mass, and perhaps another small one south-west from Sugar hill. There remain two others not yet mentioned. The first is a quartz conglomerate, about a mile above the mouth of Stony brook in Lebanon; the other is south of East Plainfield,—and both are equally distant from the other ranges. It may be that the suggested synclinal at Walker's quarry is continued southerly, so that the Enfield and Stony Brook ranges are the same, uniting again in Grantham or Croydon mountains. In that case, the two more western outcrops might be the indication of an anticlinal on the west side. With this latter range would naturally be associated the Bald Mountain outcrops in the north-east part of Claremont. There are three bands there, at least one of them being a beautifully spotted rock, with white, flattened pebbles in a dark, slightly argillaceous paste. One of the dips is N. 80° E. An obscure quartzite occurs a short distance above J. Clark's saw-mill, which may connect with one of the Bald Mountain exposures. After another look at the map, it seems possible that these eastern ranges are all converging towards the Craft's Hill range. The nucleus of Bethlehem gneiss undoubtedly causes this convergence, and further exploration may possibly illustrate this feature more strikingly. The most western of the eastern ranges, near the mouth of Stony brook and Bald hill, is the one most like the Craft's Hill band, and the one that would most naturally join it in case the convergence became conjunction.

Croydon Range. One gets the impression that the whole of Croydon mountain, in Grantham and Croydon, must be composed of quartzite. Plans that were made for the exploration of these mountains have failed to be carried out; and therefore the coloring of this area must not be regarded as necessarily correct. Beginning quite high up, near Cranberry pond, with westerly dips, the rock continues southerly into the Grantham mountain, the land rising all the way. Traversing the road at the east foot of the Grantham mountain, one gets glimpses of supposed quartzite ledges on the summit. In the notch, where the Croydon road passes over to Cornish Flat, the quartzite is abundant. At the east base it dips 75° N. W., or at a much higher angle than the underlying gneiss. After passing a band of white, vitreous quartz in the ascent, there is a mica schist dipping 50° S. 80° E.; and this is probably the range which extends northerly to the Croydon trigonometrical station occupied by the Coast Survey party in 1874. At the summit there is more quartzite, dipping 50° southerly. The south end of Croydon mountain is certainly quartzite, dipping 70° N. 75° W. and 60° N. 85° W., and to some extent is interstratified with varieties of mica schist in the district a fourth of a mile west of the Croydon mine. I have no evidence to show that the quartzite extends out of Croydon into Newport.

Claremont Area. There may be quartzite upon the north-west side of Green mountain. There is but little adjoining the slate by C. Dean's, on the south side, but it widens southerly. It is quarried near R. Page's, and is near hornblendic, chloritic, and garnetiferous schists. At A. C. Dodge's it is a conglomerate, composed of flattened pebbles, dipping 75° S. 85° E. There is said to be quartzite on the south side of Sugar river, on the east side of Bible hill. If so, it is the natural continuation of this range. I have seen there only a very large vein of white quartz, cutting the mica schists west of D. W. Barney's, near the south line of Claremont. It appears that the gneissic rocks east of this range belong to the Bethlehem group; and that around its north end, in Claremont and Newport, the same band occurs, perhaps all the way, though colored upon the map only where it has been seen.

5. Coös Schists and Slates.

Most of the area between the Huronian and the Quartzites is occupied by mica schists, clay slates, and a few hornblende schists, believed to belong to a group of strata not well understood, and therefore described under a local geographical name of no original geological significance. Their easy passage into the group described in the Vermont geological report as the Calciferous mica schist, makes it difficult to decide between them in many cases. I am sometimes disposed to maintain that the two were synchronous, the calcareous layers forming in deeper waters than the sandy and clayey sediments of the Coös series.

There is a natural separation between the Coös schists of the Ammonoosuc and Connecticut Valley areas. The Haverhill gneisses form an impassable barrier between them, not likely to have been overcome unless it were far back in Paleozoic time. The rocks are largely argillo-micaceous schists in the south part of Haverhill. Perhaps the most northerly outcrop of it is on the south slope of Knight's hill, dipping 80° N. 20° W. They crop out on the ridge east of Wood's pond, with an inclination of 75° N. 40° W. Fig. 48 shows the order and position of the formations near the southern line of Haverhill. Leaving the gneiss inclined only twenty degrees westerly, the quartzite first appears, dipping 45° N. 30° W. Then we have wrinkled staurolite slate, with a smaller dip. This is followed by hornblende schist, dipping 80° N. 80° W., occupying about half the space between the quartzite and the turn of the road down Eastman's brook; afterwards, in the whetstone slate at a quarry, with a variable dip of 30°–80° W. This is followed by hornblende again, the slate having been quite limited in amount. Near the forks of a road leading to East Haverhill there is a broader band of whetstone, three hundred feet wide, and a larger (the principal) quarry. This extends north-easterly to join other gneisses of the same material in East Haverhill. Hornblende succeeds again. Without specifying the changes in order, it is sufficient to say that there are five bands of hornblende schist and five of whetstone slate between the quartzite of Iron Ore mountain and the stream flowing northerly into Oliverian brook on the north-east part of the town line between Piermont and Haverhill. The map shows only one of these hornblendic outcrops. The last half mile of Piermont shows a good soil, with the ledges mostly concealed. This suggests the presence of the limestone of the Calciferous. The hornblende, close to a school-house near the town line, dips 65° N. 70° W.

I am inclined to carry out the suggestion of a previous page, to the effect that much of this hornblende should be regarded as Huronian. In agreement with this notion, it would form hummocks underlying the mica schists, probably unconformably. Such is the present relation of the first staurolite and hornblende schists mentioned upon this section. Lateral force exerted in subsequent periods seems to have exaggerated the discordance. This theory will explain the occurrence of the whetstone rock, in limited outlying patches, sometimes exhausted by quarrying. Were it interstratified with the hornblende, it should descend into the earth at the same angle to indefinite depths. This theory, then, regards the eastern part of the hornblende of Piermont the same with that in Hanover, Lyme, and Orford, bordering the west line of the Bethlehem group. A similar view will make plain the proper relations of the hornblende rock in Fig. 59; but the more western of these hornblende ranges must remain with the Coös group, as they are evidently interstratified with each other.

On ascending the west side of the valley, on the town line just named, the ledges bear more resemblance to the calciferous layers found in Vermont. They dip 70° S. 75° W. There is a little hornblende with it at first, then it is soft, and, by J. Wallace's, hard, from the abundance of silica. On Catamount hill, just in the edge of Piermont, is an interesting mass of eruptive granite, unlike any other granite seen in the state.

The three constituents are about equally developed. The general effect of the stone is like that of the Concord variety, only the mica is blacker and more abundant. It is extensively quarried. Its period of eruption must be set down as subsequent to the deposition of the Coös slates, since the latter have been disturbed by its protrusion; yet the direction of the dip is unchanged, as at J. Blaisdell's in Piermont, dipping 70° N. 50° W. The Haverhill Corner (court-house) village lies on a hill of drift, and hence the junction of the Coös and Huronian systems is not exposed; but, by following up the valley of the Oliverian stream, one can see much of the structure. At the bridge in the village the rock is the argillitic Huronian quartzite, dipping east and S. 65° E., and continuing for a quarter of a mile up the brook. The Coös schists commence near D. Randall's, dipping 70° west. It slightly resembles hornblende when water-worn, decomposing readily. Higher up the Oliverian, the strike changes to east of north. At P. P. Bowen's the dip is west. There are several good exposures of these schists on the railroad between Haverhill and East Haverhill stations.

The order of rocks down Eastman's brook in Piermont has been carefully ascertained. As before (Fig. 48), we start with quartzite, staurolite schist, hornblende, and the first whetstone slate dipping 70° W. at the junction of the roads from Piermont and Haverhill villages. Then we have hornblende, whetstone, with dip 65° W., and hornblende with strike N. 30° E., vertical. On the hill south the next layer is a small band of quartzite, with whetstone slate, dipping 60° N. 80° W. Then comes another small quartzite layer. Between A. C. Walker's and H. Chandler's there is a synclinal of argillaceous schist or slate, the dips being 70° N. 60° W. and 80° S. 55° E. This is related to the slates occurring northwesterly at A. W. Putnam's, just in the edge of Haverhill. The rest of the rock to the village of Piermont is mostly mica schist, with and without staurolite. Our observations are 54° N. 50° W., 50° N. 60° W; hornblende band, 55° N. 20° W., 35° N. 60° W., 45° N. 55° W., and 45° N. 60° W. at the village. Just to the south of the river is a noticeable conical hill, called "Peaked," whose composition is the prevailing rock of the country. It is not easy to comprehend why this conical mass should have been spared, while the adjoining strata were eroded. Similar cases, however, occur in the towns south. First, we have Sunday mountain in

Orford; and, second, Acorn hill in Lyme,—the first more difficult to understand than the Piermont Peaked hill. West of Piermont village there is a hard argillite, dipping 20° N., adjacent to Huronian protogene. On the road to Haverhill, the Coös rocks come in contact with the Huronian, likewise, in connection with a fault. The protogene dips 60° S. 20° E.; while close by the mica schists dip 70° S., the common position being to N. 50° W. The line of the fault, as mentioned upon page 359, is about N. 25° E.

There is a hilly country, not at all inhabited, between Eastman's brook and Catamount hill, concerning whose geology nothing is known. While the probabilities are in favor of its being, as represented upon the map, the continuation of the mica schists, it may be granitic, or gneissic, or hornblendic. Such a composition as the granitic would better agree with the lack of inhabitants, the presumption being that the poverty of the soil occasions the absence of farms. The west part of Fig. 49 is included in the description of the rocks along Eastman's brook. To the east of Peaked hill the line of this section leaves the river and passes directly to Piermont mountain. On that there are mica schists, dipping 50° and 55° N. 54° W., also 80° N. 40° W. These are supposed to continue uniformly to the quartzite. Near the Christian church on Bean brook, a little south of this section, we have a dip of 85° S. 32° E., which would seem to indicate the place of a fold in the strata.

The hills in the south part of Piermont remind one of the characteristic domes of the limestone region. They are very high, rounded, with deep valleys between them, while good farms occur universally. Starting south-easterly from Piermont village for Indian pond, we find the following facts: At the village the dip is N. 50° W.; on top of the first hill, the continuation of the Peaked Hill range, the mica schists are slightly stauroliferous, dipping N. 60° W., with a small overturn anticlinal, the steepest pitch being upon the south-east side. Whether this small fold is local or not, I cannot say. The north-west dips occupy the south-east side of the range. Beyond Bean brook there is a higher hill, with mica schist dipping 80°–85° N. 70° W. Just in the edge of Orford the schists are pyritiferous.

These rocks in the north part of Orford are represented in Fig. 50, a section from Pine hill to the Soapstone mountain. On Pine hill are the highly inclined strata of Bethlehem gneiss (p. 351). Near the four corners, south-west from Indian pond, is a band of quartzite dipping 65° N. 60° W. At the school-house by the corners are vertical slates, becoming notably minutely contorted beyond. A little north of the road, by J. Stickney's, the dip is 67° N. 38° W. The dip is obscure west of T. Ames's, thought possibly to be easterly. At E. Lovejoy's are large loose slabs of siliceous limestone. On the long dome hill beyond, the north-westerly dip is the common one, one observation being 75° N. 34° W. Echo hill is a conical, isolated rock, precipitous on the east side. South-west from it, near T. Ford's, the rock is sandy, dipping 20°–30° N. 40° W. The strike is perceptible here for several rods in extent. On top of Soapstone mountain, which is properly on the section line, the dip is 30° N. 25° W. The mica schist here is full of small contortions, whose axes run north and south, like those on Sunday mountain, showing that the shoving force came either from the east or the west. This moderate dip continues to the soapstone quarry on the southern slope, where it varies from 30°–40° N. 45° W. Some of the layers have a little feldspar; but this soapstone is essentially in the Coös formation. There is a suggestion, not yet verified by analysis, that the mineral is agalmatolite. It contains the rare brown tourmaline. The bed is forty or fifty feet thick, and is not now worked.

Next we have a section from Cuba across Sunday mountain to Orford street (Fig. 51). The rocks of Mt. Cuba have been somewhat noticed already. A bunch of mica schist seems to be caught in the quartzite, and there is another mass on the west side below the quartzite. Both these formations rest on the edges of Bethlehem gneiss. Between Cuba and Sunday mountains we find an anticlinal of gneiss in the low country. The first of the mica schists dip 75° N. 40° W. at the union of the four roads. Two miles north, on the strike of the east part of Sunday mountain, there is a slight leaning to the west; and the course of the schists on the north side points towards the curious conical mass. On top of Sunday mountain garnetiferous schists dip N. 30° W. It is a little feldspathic on the west slope. At the west base of the highest part of the mountain, in a small valley, soapstone crops out, inclined 60° N. 58° W. The same rock occurs on the south-east slope, and there is said to be another to the north, thus making four beds of this mineral in Orford in the mica schists. Probably these four are continuations of the same bed, repeated by undulations of the strata. As the dip is essentially monoclinal, the repeated occurrence of the same rock indicates overturns. On the south side are nests and crystals of chlorite. The west side of Sunday mountain furnishes admirable examples of contorted strata on a small scale; and I have obtained a large block of the stone showing them, for the museum. If it were figured, the curves would be like those already given, on Plate X, of the boulder from Bemis brook. The dip by the town farm, on the north-west slope, is N. 40° W. On the line of section, just west of the North Branch valley, the dip is not more than thirty degrees in the same direction. At the grist-mill, at the north end of the "street," we find argillo-mica schists, with staurolite in distinct crystals, in horizontal disposition, and also inclined as high as 25° N. 50° W. At one exposure there is a small, shallow synclinal. Cleavage planes, cutting the strata and highly inclined, are also present, which is uncommon in New Hampshire. A related example may be seen east of the cheese factory, perhaps two miles east of the centre of the village. The first ledge is of argillaceous schist, at the fork in the roads, apparently dipping 65° N. 45° W. A few rods east there seem to be stratified layers, dipping 20° S. 15° E., while cleavage planes occur corresponding with the supposed strata of the first ledge described. There are several other outcrops similar to the first; but no others, like the second case mentioned, have been seen close at hand.

The north-west dip is resumed at Orfordville and westward, but there is a development, a hundred yards wide, of what is probably Huronian. In the east part of the village is a bed of soapstone, in argillitic schists, with mineral aspects different from that in the other localities described. It is green, like chlorite. The excavation, when examined, Sept. 20, 1872, proved to be about sixty feet long and twenty feet deep in one part. The stone occurred in three places, and seemed to occupy three undulations of the strata, with two small faults. The strike is N. 17° E., and the dip is N. 73° W., all the layers being inverted. The course is towards Sunday mountain. Should this ancient rock occur beneath that eminence, we can understand its origin, since the elevation of the floor must of necessity raise up the underlying schists above those of the neighborhood. A narrow Huronian axis, just including the soapstone band and inclosed within newer Coös rocks, with the same monoclinal dip, would not be the most unreasonable method of accounting for the presence of this rock, which has heretofore been supposed to be confined to the older formations in New England.

A visit to Strong's quarry in 1875 showed a greater thickness of soapstone than appeared at first; and many of the adjacent rocks seemed to be charged with talc, so as to be genuine talcose schists. Passing to the south-west, a mongrel rock occurs, covering the soapstone quarry universally, with the dip of N. 45° W. along the line of the quarry. This is followed by a hornblende, dipping 65° N. 55° W.

In Fig. 52 there is a section from Bass hill to the Connecticut, a mile north of the south town line. The east side of the hill consists of the granitic Bethlehem gneiss, which dips N. 55° W., probably 80°. At the summit, or a little west of it, may be seen the meeting of the gneiss with argillo-arenaceous schists, dipping 80° S. 50° E. This is an overturn, and is not seen away from the hill-top. At the west base the dip is 75° W.; and farther north mica schists, with alternating bands of quartzite, dip 70° N. 47° W. At the first bridge east of the Strong quarry, the dip is 58° N. 46° W. Then occur the dips at the quarry and farther south, mentioned above. Near N. & T. M. Rugg's, the dip is 70° N. 60° W.; west of the same, 68° N. 50° W.; half a mile west, 50° N. 60° W.; at J. C. Sanborn's, 65° N. 55° W.; near D. E. Tillotson's, 50° N. 80° W. These are all argillaceous. A mile west of Tillotson's is mica schist dipping 48° W.; the same, 50° N. 40° W. in contact with a mass of eruptive granite from ten to fifty rods wide. Bands of mica schist follow, dipping 25°–35° S. 30° W. Hornblende schist, with a north-westerly dip, succeeds, thirty feet wide. Mica schist comes in again before reaching the alluvium, dipping 65° N. 60° W. There is not much variation in the position along this section line.

Fig. 53 presents the strata from the North Thetford bridge to Davison hill in the north part of Lyme. The Huronian of Lyman aspect occurs at the bridge, with dolomite near by dipping 70° E. The same rock is seen at C. F. Carr's, dipping 50° W. The ledges, a fourth of a mile north of the road, particularly back of M. D. Baxter's, seem to possess the same inclination. Alluvium conceals the ledges for a mile along the road; and the first rock peering above it is hornblende schist, by J. Wise's, dipping

—SECTIONS IN THE CONNECTICUT VALLEY.—

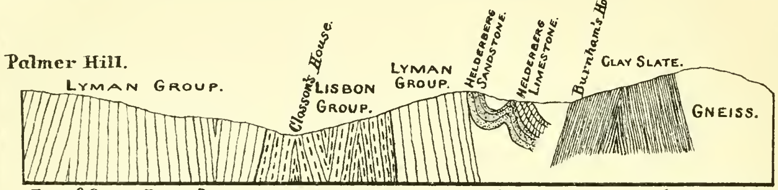

FIG. 36 a. FROM PALMER HILL THROUGH BURNHAM'S LIME QUARRY. (See pp. 326-7.)

Scale of Figures below; { *Vertically, 3000 Feet to an Inch.* / *Horizontally, 2½ Miles " " " .*

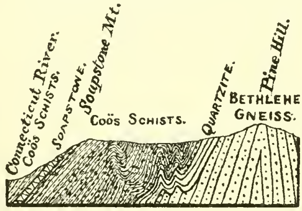

FIG. 50. SOAPSTONE MT. TO PINE HILL.

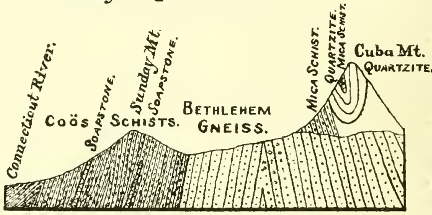

FIG. 51. ORFORD STREET TO CUBA MT.

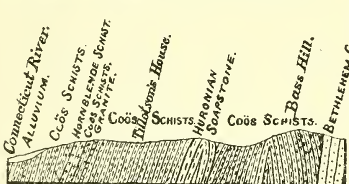

FIG. 52. CONNECTICUT R. TO BASS HILL.

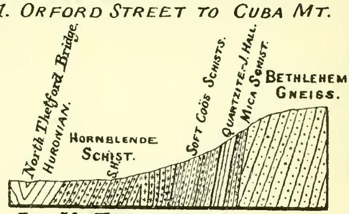

FIG. 53. THROUGH NORTH LYME.

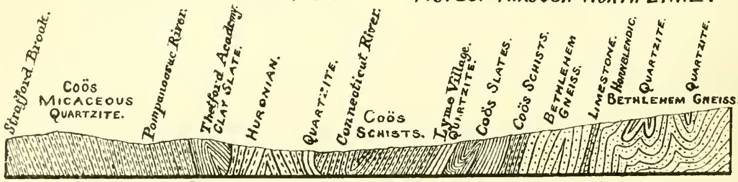

FIG. 54. FROM STRAFFORD BROOK, THETFORD, TO EAST LYME.

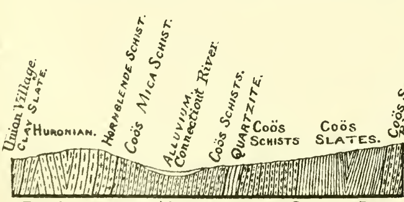

FIG. 55. UNION VILLAGE TO BLISS POND.

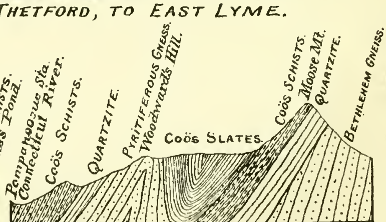

FIG. 56. POMPANOOSUC TO MOOSE MT.

50° N. 70° W. The same, with talcy seams, occurs in the valley of Clay brook and at a school-house to the east, with probably no change in the dip. Ferruginous schists occur next, up a hill. A very tough and ferruginous hornblende rock crops out at Mrs. J. A. Whipple's, dipping 80° N. W. No outcrops appear in the valley south-east; but their strike leads north-easterly to soft talcy schists, resembling hornblende superficially, with the same position as the last, also, 46° N. 48° W. at J. Converse's. At J. Hall's comes the narrow band of quartzite alluded to previously. East of the quartzite, protogene gneiss occurs on Davison hill.

This section differs entirely from that in Fig. 52, a distance of not over four miles. Between them, on the roads passing Turtle pond, we have chiefly the soft, green schists. On the Bass Hill road a mica schist touches the gneiss, by A. English's, with dip of 70° N. 60° W. On the north-east side of Acorn hill there is a greater resemblance to limestone, at E. F. Cutting's. It is pyritiferous at J. and H. P. Stetson's.

The next important section is given in Fig. 54, through Lyme and Thetford. This afforded one of the typical sections of the original Coös group, as published in the report for 1870. We find layers of Bethlehem gneiss and hornblende on the road to Smart's pond, the latter dipping 48° N. 60° W. north from E. Blaisdell's. Just east of the cemetery is a band of quartzite, which is the eastern branch of the principal range, as given upon the map. Between the cemetery and saw-mill, I found gneiss like that common in Enfield village. The quartzite by the mill dips 85° N. 70° E., and this is east of the crest of the mountainous range. Hornblende rock shows itself farther west, having the same position with a strong band of vitreous quartzite, dipping 55° N. 62° W. The quartzite seems to lie east of the road, after it bends to the south-west, near A. W. Clough's; and there occur, first, epidotic gneiss; second, hornblende rock, dipping 15° N. 30° E.; and by P. Allen's, where the road joins the Canaan branch, limestone dipping 50°–60° N. 70° W. Westward along Grant brook extensive outcrops of Bethlehem gneiss show themselves, as at L. Conant's and A. B. Dimick's; but the position of the strata is not easily ascertained. I thought, at my first visit, that Dimick's ledges authorized the figures of 25° N. 48° W. I should say now the position had better be made to agree with that of the limestone. The rock is unusually massive, planed down thoroughly by ice action, and simulates granite.

This quartzite range seems to lie altogether upon the ancient gneiss, and does not connect at all with the mica schists in East Lyme. A band of mica schist occurs next, about three fourths of a mile wide. There are no outcrops in the valley; but about a mile north the dip is 70° N. 63° W. Other observations near by give 60° N. 50° W., both of which may represent the average position of this formation. It is succeeded by clay slates, both garnetiferous and stauroliferous. In the eastern part of the belt, or by a road-crossing of the stream, the dip is 50° N. 50° W. It is about 30° at another crossing by a tannery. Farther west the dip may be 35°–40°; and at the western limit of the formation, by A. A. Lamphere's, the position is 50° N. 40° W. These slates have thus a much lower dip than the schists eastward. By D. Fales's and at the church, just in the edge of the village of Lyme, the western quartzite range crops out. From here to the river there succeed greenish, soft schists, with a mineral much resembling chlorite. The dips observed are the following: About 50° N. 60° W. just north of the village; 50° N. 68° W., slightly calcareous, at a bridge at the south end of the village; about the same at numerous exposures for a mile and a half along Grant brook; at its mouth, hard mica schists, 50° N. 40° W. Similar ledges occur between the brook and Gilbert's bridge over Connecticut river, the rock resembling hornblende schist, though quite soft, and dipping 60° N. 30° W.

In Vermont there is a band of Coös schists, like that in the north part of Orford, and carrying steatite, near the Norwich line. Two outcrops of the soapstone are represented upon the map. At the school-house west of Childs's pond is a quartzite, constituting the west edge of the Coös rocks, dipping 50° N. W. A band of these schists, in which staurolite and kyanite occur prominently, extends southerly over Oak hill till it is covered by the sand of the Pompanoosuc basin. It is represented as extending to the west of a hornblende range. West of this there is about a mile width of the eastern slope of Thetford, underlaid by the characteristic Huronian schists, dipping, in accordance with some observations in the Vermont report, 80° E., and, by my own measurement, 80° N. 30° W. Before reaching Thetford hill, the clay slates succeed, with south-easterly dips. At Thetford Centre, and generally along the valley of Vershire brook (or Pompanoosuc river), the rock is a micaceous quartzite, dipping 80° S. 50° E. This was at first placed with the Calciferous mica schist.

Recent studies in Thetford and Fairlee lead to the opinion that this quartzite may be the proper equivalent of the quartzite described as a part of the Coös group, as in Hanover, etc. There is nearly as much silica in the Thetford as in the Moose Mountain series, the first adding mica in small proportion to the usual vitreous compound seen east of the Connecticut. In agreement with this suggestion, I have colored quite a large area west of the Cambrian slates as belonging to the Coös group. It is worthy of notice that this formation carries the copper beds of Vershire, and perhaps the pyrites of Copperas hill. It is represented as extending to meet the ancient gneiss in the west part of Hartland. Its occurrence at West Hartford and to the south of Quechee village has been particularly noted. The resemblance between these schists and specimens from Littleton is very marked.

In the south-west part of Lyme there is a large development of soft, green schists, whose silicate mineral seems to be talc or chlorite. They are well seen on the hill road to Hanover, between Grant and Fairfield brooks. Without close inspection, one would be disposed to say the rock was hornblende;—in fact, some of my earlier notes give that name to it. With it are occasional calcareous seams, so that it presents a resemblance to the formation about to be described as the Calciferous mica schist in Lebanon and Cornish; and I have sometimes thought the Lyme area, as well as much of the Hanover rock, should be regarded as Calciferous. The position is uniform over this part of Lyme, except a dip of S. 50° E. at C. C. Webb's. At N. Kendrick's it is S. 57° W. 70°; at S. Hewe's, 70° N. 80° W.; but farther north not more than 60°. Towards the Hanover line, the rock becomes considerably ferruginous. At a bend in the road by A. Smith's, in the north-west part of Hanover, the limestone is present in the greenish schists, with a north-westerly dip. To the south, we find the ferruginous schists of Spencer, Lord's, and Prospect or Pinneo hills, which have been noticed under the head of Bethlehem group (p. 353), and are more likely to belong to the Coös than the other series.

The section in Fig. 55 shows the position of the layers from Bliss pond and near the south line of Lyme to Union Village, Thetford. The quartzite is wanting east of the pond; and the mica schists join the gneiss without it a little west of J. Tyler's, south of Bear hill. Hornblende schists are interstratified with them at A. Blood's, standing nearly perpendicular.

From the vicinity of the pond is seen an abundance of slate ledges on the west slope of Bear hill, apparently dipping north-westerly. South of Bliss pond we find the beginning of the more argillaceous band, dipping 80° N. 50° W. From Fairfield brook the land rises gradually but considerably to Hanover Centre, and consequently afforded an excellent lodging place for the drift. Hence it is rare to see any ledges near the town line. West of I. F. Clark's, a mile and a half from Bliss pond, the slate dips 85° N. W. The green schists, referred to above, replace the slates before we reach the place where the stream crosses the town line. A short distance west occurs the quartzite; then the schists at S. Hewe's, which continue westerly until concealed by the alluvium. On the west side we find chiefly Huronian rocks, with a supposed outcrop of hornblende, and, possibly, mica schists on Oak hill, by the south line of Thetford. The Huronian has the anticlinal in it at Union Village, and an overturn easterly dip of the slates on the west side of it.

Fig. 56 contains a section from Moose mountain to Connecticut river, near Pompanoosuc station. At the east end is a porphyritic gneiss, supposed to be a lower member of the Bethlehem group, with a north-westerly dip. The Moose Mountain ridge is entirely of the Coös quartzite dipping 50° N. W. on the section, though usually the angle is greater. The schists of the Coös group adjacent hold the same position, as do the clay slates along their eastern border. Hornblende schists are interstratified with these slates. Boulders of siliceous limestone are plenty at the west base of the mountain. On the main road to Lyme from Hanover Centre the slates dip very high N. 60° W., and at their west border are fairly vertical, with the same strike. Woodward's hill, though mainly of drift, shows ferruginous schists. Lower down, we find the western range of quartzite, with its north-westerly dips, and, last of all, the mica schists overlying them.

Fig. 57 is designed to illustrate the Bethlehem group. Fig. 58 shows the rocks along the route of Section VI in Hanover. The Bethlehem gneisses, with a dip of 75° W., are followed by the quartzite similarly disposed. The Coös mica schist range occupies the steep west slope of Moose mountain, with a breadth not exceeding half a mile, conforming essentially with the quartzite, and both perhaps constituting a ridge beneath the slates succeeding. It is not certain that the Coös schists recur again upon this section, as their place, between the gneiss of Corey hill and the hornblende schist of Observatory hill, is covered by clay. The section crossing Craft's hill in Lebanon, which is a very important one, has already been described upon page 363, Fig. 59.

Fig. 60 shows the position of the rocks along Mascomy river, through Lebanon to Enfield village. West Lebanon shows hornblende schist in the Connecticut river. The village is entirely covered by alluvium for a mile back from the mouth of the Mascomy; and then succeed ledges of argillo-mica schist, vertical, strike N. 24° W. Massive hornblende comes next, at the joint crossing of the Mascomy by road and railroad, dipping 42° N. 63° W. The mica schists of Craft's hill are believed to succeed on the east, before coming to the Bethlehem area. Hard sienitic ledges are seen near the scythe factory. These are replaced, near the village of Lebanon, by protogene gneiss. In the south-east part of the village are many ledges of mica schist, dipping 60° S. 40° E. Among them are layers carrying patches of the peculiar variety of fibrous hornblende, called locally "Bentonite." Other ledges are conglomerates, holding distorted pebbles. One of them, consisting of a decomposing feldspathic material, is represented—half the natural size—in another part of this volume. I have in other publications enlarged upon the distortion of pebbles, and their bearing upon the subject of metamorphism, and will not say more, now, than that the shape of this pebble is not a natural one. The upper end of it has been compressed more than the lower, so that it has been drawn out, as if plastic, and somewhat bent. Other ledges in the village show abundant cavities, produced through atmospheric decomposition of limestone patches. On the hill, also, is a nodular vein of quartz, carrying hornblende, sometimes fifteen feet thick. South of the village are ledges thought to dip 75° N. 23° W. Half a mile east of the village a railroad cut develops similar ledges, thought to stand vertically, with the strike N. 53° E. This is somewhat like the gneiss of Mill Village, Hanover. The hills north-east are of mica schist, often considerably ferruginous. Near the mouth of Stony brook, ledges of ferruginous mica schist, with a north-east strike, are visible as one rides past them on the cars. The section crosses next two bands of quartzite, with the intervening argillaceous schists. In Enfield the staurolite mica schists are finely developed. The railroad cuts through them near the lake, west of the village, where the dip is about 75° easterly. In the west edge of Enfield village the dip is 72° N. 72° E. The gneiss at the east end of the section has a dip a few degrees less; but there is no change of importance in the strike.

The range of mica schists, on the western flank of Moose mountain through Hanover, is comparatively narrow, but in Enfield it covers four or five times as much width. There is a bed of magnetic pyrites, with chalcopyrite, dipping 75° N. 40° W., on the water-shed between Mink brook and the Mascomy, in the south-west corner of Hanover; and a bed of the pyrites, said to have been mined once for iron, in the west part of Enfield, near the lake, dipping northerly. The Shaker villages are situated mainly upon these schists. At the road turning off southerly from them there is a ledge of hornblende, dipping 75° N. 75° E. A mile to the south the mica schist dips 75° N., succeeded by the staurolite layers, dipping N. 55° E. on top of the hill. I have never seen staurolite crystals more abundant than in the neighborhood of West Enfield post-office. The layers have an easterly dip. On the surface are large boulders of siliceous limestone. On an old road to the Lily ponds, now abandoned, the mica schists appear, with some conglomeratic beds, dipping due east. The ledges about here are greatly distorted. It is probable that these Coös schists rest unconformably upon the gneiss. In the south-west corner of Enfield the dips are about S. 70° E. After leaving Enfield, these schists begin to narrow, and in Cornish and Claremont they are not much broader than in Hanover. The north-west corner of Grantham shows these rocks also. The westerly restriction of the mica schists is caused by the presence of the same related rocks, interstratified with siliceous limestone, and described under another head farther on. The correctness of the line of demarcation, as well as of the distinction, may be questioned; but we cannot do better at the present state of knowledge. The following are the rocks and their dips from Lebanon village up the valley of Great brook to Cranberry pond, by the east line of Plainfield: Mica schists, 75° N. 23° W. for a mile; 50° N. 35° W. at H. Wood's, on the road crossing the brook; occasionally the same as far as East Plainfield, the dip not changing till we reach T. Cutt's on the Meriden road. It is mostly drift from East Plainfield to school-house No. 14; west of which are two quartzite bands dipping 52° S. 54° E. By H. L. Sleeper's the schists dip 48° S. 50° E. Staurolite is abundant between Sleeper's and Cranberry pond, dipping 35° S. 40° E. Near the pond I have seen some of the limestone. Between it and the quartzite is a band of shining mica schist, which dips 65° S. 40° E. On Blood's brook the greenish calciferous schists are made to extend to school-house No. 16; then come the clay slates before alluded to, while all the Coös schists, both those containing staurolite and others, are confined to the area between the slates and quartzite of Grantham mountain.

In Cornish, on the road over Croydon mountain (Fig. 62), the staurolite schists overlie the Calciferous, dipping 50° E. into the mountain. On their western flank, mica schists, without very much staurolite, seem to be interstratified with quartzite; and there is a band of the schist on the very apex of the mountain, at the trigonometrical station. The staurolite schist east of the slate quarry, close by the east line of the town, dips 55° S. 80° E. Taking the road over the south end of Croydon mountain, from Cornish to Newport, there is a perplexing succession. Leaving the main Calciferous, with a high south-easterly dip, argillaceous schists may follow for half a mile, passing into the Calciferous; then a band of staurolite rock, with the same dip, to O. Fletcher's. For a mile along the road the genuine Calciferous reäppears as far as Wm. C. Poole's, where large veins of pure white quartz show themselves. These look like large snow-drifts, from a little distance. From here to the gneiss, mica schist, holding staurolite crystals in abundance, is the only rock seen. At first the dip is 28° southerly, then only 15° N. 70° E., with gray sandstones. Ledges similar to the last are at a charcoal furnace in the edge of Newport. East of A. Ward's, Croydon, the mica schist of the gneiss group dips 75° N. 70° E.

The cat hole road in Claremont affords a display of staurolite ledges similar to those just mentioned at the south end of Croydon mountain. Leaving clay slates at the road fork between Bald and Green mountains, they dip 85° N. 5° W. about a quarter of a mile below the summit, and 70° E. at the latter locality. Within a distance of eighty rods the strike changes ninety degrees. Still farther east on this road, quartzite appears, and the staurolite rocks cease. This range seems to be pinched out to the south of Green mountain, but reäppears south of Sugar river, a mile east of Claremont village, and southerly along Quabbinnight brook, with high easterly dips. This rock widens much in proceeding southerly.

In the south part of Lebanon the mica schists fold around the area of Bethlehem gneiss, and in Fig. 61 we have a section illustrating the fact. It begins on the west, with a hill of hornblende schist back of S. Waterman's, dipping 50° N. 85° W. Next will come the continuation of argillo-mica schists, believed to dip west. At A. Hall's and sons the argillaceous matter predominates, dipping south-west, with conglomerates. Farther south, near S. Wood's, are vertical layers of hornblende, with a course north-south and N. 20° W. By O. S. Martin's the green, soft schists of the Coös group appear, dipping 80° W. The same occur half a mile east. The gneiss is not seen upon this road, as it does not extend so far south. Its central line should strike by R. Wood's. The gneiss is visible from the road upon the hill north, with a north-westerly dip; and the outside of the area corresponds with the upper layer of this rock, as observed farther north in Lebanon and Hanover. Farther north, by F. Peabody's and a school-house, the gneiss has the same position. The green schists east of the axis, by L. Freeman's, dip north-west, and are very fully developed at J. Hebard's. About three fourths of a mile east of the gneiss, the same mica schists dip north-west, and still farther east, 75° N. 35° W. Where a north-south road crosses the east-west one, near W. and E. Kimball's, the same rocks dip N. 25° W. This section illustrates, therefore, a very clear case of inversion. The gneiss has a monoclinal, north-westerly dip, the same with that of the soft, green schists; but the inclination is steepest upon the west side. The force of compression has been so great that one side of the anticlinal has been forced to dip in unison with and beneath its opposite; and the overturning has affected the Coös schists as well as the gneiss. The hornblende does not appear to have shared in the overturning, as it is not repeated on the east side; but its course has been made to agree with that of the central axis. The curving of the newer schists around the gneiss is also illustrated in the strike of N. 40° W. of the former at T. Wood's, half a mile south of O. S. Martin's. A north-west course is extremely rare in this vicinity, and its occurrence here has an important significance.

Coös Slates. We hope to distinguish several areas of slate from the mica schists upon the map, partly because some portions of them are with difficulty separated from the Cambrian series. It may prove hereafter that the distinction we have made is untenable; hence their separation from the Coös schists may enable us in the future readily to assign them where they belong. As a rule, the Coös slates differ from the Cambrian by the occasional presence of staurolite and garnet; by standing at smaller angles, the latter being very commonly vertical; and by the absence of auriferous quartz veins. The first area of this kind in the Connecticut valley has already been described in Lisbon (p. 318). Next are two small areas in Piermont. Two others in Orford have been alluded to, upon page 383, where reference is made to the existence of cleavage planes distinct from the stratification. The largest one known begins south of Acorn hill in Lyme, and extends through Hanover and East Lebanon, being almost the continuation of the Cambrian range from Springfield, Vt., to Plainfield. This is crossed by sections in Figs. 54, 55, 56, 58, and 60. The smaller areas are all readily referred to the synclinal form, and are believed to be small fragments of a newer series than the adjoining schists. This larger area is not so easily disposed of. It is easy to call its position on the Lyme section (Fig. 54) an anticlinal. Figs. 55 and 56 show a still better correspondence with the basin structure. We have more abundant information concerning the region of Fig. 58, along the valley of Mink brook and over Hayes hill in East Hanover. Passing up Mink brook, we find the gneissic series extending as far as the first crossing by the road above the Baptist church. The slates succeeding at the second crossing dip 75° and 60° W., the latter in the road turning northerly. A few rods higher up, at a small fall, the slates dip 80° W. There and farther along are frequent layers of a slaty conglomerate. This must be newer than the ordinary slates, since it is composed of the ruins of an older series. I have sometimes surmised them to be as recent as the Helderberg, an impression heightened by the occasional occurrence of patches superficially resembling corals. At an old mill-site, at the upper end of a sort of gorge cutting through the glacial drift, we find similar slates, with conglomerates, standing vertically. There are bluish quartzites interstratified with the slates at the brook crossing above the gorge, also vertical. The slates at a road turning northerly to a school-house, up a large tributary, are slightly plumbaginous and soft. A quarter of a mile beyond, after passing several slate outcrops without essential change of position, an interesting dyke of dolerite cuts the slate at a slight angle. This trap is remarkable for containing perfect crystals of labradorite, some of them two inches long. This is about the eastern limit of the slate.

If we pass over the hill, directly east from Mill Village, the last of the Bethlehem series occurs about half a mile up the hill, the rock being white and ferruginous, and therefore becoming reddish-brown upon exposure. A band of quartz occurs here, such as is found in this gneiss area in two localities near the river (p. 353.) The dip is 55° N. 65° E. Drift conceals the ledges over most of the westerly slope of the hill. At I. Fellows's the slate runs N. 35° E., and stands on edge. On the top of the hill the dip is 85° S. 50° E.; on the eastern slope, near the eastern edge of the formation, the dip is 73° N. 40° W. These observations do not give much insight into the number or nature of the foldings, because the dips are mostly perpendicular; and such ledges may have been folded without giving any indication of an axis. By Walker's slate quarry there are indications of a synclinal and an anticlinal. This range may be separated from the other by a narrow band of mica and cupriferous schist, on the water-shed between Mink brook and Mascomy river. I find that the observations in the Mink Brook valley show a northerly strike, while those on the hill are north-easterly. Further search will show whether this variation is correct, and, if so, whether it is due to the presence of cleavage planes, or whether it has a deep significance, due to the occurrence of different formations unconformable to each other. The western border of these slates, just south of the Hanover line, joins ferruginous schists, both dipping 80° S. 43° E. At the slate quarry in East Lebanon the slates are mostly vertical, with a north-south strike. Those due east over the Enfield line are inclined at a very high angle to the east. Back of Cleveland's house the slates are about vertical. On the hill south, by I. Eastman's, the dips are quite irregular, one observation being 60° N. 20° E. That is not a common position; and my notes speak of a change in the strike of thirty or forty degrees from this within half a mile, in proceeding southerly. I think there is an anticlinal in the slates between the two quartz ranges of East Lebanon. There are several slate outcrops upon Stony brook, which I think dip to the northwest, but I have preserved no record respecting them. Certainly all the ledges to the west have that position, while those on Eastman's hill to the east dip in the opposite direction.

6. Calciferous Mica Schist.

This name is adopted from the Vermont final report. Professor C. B. Adams called them "Calcareo-mica slates." Both the expressions really ought to be replaced by a geographical designation.

The formation consists of mica schists, micaceous quartzites, argillaceous schists, and especially siliceous or bluish micaceous limestones. The limestone is the most abundant at the north end of the Vermont deposit, while the mica schists predominate in Massachusetts. The formation is broadest in Caledonia and Orange counties, narrowing nearly one half as it enters Canada. Below White River junction it divides, the broadest area running down to Proctorsville, where it terminates, and the other following the west side of the Connecticut through the state, with a nearly uniform width, enlarging a little near the Massachusetts boundary. The strata are less highly inclined in the broadest portions of the area, and they are much tilted up where the band is the narrowest.

Two areas of the formation occur in New Hampshire. One is in Colebrook, Columbia, and Clarksville; the other is in the present field of description, extending from the southern part of Lebanon to Charlestown. The first is isolated; the second is a part of the great Vermont range, separated from it by the Connecticut river.

Passing up Blood's brook, from the last of the hornblende rocks to Meriden, the rocks are mostly soft, greenish schists, commencing near the mouth of the tributary following down the valley on the west side of Morgan hill. We find a sandy schist, with the dip 80° N. 30° E., at the mouth of this stream. About a mile higher up, the greenish schist dips 45° westerly; and the rocks have essentially the same position all the way to Meriden, save that the angle of inclination is constantly becoming steeper, reaching 75° or 80°. Narrow seams of limestone occur in the square fronting Kimball Union Academy. The easterly dip begins just east of the academy; and the rocks may be followed to the clay slate band near school-house No. 16. The hills to the north of Meriden, as Batchelder and Morgan, with the Pinnacle in the extreme south part of Lebanon, are composed of the same formation, the axial line running from the academy to T. Cutts's, and perhaps to the anticlinal recently spoken of east of Stony brook, as well as to Walker's slate quarry in south-east Hanover, but in a different formation.

From Meriden to Cornish Flat—four miles—we see the same rock in abundance, with a south-easterly dip. Bean's, Colby's, Fifield's, Smith's, and Jordan's hills, and French's ledge in Plainfield, are all of this type of structure. A northerly projection of the formation, to connect the Plainfield area with that in North Hartland, would add Prospect and Home hills to the list. On the first there is a considerable band of a grey dolomitic limestone, unlike the usual variety of this rock. I suppose it to be the same with that analyzed by Jackson, giving, of siliceous matter, 25; peroxide of iron, 2.8; carbonate of lime, 23.8; carbonate of magnesia, 46.6=98.2. We have traced it through Prospect hill, about three quarters of a mile. It may extend to some of the localities mentioned by Jackson south of the "Plain." This rock is unlike anything else in the neighborhood, and we have had suggestions of its reference both to the Huronian and to the Helderberg. It is on the line of the Huronian of Willard's ledge. There is another outcrop of similar material south of A. Bugbee's; and Mr. W. H. Daniels thinks its continuation may be seen on the west slope of Black hill. The question of age cannot be decided without further study.

Mr. Huntington has carefully studied the rocks of Prospect hill, and presents us with the following additional statement respecting them:

"Just below D. Burnap's there is a synclinal in the hard, green schist, with strike north and south. The limestone crosses the road fifteen or twenty rods below Burnap's, and dips N. 50° W. 64°. Directly west a quarter of a mile, the strike is nearly east and west; three fourths of the way to A. D. Reed's the strike is nearly north and south. Above Burnap's the green schist is strangely contorted. On the hill, a little west of north from Burnap's, a whitish mica schist dips S. 80° E. 75°, but it is bent very much in places. South-west of A. K. Reed's, a green schist dips S. E. 72°.

"The limestone north of Burnap's has a strike nearly north and south, with westerly dip. There is no absolute proof that this limestone is Helderberg. The surrounding rocks certainly are Huronian."

Along the Connecticut river, the Calciferous ledges extend to Beaver brook, the first seen there dipping easterly, and being quite argillaceous.

—SECTIONS IN THE CONNECTICUT VALLEY.—

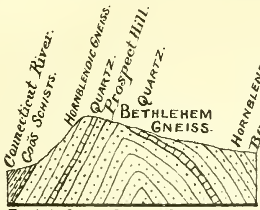

FIG. 57. CONN. R. TO BAPTIST CH.

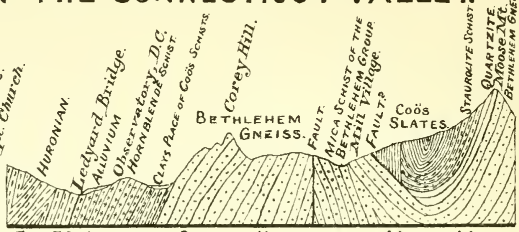

FIG. 58. LEDYARD BRIDGE, HANOVER, TO MOOSE MT.

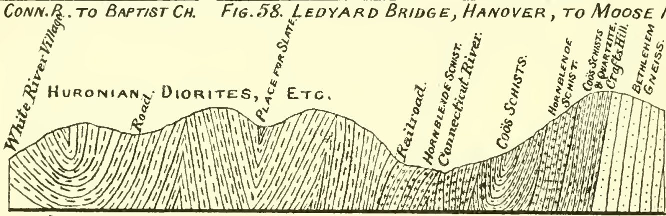

FIG. 59. WHITE RIVER VILLAGE, VERMONT, TO CRAFTS HILL, LEBANON.

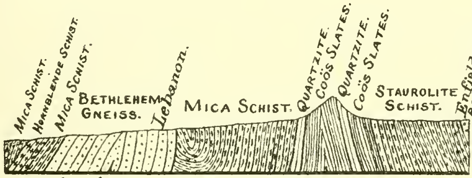

FIG. 60. ALONG MASCOMY RIVER.

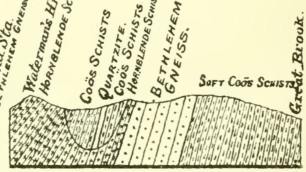

FIG. 61 IN SOUTH PART OF LEBANON.

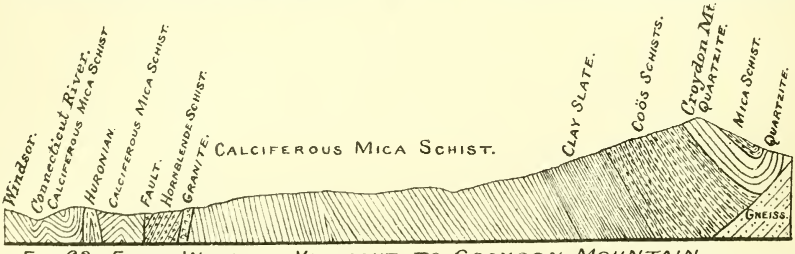

FIG. 62. FROM WINDSOR, VERMONT, TO CROYDON MOUNTAIN.

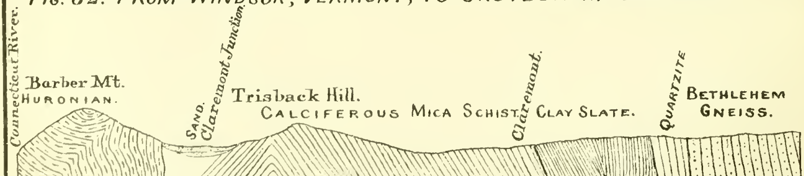

FIG. 63. SECTION THROUGH CLAREMONT.

VERTICAL SCALE OF FIGS. 57, 58, 60, 61, AND 63 = 2000 FEET TO AN INCH; OF FIG. 59 = 1200 FEET; AND OF FIG. 62 = 3000 " " " ".

HORIZONTAL SCALE OF FIGS. 57, 58, 60, AND 61 = 2½ MILES TO AN INCH; OF FIG. 59 = 1 MILE; AND OF FIGS. 62 AND 63 = 1½ MILES " " ".

On the west slope of Home hill are several prominent veins of quartz, perhaps the continuation of those carrying a little argentiferous galena at the Ascutney Mining Company's property in Hartland. These occur at the house of Capt. C. Gallup. Near the old Hart's Island bridge the schists dip south of east. A mile south-west of the plain the dip is 35° S. E., and 30° S. W. at A. K. Reed's, two miles north. The most northern outcrops of this rock on the hill road north from the plain are at L. Williams's, on the west side of Prospect hill.

Cornish is nearly all underlaid by this formation; and the characteristic topographical features of a limestone country are well exhibited both here and in Plainfield. This consists in rounded steep hills and deep valleys, everywhere fertile. Along Connecticut river the normal dip is easterly. At E. Pike's, at the most north-western road fork in the town, the dip is 75° south-east. At the crossing of Blow-me-down brook, near its mouth, we see dips in both directions, making an anticlinal. The westerly dip is shown nearly a mile farther south, at Capt. D. D. Freeman's, and in small, rocky islands in the river. Near Windsor bridge the dip somewhat south of east prevails to the exclusion of the other, save as it may exist unseen beneath the waters of the Connecticut. The strike carries the easterly dip in such a way that we may believe in the existence of an anticlinal certainly two miles long, and lying near a Huronian ridge (Dingleton hill, p. 364). The westerly crowding of the older ridge would naturally produce this arching of the strata.

The rest of Section V, through the central part of Cornish (Fig. 62), gives a good idea of the position of these rocks, the dip being mostly in an easterly direction. At the east edge of the formation the schists dip about 57° S. 30° E. This is on the east side of Parsonage hill; and the dip 60° S. 50° E. occurs next, the strata being much crumpled and decayed. At the town farm and hall the limestone is abundant, and the dip is 57° S. 40° E. Near the Methodist church, on reaching Bryant's brook, there are bands of a decomposing, fine-grained white granite, dipping 85° N. 30° W. At the school-house No. 11, hornblende schist occurs, dipping 55° N. 70° W. East of a cemetery it is more massive, and is properly a diorite. West of this, near the saw- and grist-mills, the Calciferous schists recur, crumpled, and dip 57° E. This is just east of the Dingleton Hill Huronian ridge. Two faults probably exist here, so as to account for the presence of this segment of mica schist in the midst of Huronian ledges. We have reason to believe the mica schist possesses the anticlinal form at its recurrence in Connecticut river. On the west bank of the river in Windsor the Calciferous group is present, with its normal appearance and dip of 55° S. 80° E. It continues up on to the flank of Mt. Ascutney. At a quarry at the north-east base of the mountain the dip is 80° E., where the rock is quite argillaceous. At the crossing of Mill brook the rock is micaceous quartzite, like that of Fairlee and the Ely copper mine. The eastern part of Weathersfield shows the Calciferous series, with dips like those in Windsor. The south branch of Bryant's brook, between Kenyon and Wellman's hills in Cornish, shows mica schist, chiefly, with a few beds of limestone, and positions corresponding with those along the line of the section. The same general statement will apply to much of the northern part of Claremont west of Bald mountain. At the Lottery bridge over Sugar river, very near the Connecticut and in the valley between two Huronian masses, the limestone layers show themselves, dipping on the average 50° W.; but the layers are badly doubled up, as would naturally be expected from their position between older rocks, and also the neighborhood of Mt. Ascutney. There is a large precipitous ledge of Calciferous rocks at the high railroad bridge over Sugar river, dipping easterly.

Fig. 63 shows a section along Sugar river, in Claremont, where details have been carefully worked out. At the west end is the Huronian Barber's mountain, with its irregularities, perhaps an inverted anticlinal. The Calciferous mica schist shows a well marked anticlinal in Trisback hill; and the facts are best explained by supposing this rock to rest upon the dolomitic and sandy schists to the west. The axis lies just to the west of the mass of the hill, the western dip being 50° S. 75° W. On the east side limestone is unusually abundant. Near the mouth of Redwater brook the dip is east. On arriving at the edge of Claremont village, at the lowest fall of water in Sugar river, where two mills are located, the argillaceous variety of the formation dips 60° S. 70° E. At the dam of the paper-mill the dip is 56° S. 67° E.; and the rock weathers like the average of this formation in Vermont. At the bridge just above, the strikes N. 20° E., N. 10° E., and N. 27° E. were measured. Above this bridge the strike N. 20° E. was observed, and also at a dam near two large mills. Near the first dam below the upper bridge the dip is 61° S. 70° E. This is an excellent exposure of the soft, green schists, like those described heretofore as belonging to the Coös group, with many strings of white lime interstratified. At the bridge itself, the schists dip 68° S. 38° E. Above this the clay slates, with high easterly dips, succeed, followed by quartzite and gneiss, whose details of position have been described heretofore with sufficient minuteness. Trips to Cornish, over any of the roads leading there from Claremont village, show occasional good exposures of the soft, green schists, with easterly dips. They also occur to the south-west, just encroaching upon the borders of Charlestown. Near school-house No. 9 they dip about 65° S. 70° E. On the north-west flank of Bible hill the dip is 63° S. 48° E. At W. Clark's a tougher variety of the rock, making a ridge, dips 59° S. 42° E. At the edge of the formation, near N. Stone's, the strike is N. 30° E., and the strata nearly perpendicular. About school-house No. 16 the green schists are very abundant. They likewise occur in many excavations for building purposes within the limits of Claremont village. A review of the dips about Claremont would indicate an anticlinal and a synclinal, the latter inverted, in this area of Calciferous mica schist. The rock is believed to be newer than either the schists on the west or the slates on the east side of it in Claremont.

On comparing together the positions of axes, it seems not improbable that the Trisback anticlinal may run northerly to join that in the displaced segment by the mills in Cornish, and thence north-easterly past Meriden to East Lebanon and Hanover into another formation. The direction of the axis being more easterly than that of the strata, it runs off into the adjacent formations beyond East Plainfield. A comparison of the dips with those in the gneiss of Enfield and Canaan, in the next chapter, will show whether this line of elevation also affected the older gneisses, and should therefore be regarded as occasioned by a very powerful earth movement.

The Calciferous in Vermont. Hardly any group of strata occupies more space than this in Vermont; and as our thirteen sections across that state, the continuation of those measured in New Hampshire, have recently been reëxamined, it seems proper briefly to refer to what has been learned there respecting their formation.

On Section I, in the eastern part of the area, an anticlinal brings up gneiss and hornblende schist. The same is true in Massachusetts to the south, and at West Brattleboro', on Section II, to the north. This is the same with the granite of Black mountain in Dummerston. The same three sections allow certainly of a synclinal west of this anticlinal, narrowing on Section II. It is known to extend as far north as New Fane and Dummerston. On our revised Section III, in Westminster, observations are wanting on this formation; but in Section IV, of Vermont, the dip is altogether monoclinal, with the average easterly dip of 60°. This being the narrowest part of the formation, I calculated the thickness here, in the report upon the geology of Vermont,* finding it to be 4800 feet. It was presumed the narrowness of the band might indicate its true thickness, without any repetition, such as occurs almost everywhere else. Essentially the same state of things is believed to occur on our No. IV in Springfield. Section V crosses Mt. Ascutney, an eruptive mass in the midst of the mica schist, and therefore teaches nothing concerning this rock. I believe the strata on both sides of Ascutney are monoclinal, and dip easterly. But we have stated evidence of the existence of two anticlinals in this rock on Section V in Cornish, besides the possible inverted synclinal to the east of the last ridge. The western arm of this formation is crossed by this section in Reading, where it may be a synclinal of limited extent.

Section VI first gives us an idea of this formation where it is very broad. There would seem to be a synclinal of this schist in Hartford,—clay slate to the east and a Coös micaceous quartzite to the west,—the same range with that holding the copper and pyrrhotite ores to the north at Copperas hill. It is very likely a fault occurs west of this quartzite. The Calciferous group following in Pomfret is largely composed of limestone as far as to the argillaceous schists in Barnard marking the western limit of the formation. In this area there are two anticlinals and three synclinals, the last joining a faulted fragment. Section VII shows the Coös quartzite, extending as far as the eastern part of Strafford, occupying a place between the clay slate, which usually adjoins the Calciferous, and the Calciferous itself, with a uniform, probably inverted easterly dip. A fault may, perhaps, separate it from the Calciferous, which consists of

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* Vol. ii, p. 617.

an inverted synclinal to the east of Strafford Centre; a normal anticlinal in the west part of the town; a synclinal in South Tunbridge; an anticlinal, followed by a synclinal, beneath argillaceous schist; and an anticlinal again before touching the western band of Cambrian slate at Bethel. On Section VIII there may be a band of Coös rocks in Newbury, consisting of argillaceous seams much twisted and devoid of limestone, in a possible anticlinal aspect. The Calciferous group succeeding is mostly limestone; and four or five duplications may be made out in it before coming to the central hill in Washington, where we find a very low easterly dip of massive limestones. These supposed duplications are monoclinal, with various degrees of dip. From this central range the dips are all westerly to the slates of Northfield, with certainly indications of three axes, occasioned by different inclinations of the strata. As originally published, this section seemed to be one gigantic anticlinal; but our repeated observations indicate the existence of several closely pressed folds upon both sides of the centre, and this middle point may be the newest part of the formation. Sections V–VIII were carefully resurveyed by me in 1875, and hence are understood in greater detail than before.

Section IX loses its central hill of limestone, and its place is taken by an enormous mass of granite, perhaps erupted in a period subsequent to the deposition of the limestone. On the west side of it is a satisfactory synclinal overturn at its junction with the western band of Huronian. On the east the dips are monoclinal, probably all overturned to the east. Section X is more singular still. Most of the area is a high table-land of limestone, the recurrence of the Washington ridge; and at both sides there is a narrow synclinal, closely pressed and adjoining Cambrian slates. Section XI shows the central plateau, disturbed and broken in two by eruptive granite. On the east the inclination is gentle towards the rising sun; and at East Burke the crowding westerly of the older rocks has inverted the limestones to dip high to the west, and thus show a synclinal basin. West of the granite are two regularly formed basins, separated by a symmetrical anticlinal. This is succeeded by a smaller portion of the schist caught in eruptive granite adjacent to the Cambrian slates. Section XII gives us an anticlinal in Brighton, elevated apparently by an upward push of granite. It joins an older granite directly on the east side, as the slates usually bordering it farther south have disappeared. West of this anticlinal there is another mass of granite, which seems to mark a fold in the Calciferous. To the westward the dip is altogether westerly; and three or four supposed overturn synclinals appear there. The dips in Section XIII, naturally protracted, give us the fan-shaped structure, which may be easily resolved into a double synclinal basin. The synclinal form appears yet more distinctly after passing into Canada. I do not present any diagram in the text to illustrate these sections, hoping that the way may be opened to publish in the Atlas the entire group of them as they cross the two states of Vermont and New Hampshire. Their publication is not authorized at the time of writing this brief notice of them.

In brief, all the sections across this Calciferous formation can be best interpreted by constructing them upon the theory of their more recent age than the adjoining bands of Huronian,—one, in the Connecticut valley, and the other, skirting the east base of the Green Mountains. This is also the position assigned to the continuation of the limestones into Canada by Sir W. E. Logan. He did not speak so clearly of the clay slate band, not separating it from the limestone, and calling them both by the indeterminate name of Gaspè. If the first position assumed is sound, that the limestone or Calciferous overlies the Huronian, then it will easily follow that the slates will come between them in age, as they do in territorial distribution, and are to be called Cambrian. Another view might be taken of the westerly band. It might be considered as a narrow, closely pressed Helderberg synclinal, inasmuch as Upper Helderberg fossils occur in somewhat similar layers on their course at Lake Memphremagog. It would be better to say that the band belongs to the Cambrian series; but in Helderberg times, when this entire northern region was submerged, there was a subsequent slaty deposit of that later age directly over and derived by disintegration from the Cambrian. The same supposition may be extended to the eastern band, as all observers so far have agreed that this series underlies the Bernardston Helderberg. These slates make up the mass of West mountain, situated to the west of the village, underlying the Helderberg limestones.

7. The Ascutney Area.

Mt. Ascutney is the highest mountain immediately adjoining the Connecticut river in any part of its course. The nearest one to it is Bowback, in Stratford, which falls short of it about two hundred feet. Ascutney is also more conspicuous than any other mountain near the river, since it rises from a lower plain. It is essentially a cone, nearly three thousand feet higher than the river at its eastern base, only three miles distant; and there is a small subordinate cone on the west. The principal cone is composed of eruptive granitic material. The smaller mountain is in part eruptive, but is mainly made up of gneiss of Eozoic times, probably older than Montalban. The larger mountain rises from a fissure cutting directly across the Calciferous mica schist, indurating but not greatly disarranging the course of the strata.

Our map shows a strip of gneiss in Vermont, extending from Marlboro', or Athens, to Hartland. This has a narrow band of hornblende schist upon both sides of it. We should have been glad to study it carefully, but it lies outside of our field of labor. It is thought to agree with the gneiss of our Lake period, while some parts of it resemble the Montalban. Its environment by the hornblende suggests its equivalency with the Bethlehem group of Cheshire county, where a similar concentricity is displayed. Upon Section V we find a very distinct anticlinal in the south part of Reading, just west of Little Ascutney. It is our theory that that range of gneiss is a repetition of the Green Mountain rock, and that both are older than the intermediate Huronian. The Ascutney rocks are situated on the east side of the northern part of this ancient gneissic range; and the eruptive portions cut across both this older rock and the adjacent Calciferous mica schist. A careful delineation of the boundary between these two formations, upon both sides of the eruptive mass, indicates the course to be the same, and to have been continuous before the eruption. The erupted materials came from an east and west rent in the strata; and, in consequence of the abundant liberation of heat at the time of their protrusion, the character of the limestone and other rocks adjacent to it has been changed.

There is reason to believe the nucleus of Little Ascutney belongs to a period distinct from either the Lake gneiss or the eruptive age. There is a conglomerate upon its summit, associated with porphyry, both of which are unlike anything in the neighborhood, while slightly similar to certain ledges in the White Mountain district. The phenomena upon this mountain have been described in the Vermont report (vol. ii, pp. 565, 624) as illustrations of the alteration of conglomerate into porphyry and granite. It is stated that

On the top, just where the southern slope begins, masses of a conglomerate of a decided character, several feet and even rods wide, appear on the side of porphyry and granite. All traces of stratification in the conglomerate are lost, and it passes, first, into an imperfect porphyry, and this into granite, without hornblende, in the same continuous mass, without any kind of a divisional plane between them. Where the conglomerate is least altered, it is made up almost entirely of quartz pebbles and a larger amount of laminated grits and slate, the fragments rounded somewhat, and the cement in small quantity. It is easy to see that a metamorphosis has taken place in all the conglomerates, and some of the pebbles might even be called mica schist. In the cement, also, we sometimes see facets of feldspar. In short, it is easy to believe that the process of change need only to be carried further to produce sienite, porphyry, or granite. One cannot resist the conviction that the granite rocks of this mountain are nothing more than conglomerate melted down and crystallized, or, at least, that such was the origin of a part of them. [Page 566.]

The basis of this theory rests largely upon the supposition that these three kinds of rock occur along the line of strike. A revisit to the locality in 1872 shows that these three sorts of rock occupy different layers, the strike being N. 80° W., or nearly at right angles to the course common in the neighborhood. The ledge exposure showing them all is continuous. I do not see why the change in the direction of the strike should have been overlooked in 1858. The fact of this change in the strike, together with a variation in the nature of the rock matérial, suggests whether we have not here the relic of a different formation, resting upon the gneiss. We shall see presently that it extends farther east than the gneiss, bordering the granite of the larger mountain. Little Ascutney has two peaks. The more northerly one is close by Mill river in West Windsor; the other, which is higher, is in Weathersfield, overlooking Black river. I will describe the rocks as they occur on a line from about the house of Mrs. T. Piper in Weathersfield,—the southern foot of the mountain,—over the two peaks towards Brownsville in West Windsor. The south slope is quite steep, and furnishes several outcrops of ancient crystalline gneiss. Near the road the dip is 60° N. 52° W.; forty rods north, it is 25° N.; fifty rods, 40° S. 50° E.; seventy rods, 45° S. 58° E. Next to the conglomerate the gneiss dips 25° N. 70° E. The conglomerate dips N. 10° E., perhaps 50°. The pebbles consist of gneiss, hornblendic gneiss, greenish quartzite, hard mica schist, compact feldspar, and transparent quartz. Most of these are readily referable to the gneiss near by for their origin. The greenish quartzites may have come from the Huronian. The cement is feldspathic; but there is nothing, so far as examined, that appears to have been derived from the Calciferous. Next occurs felsite, in a variety of aspects. One is that of a dark, compact variety, with whitish dots, showing pebbles only where it is weathered. Another has a slightly trachytic aspect, of gray color, having crystalline bunches scattered through a fine-grained paste sprinkled or peppered with small black grains. Other portions have black hornblendic fragments disseminated through them. Both these varieties contain crystalline bunches, having one mineral inside of another. I have specimens of hornstone from this vicinity, but do not remember how abundant it may be. Between the two peaks the ledges are chiefly common and hornblendic granites. There is a junction of granite with a ferruginous rock at the summit of the more northern peak, the line of union running north and south. In the road between the two Ascutneys the rock is mostly sienitic. Following the lower edge of the sienite easterly, we find a narrow band of gneiss extending beyond the point where the west line of the mica schist would naturally pass. I should judge this might extend three quarters of a mile east of the natural boundary line. The gneiss to the east and south of Little Ascutney dips to the east. The edge between the sienite and gneiss is quite irregular on the north and west sides.

The union of the sienite of the larger mountain with the calcareous rocks is full of interest. The phenomena clearly establish the fact that the limestones change their character in approaching the sienite, and that their strike is not affected essentially. The strata dip at a very high angle to the east, and cease abruptly on reaching the granitic rock. It follows, that the granitic rock has been protruded through a fissure in the Calciferous mica schist, and the accompanying heat and other agencies have indurated the limestones, perhaps inducing in them the formation of crystals of scapolite. The resultant rock rings like metal when struck with a hammer. The width of the space between the two walls of schist is two miles. The length of the rent,—that is, of the erupted mass,—is five and one third miles. The direction is a little south of east. It is very possible that a portion of the rock removed from this enormous gap may have been absorbed or melted by the sienite; but most of the opening must have originated from the forcible rending apart of the strata. The edges of the schist next the sienite, wherever favorably exposed for observation, show enormous granitic veins of a fine-grained variety branching out from the larger mass of sienite. One is reminded of the corresponding phenomena described upon Mt. Webster (p. 175). It is interesting to know that these branching veins are usually finer grained than the masses from which they proceed.

In a small valley on the north-west side of the mountain, opening towards Brownsville, the limestones dip 75° S. 80° E., and abut vertically against the sienite. Similar facts were observed in a valley on the south-west side, the dip of the strata being 44° N. 50° E. In the precipice here may be seen a granite vein sixty feet high and ten rods wide. In another valley farther east the limestone and granite join each other along a vertical line.

Along the path up the north-east side we find the indurated calcareous slate, about five hundred feet above the place of leaving the carriage-road, dipping 40° E. The texture of the sienite up this path is usually somewhat coarse, the crystalline *débris* resembling gravel. The masses are not so coarse, however, as those of the Conway granite in the White Mountain district. On the very summit the hornblende is scanty, quartz is wanting, and the rock is mostly a fine-grained crystalline felsite. The rock of the mountain almost always carries some mica, so that hand specimens may be procured of genuine granite. Of other granitic rocks in our field of labor, the Chocorua aggregate is the most like that of Ascutney. The conglomerate of the smaller mountain might be compared with the Franconia breccia.

Our final conclusion from the above facts, respecting the age of the mountain, is, that there must have been an Eozoic foundation for it before the production of the limestones, a hill branching off from the great gneissic range to the west. Subsequently the Calciferous mica schist covered up the first formed hummocks. Still later, the force elevating the calcareous schists showed itself; and, perhaps in conjunction with it, came the outburst of sienite constituting the principal mass of the two mountains. This was the proper epoch of the eruption of this mountain mass. In this respect it agrees with the supposed age of such mountains as Pequawket, and perhaps the whole series of elevations composed of Chocorua granite.

In the *Geology of Vermont* (vol. i, p. 225) my father presents the theory that the adjacent mica schists must once have existed upon both sides of the erupted mass of Mt. Ascutney, at least to equal it in height. If the sienite were once in a melted condition, it would require walls of schistose rock to keep it in place, and thus prevent its flowage over the surrounding county. He presented this theory in order to illustrate the fact of enormous erosions by atmospheric agents along the Connecticut valley. Other authors would not say this granitic rock had been melted, like lava, but that it was formed under a pressure equal to ten thousand or twelve thousand feet of strata. According to either view, the argument for an enormous amount of erosion would hold good.

We have been unable as yet to prepare our usual "specimen map" of this second section of the Connecticut valley, together with a catalogue of the rocks obtained for the museum, upon which our descriptions are based. Should the map and catalogue be presented, they will be found, with the corresponding descriptions of the two southern sections of the Connecticut valley, at the close of this chapter.

GEOLOGY OF THE CONNECTICUT VALLEY BETWEEN CLAREMONT AND HINSDALE, INCLUDING THE COÖS QUARTZITE ON THE EASTERN BORDER OF THE MERRIMACK TOPOGRAPHICAL DISTRICT.

BY J. H. HUNTINGTON.

General Features.

While in general the hills approach very near the river, there are localities where broad meadows extend for a considerable distance on either side. Usually, however, where an interval is found on one side of the river, on the side opposite the hills are often abrupt and near the river, but very frequently it is the case that the hills are very near on both sides; and thus we have the varying scenery that is the charm of the Connecticut valley.

Just below North Charlestown the quartzite hills approach the river on both sides. Rattlesnake hill, with its nearly vertical quartzite, and opposite in Springfield the same rock on Skitchawang mountain, forms a high, precipitous bluff. East of the road south of Rattlesnake hill the country rises quite abruptly into a high, plateau-like area, then descends into the valley of Winter brook, but rises immediately on the east border of Charlestown into Perry mountain. South of Beaver brook we have in part a terrace plain, but this is broken by the quartzite ridge of Oak hill, which is cut by Mill brook, and then rises again in the ridge directly east of the village of Charlestown. To the south-east there is no marked elevated area, except Sam's hill. Going east from the village there is a gradual rise until the country reaches the general height of 1300 feet in Acworth. In Vermont, west of Charlestown, the country is elevated and broken. Between Charlestown village and South Charlestown the meadows extend a considerable distance from the river; but the hills approach the river again, and Kilburn peak rises abruptly opposite Bellows Falls.

From Bellows Falls to Brattleboro' the valley is narrower than it is either north or south; and, since the sides of the valley are abrupt, the terraces extend only a short distance from the river. South of Kilburn peak the country rises from the river in broken, undulating ridges; those on the east side increase in height southward until they culminate in

Mt. Wantastiquit, opposite Brattleboro'. Southward the valley is much broader, but still it is bordered by high ridges, those in Vermont being near the river. So far as the general features of the country are concerned, they differ very little, as the rocks change. Skitchawaug mountain is quartz-conglomerate. Kilburn peak is gneiss, and Wantastiquit is mostly argillaceous schist or slate; yet Skitchawaug, as seen from the west, differs very little from Kilburn peak as seen from the east, or Wantastiquit as seen from the same direction. The area of country in which the rocks are here described begins with the north lines of Charlestown and Unity, and extends southward to Hinsdale. The line limiting it on the east runs a few rods east of Unity Centre, and southward just east of Acworth Centre, through Alstead, diagonally, the south-east part of Walpole, and through Westmoreland and Chesterfield. The gneiss of Kilburn peak is an island surrounded by newer rocks. In Westmoreland the east line extends westward nearly to the Connecticut, but in Chesterfield it turns eastward to a point east of Factoryville, whence it extends southward to the state line. The rocks in Vermont immediately along the river will also be noticed.

The rocks belong chiefly to the Coös group, but, considering the large extent of country, there are not many different kinds. Besides the rocks of the Coös group, we have a few that belong to the older formations. The following is the order in which the rocks occur, beginning with the lowest: 1. Bethlehem gneiss. 2. Gneisses of the Montalban series. 3. Huronian. 4. Coös quartzites. 5. Coös slates and schists. 6. Calciferous mica schist. 7. Eruptive granite.

1. Bethlehem Gneiss.

The Bethlehem gneiss does not differ essentially from that found in the northern part of the state. The feldspar is generally flesh-colored, and it contains a greenish mineral, probably chlorite, while associated with it here and in places in the topographical area east there is a very marked band of quartz. The principal outcrop is on Quimby hill in Unity, though it extends across the valley west, and appears on the eastern slope of the hill near E. T. Bailey's, and connects with that in the east part of Claremont. It can be seen in the south-west part of the town, near M. Johnson's, and it is probably continuous from Quimby hill southward to this point. It resembles in shape the areas in Hanover and Lyme, and, like that in the latter town, it is surrounded by newer rocks.

2. Montalban Series.

The rocks that appear to belong to this series are found in the south-west part of Charlestown and in the north-west part of Walpole. In some localities we have a gneiss that resembles the common or Lake gneiss, but still it is not identical with it, while elsewhere the rocks cannot be distinguished from those we have referred to the Montalban series. If the whole of the rocks of this area do not belong to the latter series, the more compact variety of gneiss being the lower division, it would naturally be classed with the Lake gneiss,—yet I suppose they all belong to the Montalban series. Like many other outcrops of rock in the state, it is a somewhat oblong area, nearly as wide as it is long, and presents rounded contours, both in its northern and southern prolongations, though it is more abrupt on the south than on the north. It begins in the hills north-east of South Charlestown, and widens so that opposite Langdon Centre it extends over a space of two and three fourths miles; but in it there is included a band of hornblende gneiss. From its outcrop on Saxton's river to Paper Mill Village, it is not far from ten miles in width. It has its southern limit about a mile and a half south of Drewsville. The rock varies considerably in texture. Along its northern border, on the west to its southern outcrop on Saxton's river, through Langdon, and at Paper Mill Village, we find the variety that is coarser in texture, and it is like some of the common or Lake gneiss of the Atlantic system. This rock, however, at the falls carries fibrolite, which is unknown in the common gneiss. Going from South Charlestown towards the south-east, through the pastures that slope to the north, there are many ledges of the gneiss that have segregated veins; and in the coarse we find a band two feet wide of the finer variety, like that at Cold River bridge.

The points where this rock comes in contact with those that surround it are all concealed by drift. At Langdon Centre we have the gneiss at the school-house, and a mica schist in front of the church. The gneiss has an easterly and the schist a westerly dip, showing clearly their unconformability. At Bellows Falls, in the gneiss beside the fibrolite, there are wavelite and prehnite. At Drewsville, in the river above the bridge, there are small but very fine crystals of prehnite in narrow veins in the gneiss. The following figures show the dip of the gneiss to be exceedingly variable: East of J. Milliken's, Charlestown, S. 50° E. 64°; at E. Osgood's, S. 36° W. 50°; at B. Sartwell's, E. 25°. On Porter hill, Langdon, S. 45° W. 30°. At grist-mill in Alstead (Paper Mill Village), S. 70° W. 24°; below Paper Mill Village, N. 23° W. 24°; at J. Chandler's, N. 40° E. 45°. In Drewsville, N. 30° E.—variable; in Walpole, at the mouth of Mountain brook, N. 12° E. 38°; at Cold River bridge, N. 35°; between Cold River Bridge and Bellows Falls, E. 35° to 60°; at Bellows Falls, by railroad bridge, N. 50° W. 62°.

3. Huronian Rocks.

These rocks, if they appear in this area, are very limited in extent. In Vermont, however, opposite Charlestown, we find a few that undoubtedly belong to this group. They begin on the west side of Skitchawaug mountain, and south of the Black river they probably extend to the Connecticut, and form a narrow band along the river to a point just south of Saxton's river. The band probably turns to the east and extends around the Montalban gneiss, since there is a limited outcrop in Walpole on the railroad some eighty rods south of Cold River bridge. The first outcrop west of the Cheshire bridge is a greenish chloritic schist, with the strata nearly vertical; but south in Rockingham we also have dark siliceous schists, and these are the prevailing rocks immediately west of Bellows Falls. In the north-east corner of Westminster, on Saxton's river where there were formerly some mills, the rocks are probably Huronian. On the hill half a mile south-east of this we have hard siliceous schists, and with these there is a peculiar breccia. This is probably near the southern limit of the Huronian rocks in this section of Vermont.

Nearly opposite this point in Walpole we have a dark siliceous schist, with a northerly dip; but where the rock is cut by the railroad south of Cold River bridge we have a distinct conglomerate. These rocks are very limited, and are the only ones that we have referred to the Huronian.

4. The Coös Quartzites.

These rocks pass on the one hand into quartz-schists, and on the other into quartz-conglomerates. The chief constituents of the latter are quartz and quartzite pebbles, from those that are very small to those that are a foot or more in their longest diameter. In some places the pebbles are very distinct, while elsewhere it requires weathering to show that the rock is not a common quartzite. Although in a very few places the pebbles are nearly round, there are many localities where they are oblong, and sometimes they appear to be elongated and bent. In the north part of Springfield, Vt., on Rattlesnake hill, there are a few argillaceous pebbles, probably derived from the Cambrian slates.

In this area there are two distinct bands of the Coös quartzites. One is in the immediate valley of the Connecticut; the other is to the east in Unity, and is an extension southward of the main band that has its origin in Landaff.

The Western Band.

The most northern outcrop of the quartz-conglomerate in the section we are describing is on Rattlesnake hill in Springfield, Vt., and here it appears to be an isolated area. It is composed chiefly of flattened quartz pebbles. There are, besides, a few fragments of slate; and the strata dip east at a high angle. The rock on both sides is calciferous mica schist. South along the Connecticut river the Skitchawaug mountain, extending from the first school-house in Springfield almost to the Cheshire bridge, is also a quartz conglomerate, and the strata have a high easterly dip. At one point it is probably continuous to the second road running parallel with the Connecticut, as it outcrops immediately east of the road near J. D. Chase's. In some places the rock has the character of an indurated schist, and the pebbles can scarcely be recognized, but elsewhere they are very distinct. In Charlestown the most northern point where the rock was seen is Rattlesnake hill; and on top of this hill the pebbles are almost altogether quartz and quartzite. The largest are from four to five inches in diameter; but descending to the railroad the pebbles disappear, and the rock has the character of many of the quartzites. The rock has a high westerly dip. Thus, with rocks opposite, we have a distinct synclinal axis.

The next outcrop southward is on the ridge extending northward from Oak hill, where it contains pebbles, and encloses many large fragments of the argillaceous staurolite schist so extensively developed to the east in Charlestown. South of the summit of Oak hill it turns eastward, and crosses the road just north of the grist-mill. Here it turns to the south again, and crosses the road running east from the grist-mill near H. Hall's; thence extending south it forms the summit of the hill directly east of the village of Charlestown, but at the south end of this hill it very suddenly disappears. Towards the south part of the town, and on a ridge south-east of school No. 1, we have probably the same band of rocks. The band comes to the road near A. Powers's, and it extends north-east towards H. Hull's, Jr.; but the band of quartz schist that extends along the road north of Hull's does not so clearly belong to this group of rocks.

The Eastern Band.

The ridge of Perry mountain is in part quartzite; but there is a large proportion of quartz, which is intrusive with other rocks. At the first cemetery west of Unity Centre there is a band of quartzite which extends through the town. South it runs nearly parallel with the road, and extends into Acworth; northward it crosses the road near P. Smith's, and outcrops between J. Lufkin's and Mason Huntoon's, but probably disappears beneath the mica schist before it reaches Newport. South of Unity Centre and east of A. C. Sleeper's there is an outcrop of quartzite, but it is very limited. On the road from Unity Centre to Gladden hill, just east of the stream near school No. 3, there is another band of quartzite; also directly south, at the forks of the two branches of Little Sugar river, there is quite an extensive outcrop. An extension of this band can be seen on the east of the road going south from this point towards Acworth.

Acworth. In this town the last-mentioned band of quartzite crosses the road going up the hill south of K. Smith's. Just south of William Putnam's, on both sides of the road, quartzite is largely developed. Half a mile south of Putnam's it is on the east side of the road only, and farther south it has not been traced, unless the small outcrop that crosses the road running north-east from Acworth Centre is a continuation. In the west part of Acworth, extending along the border of the town, there are several areas of singular shape. In the north-west corner there is an extension southward of Perry mountain. Near J. Grant's it crosses the road, and on the south it terminates in an abrupt hill, the strike pointing down a deep valley towards the south-west. The most remarkable area is at Z. Slader's, where it is circular in form; and the strike conforms to the shape of the hill as though there had been a doubling up of the whole mass. The surrounding argillaceous rock also shows great disturbance.

On the road up Stebbins brook at the first there is an extensive outcrop. It runs a little south of east, and appears on the road at T. Duncan's. Here it turns south, and can be traced for three fourths of a mile, but it outcrops on Cold river in Langdon a quarter of a mile from the line of Acworth.

Charlestown. In the eastern part of Charlestown we have Sam's hill, which, on the west, is largely a quartz conglomerate. It is an immense triangular area, sending an arm north-westerly, which crosses the road at the height of land near William Rupp's; another arm goes south-east, extends into Langdon, and outcrops near E. Baldwin's. The west point of Sam's hill is a distinct conglomerate; but the arms north-east and south-east are generally like the quartzites elsewhere. But in its extension northward, after it crosses the road near William Rupp's, where it disappears beneath the argillaceous schist, it shows pebbles on the weathered surface.

Alstead, and southward. On the south-west extremity of Cobb's hill there is a limited area of quartzite, in which the joints are not so marked as elsewhere. In the west part of the town, a quarter of a mile south of A. Alden's, there is another small area with well-marked joints. In Walpole the quartzite can be seen in the central part of the town, on the road from where the old church stood east to Fisher brook. On the road that crosses Sugar brook, where it turns to the south, there is a quartz conglomerate, and some of the pebbles are a foot in length. From the general section, it will be seen that the quartzite is unconformable with the mica schist, both on the east and west. In the south-east part of the town, on a small stream a few rods north-west of Asa Gilbert's, we find quite an extensive outcrop of quartzite; and this may be an outlier of that which is so extensively developed in Westmoreland. Although there are many outcrops of quartzite in Westmoreland, the most extensive is south-east of Granger's mill and just east of a road now practically discontinued. The strata dip nearly north-west, generally about 15°; and, what is rather uncommon, we have in it great veins of quartz. On the south-east there is a narrow band of wrinkled argillaceous schist; and on the north-west a similar rock that extends to Westmoreland depot. This wrinkled schist probably entirely surrounds the quartzite, and rests on its edges. Just above Granger's mill, in the stream, we have the mica schist with staurolite, that is the prevailing schist of Unity and Acworth. Here, with strata nearly horizontal, it lies on the quartzite. The rock that outcrops on the road near Westmoreland village seems rather to belong to some of the lower formations, though it has in its jointing and cleavage some resemblances to the Coös quartzite. On the road now discontinued, that runs east from the Hill Village, we find quartzite dipping directly north. Near Wm. Starkey's the quartz schist probably belongs to the quartzite band, and, with varying texture, extends south-west to the town line. A rock that resembles it very closely is found at the molybdenite mine; but a typical variety of the quartzite is found south-west of the mine near T. Dunham's, in the corner of Chesterfield. South-east of Dunham's, near T. Briggs's, we have a band of whitish quartz schist, which resembles that at Starkey's.

South-east of Factoryville in Chesterfield, perhaps a hundred rods from the church, there is a marked outcrop of quartzite. While most of the rock is like ordinary quartzite, where the rounded grains appear to be imbedded in a purely siliceous, glossy-looking cement, there are masses of the rock here in which the cementing material is almost altogether wanting, and the rock is really a white, friable sandstone. A few dark-shaded lines running through it give to the rock the appearance of limestone; and it was thought to be marble by the country people who had seen it. At school No. 12, south of Spofford lake, a narrow band of quartzite extends southward nearly a fourth of a mile. West of the lake, on the hill north of William Bennett's, the quartzite appears, and probably extends southward, as it crosses the road half a mile west of the Lake house; and on the road from the lake to Chesterfield it can be seen on the west of the road. In the south-west part of the town, near a sawmill, we have probably the extension northward of the quartzite so extensively developed on the mountains southward. South of the Brattleboro' bridge the quartzite is just opposite E. S. Horton's, and on the side of the mountain north it has been quarried; the stratification and jointed structure of the rock enable the workmen to break it into fragments suitable for building-stones. It is quite probable that the strata are here inverted. A more extended notice of this quartzite, in its extension to the south, will be found elsewhere.

The dip of the quartzite is as follows:

Charlestown.

At H. Hall's, S. 75° E. 35°.

On Sam's hill, N. 40° W. 40°.

On hill east of Charlestown village, N. 80° E. 15°.

North of Hull's, Jr., N. 30° W. 18°.

On Rattlesnake hill, 38° W. 40° to 70° N.

On Skitchawaug mountain, east side, N. 70° E. 76°.

Unity.

At P. Smith, S. 50° E. 20°.

West of H. Smith's, S. 80° E. 20°.

At cemetery west of Unity Centre, N. 80° E. 25°.

Near Mrs. McClure's, S. 30° E. 38°.

Acworth.

At J. H. Howe's, S. 30° E. 12°.

At K. Smith's, S. 50° E. 20°.

At J. Grant's, probably horizontal.

At T. Duncan's, S. 75° E. 58°.

South-east of N. Hayward's, N. 60° W. 20°.

At Wm. Putnam's, S. and S. 10° W. 28°.

At Z. Slader's, N. 22° and N. 50° E. 24°.

Near L. R. Hardy's, probably north.

At T. & J. F. Murdough's, N. 20° W. 25°.

Chesterfield.

North of Wm. Bennett's, S. 80° W. 30°.

East of Factoryville, S. 10° E. 15°, and S. 10° W. 62°.

West of Lake house, N. 80° W. 35°.

On mountain north-west of H. Streeter's, S. 70° E. 50°.

Westmoreland.

At Westmoreland village, vertical.

Near Mrs. Carlisle's, N. 40° W. 25°.

At A. B. Cole's, vertical.

At J. Cowdrey's, N. 70° W. 20°.

Quartzite on the Border of the Gneissic Rock of the Merrimack Valley District.

The band of quartzite that is so persistent along the eastern border of the Coös rocks of the Connecticut valley, and is sometimes found in irregular, detached areas associated with the gneiss, has its most northern outcrop in Landaff. It is usually a compact, fine-grained, and distinctly granular rock, very hard, often brittle, and is frequently, especially to the southward, divided by numerous joints, which cause it to split into fragments more or less rhomboidal. The typical varieties, when examined by a lens, seem to be made of grains of quartz imbedded in a siliceous cement; but they are found to pass, on the one hand, through a quartzose mica schist into a genuine mica schist, and, on the other, into quartz conglomerate. When the mica becomes quite apparent in the rock, we shall designate it as quartz schist, otherwise, quartzite, or, where pebbles are present, quartz conglomerate. Here, as in many places elsewhere, it consists of a narrow, interrupted band. It is first seen near the forks of the road at O. Bronson's, and south at W. Hunt's. It is unconformable with the gneiss on the south-east, and with schist on the north-west. It is found in the south-west part of the town, on the road, now practically discontinued, that runs south from Landaff village. The road passes over it on the hill south of J. Clough's. We have gneiss here on both sides of the quartzite, though unconformable, but both dip westerly. The strike of the rock would take it near the outcrop at Bronson's. To the south it keeps on the east of the road, but crosses it about half a mile north of D. N. Page's, and an eighth of a mile west of Page's it crosses the road running parallel with the river. Here the strike is somewhat variable; it has a fine-grained gneiss on the east, and a coarser variety on the west. A characteristic of this band is the low dip of the strata. It rarely exceeds twenty degrees. West, near Mrs. Grant's, there are isolated bands of quartzite that dip north.

In the east part of Benton there is one of the most extensive outcrops of quartzite that we have; and we find here all the varieties,—quartz schist, quartzite, and quartz conglomerate. It first appears south of D. Howe's, and it may be a continuation southward of the band that outcrops on the north side of the Wild Ammonoosuc in Landaff. In shape, this area, as a whole, in Benton and its extension into Haverhill, is peculiar to this rock. The strata seem to have been doubled up and bent on themselves; and where the great fold occurs it forms the ridge and summit of Black mountain. From Howe's the strike is southward; on the ridge more to the west, and on the summit of Black mountain, and on the ridge west where it has its greatest thickness, it is almost directly east and west. It differs from the area north in the greater inclination of the strata.

Near D. Howe's, east of the quartzite, we have a hornblende gneiss, with nodules of epidote; and east of this is the common gneiss. On the west of the quartzite we have gneiss, the strata of which are nearly vertical; and the inclination of the strata of the gneiss on the east is greater than that of the quartzite, though all the rocks may have a westerly dip. The quartzite extends southward along the ridge of Sugar Loaf mountain, and is followed both on the south and west by protogene gneiss. Near the summit of Black mountain, and on its southern slope, is a greenish chloritic and micaceous schist. At an old mill between Black mountain and Sugar Loaf is a conglomerate composed chiefly of quartz, quartzite, and pebbles of a whitish indurated schist. Where the quartzite outcrops in Haverhill, on the road north of Mrs. S. Tenney's, it is associated with hornblende schist, as is also the mica schist on the south side of Black mountain. On both sides of the quartzite in Haverhill we have protogene gneiss; and it suddenly terminates here, unless it forms a transition state into the arenaceous whetstone slate near E. Dean's.

In Piermont, quartzite is found in the east part of the town; and in the north part, where it is crossed by the section, we find gneiss; on the east and on the west, wrinkled mica schist, that carries staurolite, hornblende and mica schists. Farther south, on Piermont mountain, there is protogene gneiss on both sides of the quartzite; and there seems to be the same doubling of the strata that we find in Benton. As it extends south and passes into Orford, a short distance east of where the road crosses the town line, south-west of the mountain, the rock is a quartz schist. Near the house of P. C. Savage, in Orford, it is a quartzose mica schist; and it seems to be the case, nearly everywhere that this band thins out, that it forms a transition state into mica schist. In the north-east corner of Dorchester, between McCutchins pond and the summit of Smart's mountain, a band of quartzite has been traced. Whether it is connected with that to the west of E. Lamprey's we have not been able to determine, though, from the many isolated bands elsewhere, it is not improbable that this may be. The rock on both the east and west sides of the summit of Smart's mountain is a friable, tender gneiss; and it has the protogene gneiss on the west and the Lake gneiss on the east. The unconformability of this band of friable gneiss with the other gneiss will be shown when we come to speak of the common gneiss.

The quartzites, quartz schists, and quartz conglomerates of Gilsum, Surry, and Keene are among the most interesting of any we have examined, but they require a much more careful study than we have been able to give them, to understand fully their relations to the other rocks. Then there is the quartz of Mine ledge, that extends south into Westmoreland and Keene, and though with the protogene gneiss it sometimes forms a breccia, yet it is entirely unlike the quartzites and quartz conglomerates. The quartzites here do not differ essentially from those in the topographical district of the Connecticut valley. Graphite, however, has been found here, though nowhere else in the quartzites; and the associated rocks are quite different from those found elsewhere. Among the questions that arise, is the relative age of the quartzite and quartz schist, as compared with that of the quartz conglomerate. There are many reasons for supposing that the latter are the most recent of all the rocks in this section of the state. The most easterly band of these quartzose rocks has its northern outcrop a quarter of a mile north-east of the Fish place in Gilsum. The strata here have been much disturbed, though the general strike is east and west, and the dip south. About half a mile south the dip is S. 22° E. 20°. Not far from M. T. Wilcox's, the strata seem to have been little disturbed. The outcrops extend half a mile nearly parallel with the road; and the strike is almost directly north and south, while there is a slight westerly dip. Alongside of a small stream there is a fine opportunity for examining the strata, which here contain flattened pebbles. This rock is cut off on the north by a coarse intrusive granite. We have not been able to trace it south, as the valley across which the strike would carry it is covered by drift. But in Keene, on the west side of Beech hill, we find a quartz schist, also on the hill a little east of south from the station at South Keene. On Surry mountain the general strike of the Montalban gneisses is nearly north and south; but on the south end of the mountain, about half a mile north of the Austin place, we find a band of quartz conglomerate apparently resting on the contorted strata of the gneisses. It extends north-east, and is found on the hill just back of J. B. Elliott's in Gilsum, and also just west of O. McCoy's, about twenty rods from the road. The pebbles are from an inch to more than a foot in diameter, and are generally oblong. This band, running diagonally across the general strike of the rocks of the country, is shown clearly to be the most recent of all the rocks in this section. In the south-west part of Surry, a few rods east of H. Britton's, there is a limited outcrop of quartzite, and it is very near the quartz. In Keene, south of the railroad and on the range of hills known as West mountain, there are apparently two bands of quartzite, though they may be connected at the north end of the mountain. Ascending the mountain from the east, we do not find the hornblende schist that usually succeeds the protogene gneiss; but the quartzite rests on the gneiss, and has a westerly dip of from 15° to 20°. It contains what seems to be flattened pebbles. Resting on the quartzite we find a folded and contorted mica schist, which sometimes carries andalusite. The quartzite bends around as we go towards the north end of the mountain. It has a southerly dip, and is probably connected with the second band of quartzite that we find when we go directly west across the mountain. This second band has a slight dip to the east, thus giving to the quartzite a synclinal structure. The quartzite rests on the protogene gneiss; and the contorted mica schist is included in the quartzite. The two bands of quartzite near the south line of Keene are perhaps a mile apart. The westerly band of quartzite contains graphite, and there is quite a large opening where it was formerly worked. The mica schist near the graphite contains some very pure quartz veins. On the north-east side of the mountain, west of White's, the quartz found in the gneiss was at one time used in the manufacture of glass.

Dip of the Quartzite, Quartz Schist, and Quartz Conglomerate.

Landaff.

40 rods south-west of O. Brownson's, S. 2° E. 20°.

½ mile south of J. Clough's, N. 68° W. 15°.

North of D. N. Page's, N. 50° W. 15°.

⅛ mile west of Page's, N. 70° W. 20°.

Near Mrs. Grant's, N. 10° E. 40°.

Benton.

At D. Howe's, N. 72° W. 40°.

On ridge south of D. Howe's, about half way up, N. 68° W. 50°.

At top of ridge, N. 48° W. 65°.

On summit of Black mountain, N. 5° W. 70°.

At saw-mill north, N. 15° W. 40°.

At west end of Sugar Loaf mountain, N. 10° E. 50°.

Piermont.

At south end of Piermont mountain, N. 22° W. 40°.

Dorchester.

Between McCutchins's and top of Smart's mountain, N. 82° E. 50°.

Enfield.

At Lily pond, N. 80° E. 60°.

At D. L. Smith's, S. 65° E. 48°.

Grantham.

South-west of Sugar Loaf hill, S. 45° E. 80°.

At L. M. Bean's, N. 34° W. 85°.

Opposite Mrs. Chase's, vertical.

Plainfield.

At W. L. Martin's, S. 64° E. 52°.

Newport.

East side of Blueberry ledge, S. 82° E. 50.°

General strike on top of ledges, N. 11° W.; dip easterly.

The dips of the quartzites of Unity and Acworth have been given on page 416.

Gilsum.

Near the Fish place, S. 38° E. 20°, and variable.

At M. F. Wilcox's, N. 82° E. 15°.

Surry.

North of the Austin place, S. 53° E. 40°.

Keene.

On West mountain, S. 36° E. 50°.

Argillaceous and Argillaceous Mica Schists.

There are very few purely argillaceous schists in this area, and those that are found are exceeding variable in texture. In Charlestown the rock is thick-bedded, and is very little broken by joints and cleavage places. In many places it contains staurolite in tessellated crystals like chiastolite. In Westmoreland the rock is decidedly micaceous, and then further south along the Connecticut, opposite Brattleboro', it differs very little from ordinary clay slate.

From North Charlestown the argillaceous schist extends east to the top of Fifield hill in Unity; thence it extends southward through the central part of Charlestown into Langdon, until it is cut off or crowded out by the gneiss. Along the eastern border of this area the strata are frequently nearly vertical and sometimes contorted, as at Wm. Smith's. Both on the east and west, in the vicinity of the quartz conglomerate, the strata are often bent, and generally stand at a high angle. At the height of land on the road from Charlestown to Langdon, the strata are at right angles to the quartzite. But as on the road near Ashbel Hamlin's, where there is neither quartzite nor quartz conglomerate near, the strata are nearly horizontal. On the southern border of the Charlestown area, at L. Fairbanks's, we find the strata again almost vertical. With the quartzite in the west of Acworth, there is a band of argillaceous mica schist that has very much the same relation to quartzite as this in Charlestown. It extends from Z. Slader's south, and is found with the quartzite at T. Duncan's, where the strata are vertical. We have here a repetition of the schist and quartzite of Charlestown.

The area of argillaceous schist in Walpole is quite limited, and lies between Drew mountain and Walpole village. There is, however, an argillaceous mica schist that outcrops in the southern part of the town, west of the Christian church, and extends into Westmoreland. There is also an outcrop below the railroad station, and also at school-house No. 9. Southward in Westminster, along the river at H. P. Farr's, there is an argillaceous mica schist, containing staurolite that undoubtedly belongs with these Coös schists.

The principal rock of the Mount Gilboa area in Westmoreland is an argillaceous mica schist, but the hill south-east of the railroad station is eruptive granite. Immediately north of this the dip of the rock is exceedingly variable, and continues so until we reach the top of the ridge; the rock here is ferruginous, and dips N. 23° to 30°. Following the ridge, which runs north-east, the rock is quite free from iron, and carries staurolite in abundance, and there is very little change in dip. Following the railroad south from the station, after passing the granite, we find in the first cut an excellent place to study the argillaceous schist. At the north end, on the east side, the strata appear to be vertical, but suddenly they become horizontal, and they continue so, with occasional folds and bendings, to the end of the cut. The rock becomes more micaceous to the south, and at the Hill Village it is an argillaceous mica schist. East of the church it is quite ferruginous; it contains a quartz vein and a narrow band of eruptive granite. To the south-east, at Daniel Farr's, there is another narrow band of eruptive granite; and this is succeeded by hornblende schist.

On the road south from school-house No. 9, the rock is a dark mica schist. It is very much wrinkled, and has the general appearance of the argillaceous schists. South, near the town line and close to S. Amidon's, it is unconformable with a quartzite band that is on the west. In Chesterfield the distinction between these rocks and the mica schists is not so marked as in the towns north, but still it is very noticeable even here. The argillaceous mica schist occupies the central part of the town, to the west and south-west of Spofford lake. It outcrops at Capt. C. N. Clark's, C. F. Daniels's, and at many other places. We have given in Fig. 66 a section that shows the argillaceous mica schist in a new relation, from which it appears there has been an inversion of the rocks on the west, bringing up in the axis the quartz schist, and causing the western band of quartzite to rest on the schist. Southward, at the forks of the road near John Harris's and at J. B. Fisk's, there are prominent outcrops. It is the principal rock nearly as far south as A. G. Newton's in Hinsdale, where it is cut off by granite. The argillaceous schist opposite Brattleboro' seems to be rather an outlier of the great band that extends from Vernon northward along the Connecticut. The boundary between this rock and the slate that is sufficiently fissile for roofing, and the boundary between it and the Calciferous mica schist, cannot be readily traced; but perhaps closer study would enable one to do it. The strata of this band are very often nearly vertical. Opposite Brattleboro' the dip is E. from 75° to 80°, but the inclination, as we go east, is less. Going up the river, we find both easterly and westerly dips. In Chesterfield this rock does not extend along the river above Catsbane brook, for here we have a hard siliceous schist that may belong to some older group. This is suggested by the fact that we have at G. T. Dunham's a hornblende schist, which must extend some distance up the river, as it appears above Putney village. The argillaceous schist does not extend more than a mile and three fourths below the Brattleboro' bridge, and here it is succeeded by quartzite. The argillaceous schist in Fig. 67, across Wantastiquit mountain, shows the nearly vertical strata that characterize this rock here and its extension west in Vermont. The exception, as we go east from the crest of the first valley, is probably due to the folds so common in the argillaceous schist northward. On the east it is often vertical, but sometimes it has an easterly and sometimes a westerly dip. In the south part of Winchester, near C. Lyman's, we have a band of argillaceous mica schist, of limited extent, and a quartzite band on the west.

It is difficult to determine with certainty the relation of these argillites to the quartzite, since the strata seem so often to be inverted; but if the argillite of Charlestown is identical with those southward along the river, then it must be more recent than the quartzites, since the immense fragments found in the quartzite must have been folded in from overlying strata. The following dips have been observed:

Charlestown.

At William Smith's, strata nearly vertical and contorted.

At G. Hamlin's, N. 55° W. 50°.

South-west side same hill, N. 35° E. 55°.

Near forks of road east of Miss Wheeler's, N. 55° W.—variable.

¼ mile north-west of J. Gregg's, S. 30° E. 40°.; ¾ mile north-west of J. Gregg's, S. 70° E. 50°.

Near L. Fairbanks's, S. 10° E. 80°.

Near J. Gregg's, S. 50°.

Langdon.

At J. Ball's, S. 80° E. 50°.

Near E. Baldwin's, N. 62° W. 3°.

Acworth.

50 rods west of T. Duncan's, S. 80° E. 53°.

¾ mile south of Z. Slader's, N. 40° W. 64° and variable.

Walpole.

At J. W. Hayward's, N. 50° E. 20°.

At S. W. Griffin's, N. 20° W. 25°.

Near Griffin's, north, E. 58°.

Near forks of road north of Griffin's, N. 80° E. 24°.

60 rods south-west of A. P. Nichols's the strike is N. 68° W.—dip variable. The rock has a tendency to split into longitudinal fragments.

South of Sugar brook, near E. A. Marsh's, N. 8° W. 8°.

South of Westmoreland station, strata very much contorted.

½ mile north-east of the station, N. 11° W. 20°.

½ mile east of Mrs. James Ware's, strata wrinkled, but dip westerly.

Chesterfield.

At C. F. Daniels's, S. 50° E. 30°.

At C. N. Clark's, S. 50° W. 13°.

At Chesterfield village, S. 60° W. 10°.

At S. Waldo's, S. 30° E. 10°.

Near J. C. Hubbard's, strike N. 10° W.; dip both east and west.

Near J. Cobleigh's, S. 45° E. 55°.

At J. B. Rich's, much contorted, and sometimes bent at right angles to the general strike.

At Brattleboro' bridge, N. 70° W. 75°.

On Wantastiquit mountain, N. 40° E. 20°.

Hinsdale.

On Bear hill, south side, vertical, or nearly so, dipping easterly.

Winchester.

Near C. Lyman's, N. 40° W. 42°.

Mica Schist.

The mica schist of this area is characterized by having its strata, as a whole, more nearly horizontal than any of the other rocks. It is often swollen into gentle anticlinal curves, and has corresponding synclinal depressions; but sometimes, where it comes in contact with other rocks, the strata are highly inclined. It rests unconformably, both on the quartzite and the gneiss, at least on the protogene gneiss. In a following chapter on the gneissic area of the Merrimack topographical district, there are several sections across the gneiss, the quartzite, and the schist. The mica schist has generally a thin, laminated structure; it often contains staurolite crystals; cyanite is sometimes found in it, but graphite seems to be limited to the rocks of the preceding groups. Mica schist is more extensively developed in the southern part of the Connecticut valley topographical district than either of the other kind of rocks. It forms a narrow band in the central part of Newport; but where it enters Unity

— SECTIONS IN THE CONNECTICUT VALLEY. —

BY J. H. HUNTINGTON.

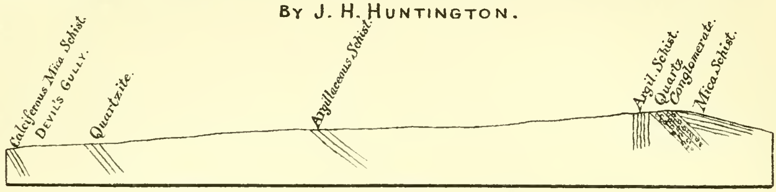

FIG. 64. FROM THE DEVIL'S GULLY, CHARLESTOWN, TO THE HEIGHT OF LAND ON THE LANGDON ROAD.

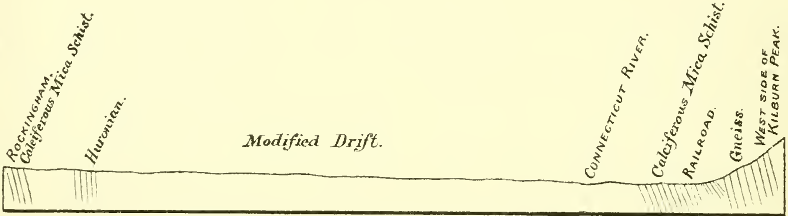

FIG. 65. FROM ROCKINGHAM, VT., TO KILBURN PEAK.

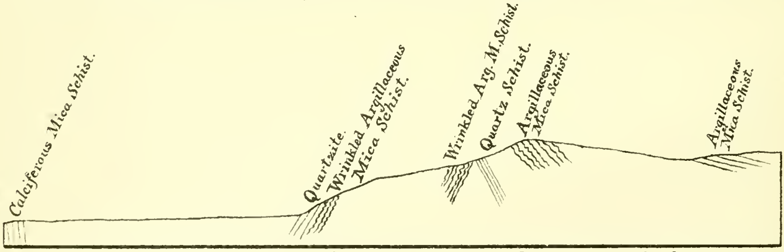

FIG. 66. FROM DANIEL BURNHAM'S, WESTMORELAND, TO CAPT. C. N. CLARK'S, CHESTERFIELD.

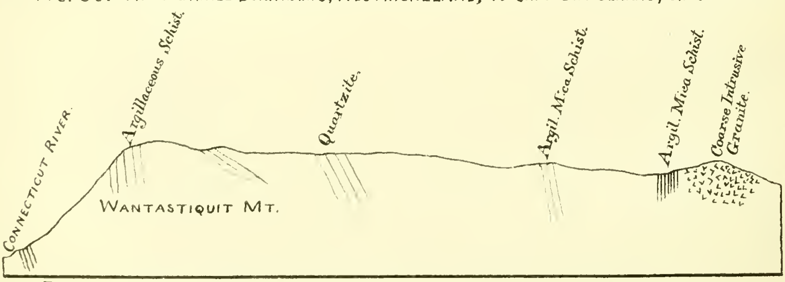

FIG. 67. ACROSS WANTASTIQUIT MT. TO ROAD OVER BEAR HILL.

VERTICAL SCALE, 1500 FEET TO AN INCH.
HORIZONTAL " , 1 MILE " " "

HELIOTYPE

it embraces a section of country several miles in width west of the gneiss. It is developed in its characteristic form in Acworth, and there is a small but important area north and east of Sam's hill in Charlestown. Just north of the Langdon road, at the height of land north of Sam's hill, we see plainly the super-position of the mica schist. In Fig. 64 the relation of the rocks in Charlestown is shown. One thing to be noticed is that the argillaceous schist, where it comes in contact with quartzite, is at right angles to it, and, on account of the argillaceous schist, the quartz conglomerate, and the mica schist dipping in different directions, it does not show the exact relations of these rocks. The strata of argillaceous schist are very much contorted, but the unconformability with the quartz conglomerate is apparent, while the latter runs under the mica schist. The western band of quartzite shown on this section is farther north on Oak hill, vertical, so that probably its normal position, in relation to argillaceous schist and the Calciferous mica schist, is an anticlinal. The common gneiss is on the eastern border of the mica schist, both in Unity and Acworth. In the south-east part of Langdon, and also in the adjoining town of Alstead, there is a mica schist that may be a continuation of that in Charlestown and Acworth. In Langdon it outcrops at the forks of the road, near G. Kingsbury's on Walker's hill, and many other places. At the first locality mentioned it contains andalusite. In Alstead, it is found on the south-west side of Cobb's hill, where it contains cyanite, which, near the surface, has undergone decomposition, so that it has the appearance of mica.

Going towards the south-east, this mica schist appears in Walpole; there are extensive outcrops on the Walpole and Surry road, especially near the height of land, and it is like that of Unity and Acworth, and very frequently it contains staurolite. South-east, in Surry, the strata are nearly horizontal, and, as in the vicinity of school-house No. 4, they rest on the protogene gneiss. The schist in the north-west part of Surry and in the south-east corner of Alstead seems to be rather the argillaceous mica schist than the common mica schist.

In Westmoreland the principal area, and this limited, is found in the south-east part of the town. Here the strata are nearly horizontal; and the rock occupies the top of the hill above L. Hyland's. In a following chapter on the gneissic area of this town, there is a section showing the relation of mica schist to the underlying rocks. East of the Hill Village, and near Fall brook, there is a very narrow band of mica schist between the argillaceous mica schist and the eruptive granite, but it has not been followed either north or south. We have on West mountain, in Keene, very much the same succession of rock as in the east part of Westmoreland. A section (Fig. 80) will be found in the following chapter.

In Chesterfield the mica schist occupies a very irregular area. This is particularly true of its eastern extension. Just west of Factoryville we have a slaty gneiss that dips at a small angle to the south. At the village, in the stream at the Turning shop, there is a quartz breccia, and directly east there is quartzite; then south of this, and on the road running east, we have the mica schist, and its greatest width north and south is not more than two miles. The eastern limit of the principal area is not far from school-house No. 14. There is, however, a narrow band of schist east of the band of protogene gneiss at the forks of the road east of school-house No. 14. South of W. Bingham's the mica schist has a laminated structure, and is very much contorted, but the general dip is southerly. This area is the limit southward of this band of mica schist. The following are some of the dips that have been noted:

Unity.

At forks of road west of P. Smith's, N. 80° E. 30°.

At J. Sleeper's, N. 80° E. 15°.

At A. C. Sleeper's, S. 60° E. 12°, and S. 30° E. 20°.

At O. Sleeper's, S. 68° E. 20°.

At Col. E. J. Glidden's, E. 8°.

At G. Breed's, S. 30° E. 15°.

Acworth.

At Acworth Centre, S. 30° W. 22°.

At G. Gilmore's, N. 40° E. 20°.

At A. J. Straw's, variable and contorted.

Near A. H. Church's, N. 80° E. 14°.

½ mile north of T. & J. T. Murdough's, N. 10° W. 8°.

South-east of N. Haywood's, N. 20° W. 13°.

Walpole.

At R. Leonard's, strata nearly horizontal.

Chesterfield.

East of Factoryville, S. 10° E. 13°.

Calciferous Mica Schist.

There are three limited areas of the Calciferous mica schist. The most northern is in Charlestown, west of the quartzite. It extends from the Cheshire bridge southward along the Connecticut river. It consists chiefly of argillaceous bands, which have an uneven cleavage, and the rock breaks up into irregular fragments, on account of the swelling of the concretionary veins of quartz between the laminæ of the schist. On the general section, there is a change in the dip of the strata. If this exists in reality, the band next to the river is probably slate and not Calciferous mica schist. This would not be improbable, since the rocks on the opposite side of the river are Huronian. The Calciferous mica schist, both in Rockingham, Vt., and on the Connecticut below South Charlestown, presents a monoclinal structure; and we have a narrow band of Huronian rock between, while in their present inverted position the Montalban rocks rest upon the Calciferous; and these relations are shown in Fig. 65. In Alstead, east of the gneiss at Paper Mill Village, there is a band of Calciferous mica schist. It extends up Warren brook above the road to Alstead Centre, and up Cold river into the edge of Langdon. The rock consists of a decomposing mica schist and a bluish siliceous limestone; and everywhere the rock appears the strata are nearly horizontal.

The third area is in the extreme western part of Westmoreland. At a spring by the side of the road, near Daniel Burnham's, there is a siliceous limestone interstratified with argillaceous schist. The strata are nearly vertical, but have an easterly dip opposite the quartzite and schist in the north-west corner of Chesterfield. At A. B. Cole's we have slate without the limestone. This band as a whole resembles very much the rocks along the river in Brattleboro' and those immediately opposite in Dummerston. The following dips were observed:

At grist-mill west of H. Hall's, S. 85° E. 50°.

At South Charlestown, S. 75° E. 60°.

At railroad a mile north of South Charlestown, N. 70° W. 65°.

East of grist-mill, Alstead, nearly horizontal.

At Farmer's foundry, W. 10°.

At D. Burnham's, Westmoreland, N. 50° E. 70°.

Eruptive Rocks.

The absence of eruptive rocks in this area is quite noticeable, as there are very few compared with those found in other parts of the state. The boulders of trap that occur may have come a long distance, since the boulder of serpentine seen in Keene must have come from Vermont, and some of them have travelled twenty-five or thirty miles. The only eruptive rock of any extent that is found is in Westmoreland, and forms most of the hill south-east of the railroad station in the west part of the town. The railroad cuts the granite near the station, but it extends only a short distance on either side. It extends to the top of the hill; but on the north side, a few rods from the summit, the schist comes in contact with it. The granite east to the base of the hill and a narrow band are crossed by the railroad nearly opposite school-house No. 12.

HELDERBERG SECTION OF THE CONNECTICUT VALLEY.

For the sake of properly setting forth the relations of the interesting series of Helderberg rocks at Bernardston, Mass., to the older New Hampshire schists more or less associated with them, I propose to describe the formations between Chesterfield or Brattleboro', Vt., and the fossiliferous group in Bernardston in a special section, having reference to the question how far the rocks connected with the crinoidal limestone are of the same age with it. The towns concerned are Hinsdale, Chesterfield, and Winchester, N. H., Brattleboro', Vernon, and Guilford, Vt., and Northfield and Bernardston, Mass. The area comprises about ninety square miles. Being at the boundary of the states of New Hampshire, Vermont, and Massachusetts, the several geologists have mostly confined their explorations to their respective territories, and I regret not to have been able to study the towns outside of New Hampshire as thoroughly as is desirable. The formations represented in this area upon a special map, with contours, Plate XVIII, are the following: 1. Bethlehem gneiss. 2. Hornblende rocks. 3. Cambrian slates with siliceous beds. 4. Quartzite. 5. Coös slates and schists. 6. The Helderberg limestone and its accompaniments. 7. Trias. 8. Alluvium. The sixth of these groups has been known for nearly fifty years; and we have on record the views of E. Hitchcock, Sir Charles Lyell, James Hall, J. D. Dana, J. P. Lesley, and others respecting it. The other formations have been examined very slightly, principally those in Vernon and Guilford, and are described in the report of the geological survey of Vermont, 1861.

1. Bethlehem Gneiss.

The gneiss of Vernon and Hinsdale presents such a likeness to the Bethlehem group in New Hampshire, that I refer it to that series without hesitation. Connecticut river flows transversely across this area in Vernon and Hinsdale. The level of the surface outcrops is invariably quite

PLATE XVIII.

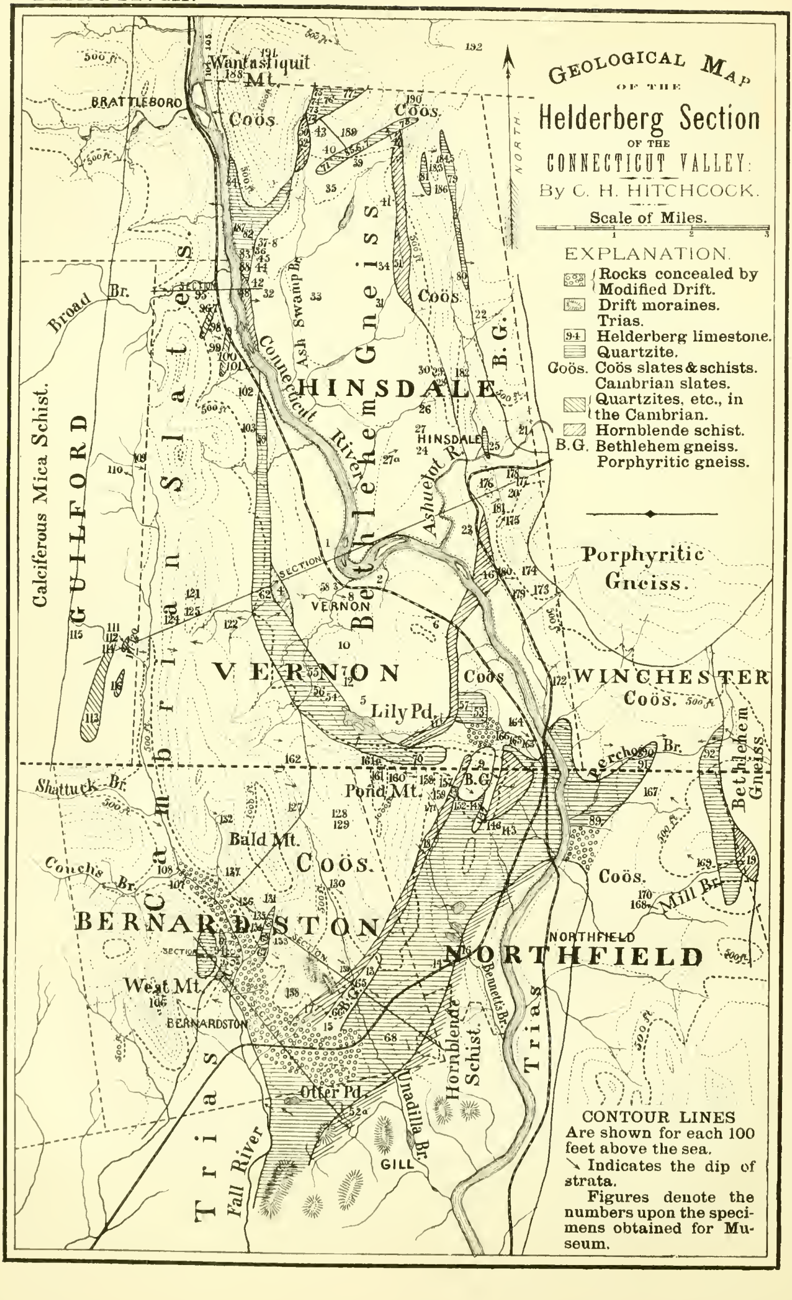
GEOLOGICAL MAP
OF THE
Helderberg Section
OF THE
CONNECTICUT VALLEY:
By C. H. HITCHCOCK.
Scale of Miles.
EXPLANATION.
Rocks concealed by Modified Drift.
Drift moraines.
Trias.
94 Helderberg limestone.
Quartzite.
Coös. Coös slates & schists.
Cambrian slates.
Quartzites, etc., in the Cambrian.
Hornblende schist.
B.G. Bethlehem gneiss.
Porphyritic gneiss.
CONTOUR LINES
Are shown for each 100 feet above the sea.
Indicates the dip of strata.
Figures denote the numbers upon the specimens obtained for Museum.
NORTH
Wantastiquit Mt.
BRATTLEBORO
Coös
Broad Br.
Calciferous Mica Schist.
GUILFORD
Cambrian Slates.
Connecticut River
Ash Swamp Br.
Bethlehem Gneiss
HINSDALE
Ashuelot R.
B.G.
Porphyritic Gneiss.
VERNON
Lily Pd.
WINCHESTER
Pond Mt.
Shattuck Br.
Bald Mt.
Couch's Br.
BERNARDSTON
West Mt.
Pecho Br.
Bethlehem Gneiss
Mill Br.
NORTHFIELD
Hornblende Schist.
Bennett's Br.
Trias
Otter Pd.
Fall River
Unadilla Br.
GILL
SECTION

PLATE XIX.

— SECTIONS ILLUSTRATING THE HELDERBERG AREA. —

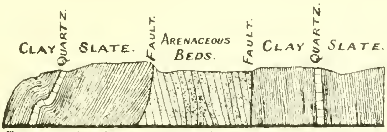

FIG. 68. AT BRATTLEBORO' RAILROAD STATION; CLIFF, 20 FEET HIGH; SECTION, 75 FEET LONG.

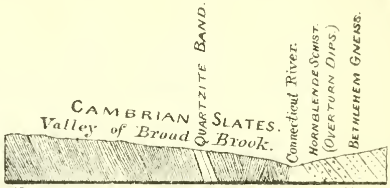

FIG. 69. ALONG BROAD BROOK IN GUILFORD AND VERNON.
— VERTICAL SCALE, 2000 FEET TO AN INCH. HORIZONTAL " , ⅔ MILE " " " . —

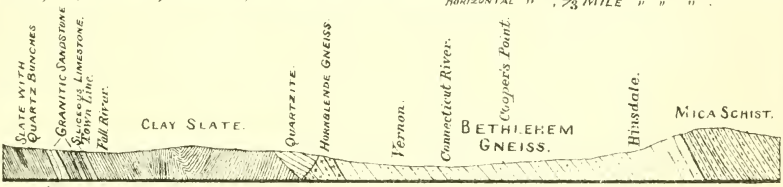

FIG. 70. THROUGH CENTRAL VERNON AND HINSDALE.
— VERTICAL SCALE, 3000 FEET TO AN INCH. HORIZONTAL " , 1⅓ MILES " " " . —

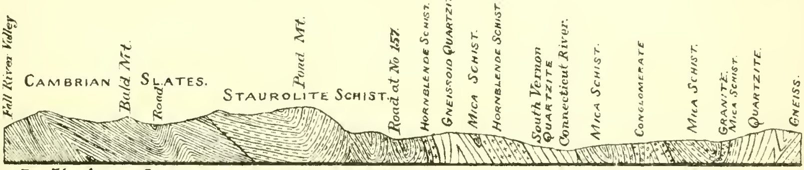

FIG. 71. ALONG STATE LINE, FROM NEAR FALL RIVER TO WINCHESTER.
— VERTICAL SCALE, 3000 FEET TO AN INCH. HORIZONTAL " , 1⅓ MILES " " " . —

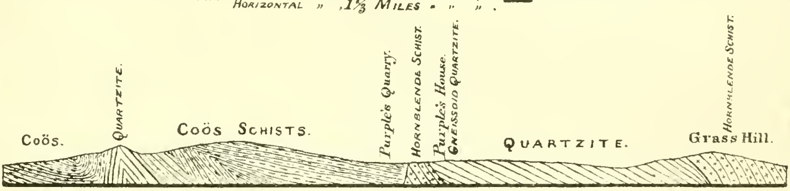

FIG. 72. FROM S.W. BASE OF BALD MT. TO GRASS HILL, IN S.E. CORNER OF BERNARDSTON.
— VERTICAL SCALE, 3000 FEET TO AN INCH. HORIZONTAL " , ⅔ MILE " " " . —

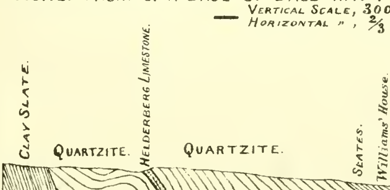

FIG. 73. ON WILLIAMS' HILL, BERNARDSTON; DISTANCE, ¼ MILE; VERTICAL SCALE, 3000 FT. TO AN INCH.

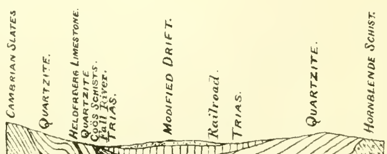

FIG. 74. FROM WILLIAMS' HILL TO NORTH PART OF GILL.
— VERTICAL SCALE, 3000 FEET TO AN INCH. HORIZONTAL " , 1⅓ MILES " " . —

low, being rarely elevated very much above the alluvial deposits. Upon the general map the latter occupy a large part of the space properly belonging to the gneiss. Ledges may crop out beneath a sand bank just enough to indicate the nature of the solid foundation, but not sufficiently to be colored upon a map of so small a scale as two and one half miles to the inch. Our special enlarged map will not be encumbered unnecessarily by the surface deposits. The basin-shaped appearance of the Helderberg section has been already alluded to in our chapter on Topography, while the recently prepared contour lines exhibit the details. There is more correspondence than is common in New Hampshire, in this section, between the topography and the stratigraphy.

Represented upon the map, upon the east side, is part of an oval area of porphyritic gneiss, ten miles long, lying in Chesterfield and Winchester chiefly. It will be specially described in the next chapter. It is regarded as older than, and hence underlying, the Hinsdale gneiss. In Northfield, boulders of this rock are extremely common, enough to suggest that it may be found in place there beneath the alluvium. If so, the length of the oval area would probably be doubled, and thus extend much farther south than the Bethlehem group, which barely reaches into Massachusetts. These two older series do not join each other visibly, because their boundary is covered by extensive developments of mica schists and quartzite.

The structure of this gneiss is like that of the Hanover area, mostly inverted, but the general inclination is reversed from that, being easterly rather than westerly. The following are observed positions:

Vernon.

Near L. F. & G. F. Gould's, school district No. 4, 45° S. 20° E.

Farther west, 55° southerly.

At school-house No. 5, 40° E.

West of railroad, between the church and the Whithed family cemetery, several ledges, 65° E.

Between the church and Vernon station on railroad, 55° E.

This region was averaged by E. Hitchcock at about 30° E.

West of E. P. Brown's, 70° E.

At west edge of formation, near school-house No. 7, 70° E.

Hinsdale.

On Elmore's island, easterly, the same as at Cooper's point.

At school-house No. 4, east.

South of E. Ashcraft's, about N. 70° E.

East of D. Fisher's, vertical; strike about north and south.

At S. E. Butler's, east.

Between F. Thomas's and Bear hill, east.

At saw-mill near S. Thomas's, northerly.

Winchester.

At west edge of formation, 50° N. 30° W.; 25° N. 40° W.; 20° N. 40° W.

Northfield.

At the west edge, 60° northerly.

South-east from village, N. 44° W. and 50° E.

Warwick.

At west edge of the town, 20° N. 12° W.

The gneiss of the last three towns belongs to a range not mentioned above, bordering the Helderberg field on the east. It is very likely of the same age with the typical area in Hinsdale and Vernon. The dips indicate a synclinal between the Vernon and Winchester areas, thus confirming the suggestion of their identity. I have not included certain gneisses in Vernon and Northfield associated intimately with the quartzite, believing them to belong to the latter series of rocks. They differ in the absence of the talcose mineral and in being fine-grained, scarcely distinguishable from the quartzite.

The principal variation from the east dip is in the first two observations. Here, there is a bed of crystalline limestone in the gneiss quite near the border of the area, and, as usual, overlaid by hornblendic rock. The southerly dip of these strata beneath quartzite and mica schist agrees with our theory of the inversion and greater antiquity of the gneiss. The limestone presents a slight likeness to the Bernardston rock; but a careful examination did not reveal the existence of any fossils. The Bethlehem group in Orford and Lyme carries a very large bed of limestone, which may be the analogue of this. Likewise, any bands of quartzite not readily separated from the gneiss might be regarded as the equivalents of the quartz seen at Hanover in it.

The general aspect of this gneiss may be expressed by the word granitic, because the stratified lines are obscure. Hence it is possible that the formation may be represented in the Whately and Hatfield area of sienite, as given in the Massachusetts map.

Hornblende Schist.

Our studies indicate the existence of a narrow band of hornblende schist adjacent to several of the areas of Bethlehem gneiss in the Connecticut valley. Allusion has been made to the positions of several of them, upon page 367, and others will be described in the following chapter. The Helderberg area contains an unusual amount of this rock, and it seems proper to refer the greater part of it to the same horizon with the hornblende bands of Shelburne Falls, Mass., Brattleboro', and the long belt from Marlboro' to Reading, Vt., Westmoreland, Plainfield, Hanover, Orford, Canaan, etc., N. H. Often the rock is properly a hornblendic gneiss, and for that reason has not been distinguished from the gneiss adjoining. In New Hampshire it seems to encircle areas of the Bethlehem group. This suggests whether we ought not to incorporate with these protogenic rocks other gneisses similarly enclosed, but devoid of talc or chlorite. Objection has very properly been made to separating formations by means of mineral characters; but we have now the means of uniting common and talcose gneisses in this Bethlehem series, which may be characterized mineralogically by the presence of the talc in a portion of the group. The classification is based upon stratigraphy, not lithology exclusively. We may be able to say that the gneiss of Shelburne Falls, the range between Marlboro' and Hartland, Vt., as well as the small Brattleboro' area, should all be ranked as part of the Bethlehem series, and hence probably corresponding with the Laurentian in age.

The hornblende rocks occur on both sides of the Hinsdale area. On the west we have an excellent outcrop opposite the mouth of Broad brook, dipping 50° east. It is about two hundred and fifty feet thick, of a glossy black color, often containing epidotic nodules (Nos. 47, 48, of the catalogue). On the north edge of the gneiss we find it at H. Streeter's (Nos. 50, 52), and above the Thomas saw-mill (No. 47). On the eastern border it appears east of S. E. Butler's (No. 51), at Davenport's island, and fifty rods east of F. Doolittle's (No. 46). These are all in Hinsdale. After crossing into Vernon I have noticed the same material, outside of the gneiss, near the Whithed cemetery.

After reaching the line between Vernon and Northfield, an abundance of hornblende rock, with a fine-grained gneiss, makes its appearance, both of which seem to belong to a formation above the Vernon or Bethlehem gneiss, as just described. Both occur abundantly farther south. On the town line the dips are all easterly, hence indicating inversions. The details will be described presently (Fig. 70). On a line diverging from this section, at the crossing of the state line by a road from Lily pond south-easterly, and thence following the track as far as the rocks extend, the position of the strata is essentially the same, while the hornblende has diminished in amount, occurring in two places. This rock occurs about a mile south of the Vernon line, along Bennet's brook, dipping south-easterly. My father's map of Massachusetts represents this hornblende band as extending along the east line of Bernardston southerly, reaching to the Connecticut river at the ferry leading to Northfield village, thence occupying the whole area from the Connecticut west to Woodard's or Unadilla brook. My own observations confirm and extend this area, at the expense of the red sandstone. Less than a mile from the Turner's Falls ferry, in Gill, the hornblende rock shows itself; and I did not see anything else as far as to the ferry crossing to Northfield, where are also some related metamorphic strata. I also find this rock over a mile to the south-west from Grass hill, dipping somewhat south of east. Between this point (four corners in the road) and Otter pond, in the north-west corner of Gill, are extensive quartz ledges, with north-westerly dip. We may therefore extend the hornblende more south-westerly than before, and perceive its want of conformity to the quartzite, on account of the change in the dip. The north part of Gill is covered with the irregular lenticular hills of drift, to be described hereafter. Without doubt their abundance has led previous observers to overlook the presence of the older schists, and to believe the place occupied by the Trias. Our sketch shows that the hornblende pursues a more north-easterly course than is indicated upon the Massachusetts geological map.

3. Cambrian Slates.

Clay slates occupy the western part of our map. It is believed to be the same band with that described in the second section of Connecticut river, between Hartland and Fairlee. The range commenced again in Rockingham, and is continuous thence to Brattleboro', Guilford, and Bernardston, terminating in the north part of Greenfield, because covered by the Trias. The last remnant of it to the south is represented upon my father's map as situated in Whately. There are quarries of slate upon this range in Dummerston and Guilford.

Observers have not been agreed as to the age of this band. My father's latest views led him to suppose these slates identical with those overlying the fossiliferous limestone at Mr. Williams's house in Bernardston;

and hence that the whole series of rocks was presumably of the same general age. Professor Dana has called specific attention to the difference in lithological aspect between the two slates, and is well satisfied that the clay slate of West mountain is an earlier unconformable formation.* This is undoubtedly the correct view.

Commencing at the north end of this field of description, I will enumerate the position of the slates along sectional lines. First, in Brattleboro' and Chesterfield. In the west part of Brattleboro' village, the Calciferous mica schist underlies the slates, both dipping 50° E. Farther east the dip 60° W. has been observed. At the depot the dip averages 66° south of east. At this locality I noted some interesting irregularities, represented in Fig. 68. The slates indicate an anticlinal dip, those at the south end of the cliff being inclined at a less angle than the others, which are vertical. Each side exhibits a band of quartz, sometimes bent and nodular, but indicating an identity to the enclosing slates. Between them is an older hard rock, separated distinctly by faults from the slates upon both sides, showing most decidedly upon the south, both by divergence in dip and a distinct fissure. This harder rock may not belong to an older formation, but the layers certainly underlie the clay slates. On following the ledge around to the village, it is seen to be much crushed and bent out of place. I think many other ledges of slate would display similar irregularities if carefully studied. At the east end of the bridge over the Connecticut in Chesterfield the slates dip 80° N. 80° W. To the east of this the slates dip easterly, thus forming an anticlinal support to underlie the Coös schist of Wantastiquit mountain. The synclinal is observable both north and south of the Brattleboro' ridge. To the north are interesting bands of quartzite, apparently elevated from beneath like the hard rock at the depot just mentioned.

South of the Windham county agricultural park in Brattleboro' the slates are minutely twisted, with the general dip of S. 70° E. The line between them and the Calciferous group is crooked. At East Guilford the Calciferous dips 55° E., followed immediately by the slates having the same position. The roofing-slate band lies just to the east of the village, and is supposed to stand at a higher pitch. Near the mouth of

* *Amer. Jour. Sci.*, iii, vol. vi, p. 343.

Broad brook in Vernon is an anticlinal in the slate; and there is reason to believe much of the rock in the neighborhood dips to the west. Fig. 69 illustrates the Broad Brook line.

Another sectional line, across school districts Nos. 4 of Guilford and 1 and 2 of Vernon, is the following: In the valley of Fall river we find the old slate quarry, that has been known for so many years. This is an anticlinal valley, with dips of 80° N. 80° W. and 77° S. 80° E. West of it, in Guilford, is an extensive area of novaculite. There is also an anticlinal, with similar steep sides, near school-house No. 1 of Vernon. The most eastern outcrops of slate dip at a higher angle to the east than the overlying quartzite. Between the two last sectional lines are abundant slate exposures. The best known of these lines starts from school-house No. 9, in Guilford, and crosses the slate ridge a little north of east to Vernon Centre. This is shown in Fig. 70. At the school-house and its vicinity is the quarry range, dipping 75° S. 20° E., with its bosses of white quartz. On crossing the ridge to school-house No. 13, two bands of a white granitic rock, possibly conglomerate, separated by slate, are passed. The last is at the more eastern school-house, dipping south-east. Next succeed a few feet thickness of siliceous limestone, like that belonging to the Calciferous. Associated with these rocks by the school-house are feldspathic sandstones and felsites, and talcose conglomerate. These conglomeratic, feldspathic, and calcareous rocks occupy a breadth of less than a mile. They seem to belong to some older group that is just touched by the erosion of the slates to form the valley of Fall river. Passing into Vernon the older slates reäppear, with the usual easterly dip. Towards the top of the hill there is a westerly dip. A small anticlinal appears near the summit; and the westerly dip is restored on the crest of the ridge, and continues all the way down the east side. The last ledge of it east of M. Lee's dips 80° W. The first ledge of quartzite succeeding dips 30° N. 50° E. If these observations represent the mutual relations of these two formations, the latter rests very unconformably upon the former. The slates of this ridge are almost black, without lustre, and remind one of the darker slates of Blueberry hill, Littleton, formerly believed to belong to the Helderberg series, but now referred to the Cambrian.

At about the crossing of the state line are slates, with a dip of S. 60°

E. 50°. Some of the layers are sandy. Near the line, on the west side of Bald mountain, Bernardston, the dip of the black slate is 15° S. 50° E. Clay slate occurs along this road for two miles north and south. At the crossing of the state line by the back road from Vernon to Bernardston, on top of the water-shed, twisted slates dip only 5° S. 20° W.—possibly an abnormal position. On the west side of the road the dip is 70° S. 70° W. A quarter of a mile south the slates dip 15° S. 50° E. on top of a cliff, and then 50° E. A mile and a half east, on the line, we come to an argillaceous schist, with staurolite on Pond mountain, which is supposed to belong to the upper or Coös series. On passing to the "Basin" in district No. 9, from the base of the hill, we find, first, a schist similar to those holding imperfect crystals of staurolite, dipping east and north-east. This is followed by a neatly-splitting slate, dipping 75° W. In the "Basin" the rocks are slaty, twisted, with white quartz bosses, and a general inclination to the east. This locality is close to the town line. The hill west of Fall river is composed of this same slate, including West mountain, where the dip is 60° N. 86° E.

We see that foldings occur on all these sectional lines across the clay slate, and that anticlinals are prominent. They may perhaps best express its stratigraphical structure, and that it unconformably underlies the Vernon and Bernardston quartzite series of formations.

There is a singular interstratification of slates, with siliceous rocks, in the north-east corner of Vernon. On passing to the north we find the usual quartzite at the Hubbard place, opposite the location of old Fort Bridgeman, dipping about 35° E. The range may be half a mile long (No. 103). At Mrs. E. Howe's, by old Fort Sartwell, is an argillaceous schist (No. 102). Just north of the Witch gutter the quartzite reäppears, with the same dip as before. The slates succeeding are much contorted and broken, as if by pressure between the sandstones. Nos. 99 and 100 are quartzes, one hundred and thirty rods south of Broad brook; No. 98 is a slate, ten rods farther north; Nos. 96 and 97 are siliceous rocks, with a little mica and iron, ninety rods south of the brook. From this point to Brattleboro' all the ledges are of slate. These siliceous rocks may be continued in the quartzites appearing on the east bank of the Connecticut, just above the Brattleboro' bridge (Nos. 104 and 105).

4. Quartzite.

The quartzites in the Helderberg area are gray, white, and blue, in different localities, and are very abundant. They are often quite friable sandstones, and again approximate to the usual vitreous variety most common in the Coös group. Whether they belong to more than one series, remains to be proved.

The first range to be described seems to skirt the Vernon and Hinsdale gneiss area, bordering it almost everywhere. In the north-west part of Hinsdale, about half a mile south of the Brattleboro' bridge, we find bluish quartzites (Nos. 83, 84). At a quarry the dip is east. Farther south it adds mica to its composition, and has a slaty color. At a shanty near G. Thomas's is a little slate with it, dipping east, and then standing vertically. The quartz continues along the river bank till we reach the hornblende just opposite the mouth of Broad brook. It may strike across the south-west spur of Wantastiquit mountain to the valley of Ash Swamp brook. Nos. 71–75 represent the quartzite from one mile south of H. Streeter's north to the line between Hinsdale and Chesterfield. Daniel's mountain is composed of it, lying to the east of the stream (Nos. 76, 77). Next we see it a little north of the saw-mill near S. Thomas's, between Daniel's and East mountains. The dip is 60° N. 60° W., overlying hornblende schists, and followed by staurolite schist dipping east. The map would seem to imply the existence of a separate range from No. 71 to the saw-mill, resting upon the gneiss, and perhaps not connecting directly with what succeeds. A little south of the summit of Bear hill is an easterly-dipping quartzite, which has been traced more than a mile a little west of south, just overlying hornblende rock. The range is seen farther south, at A. H. Sumner's. Another exposure is in the east part of the village of Hinsdale. We have no well defined quartzite along Foxden mountain, south of Hinsdale village, though its components are largely of silica. The range may reäppear on the south side of Great brook, with the dip of 80° N. 30° E. It probably crosses the Connecticut near South Vernon bridge to join the quartzites at the railroad cut on the state line, and also nearer the Connecticut. The dip may be 20° N. E. at the cut, but much higher near the river. About two miles south of the Great brook locality, at a saw-mill in Northfield, is a quartz conglomerate (No.

89) which may be connected either with this range or another to be spoken of hereafter.

Just out of the village of South Vernon, to the north-west, the quartzite dips 20° N. 35° E. It is likely this continues to join the quartzite farther west, or No. 53, north-west from a brickyard near C. D. Severance's, with the dip 25° S. 80° E. On the west side of this small hill is a siliceous conglomerate, dipping 45° S. 80° E. I will not repeat the observations along the state line, where quartzite and hornblende rock alternate, and will be noticed presently. It is not clear that the quartzite is continuous from the railroad cut in South Vernon to the exposures near Lily pond, though presumable. The quartz (No. 20) has a strike nearly with the road, or north-westerly, between Lily pond and the state line. Directly south from the pond there is a south-east dip, with irregularities. From here to the old fort in the north part of Vernon the outcrops are easily traceable, curving from north-west to north, and then crossing to connect with the quartzite in the north part of Hinsdale. The gneiss east of the pond and along the direct road to Vernon is very siliceous, and is with difficulty separable from it. Different observers would not draw their boundary lines in the same place. By G. W. Lee's, in district No. 9, the dip is east. Farther on, or near the school-house, the dip is N. 48° E. Near L. C. Brooks's, the dip is 30° N. 50° E., but more easterly at the Hubbard place. This range invariably dips easterly, towards if not beneath the gneiss. It is probably to be regarded as inverted, and thus passing beneath the older rock, rather than resting unconformably upon it.

The following is the order of rocks for two fifths of a mile in length, from the edge of the alluvium in West Northfield, along the road nearest the state line, illustrated by Nos. 143–156:

143, Quartzite, one fourth mile west of the railroad,—dip, 60° S. 35° E.

144, Micaceous quartzite—same dip, also dip of 60° S. 80° E.

145, 146, Quartzite, weathering as if from feldspar.

147, Argillo-mica schist,—dip 70° S. 35° E.

148, Hornblende schist,—dip, S. 38° E.

149, Micaceous quartzite.

150, Breccia of quartzite and schistose fragments,—dip, S. 35° E.

151, Argillo-mica schist.

152, Gneissoid quartzite.

153, Compact hornblende.

154, 155, Staurolite mica schist,—dip, 40° S. 45°–50° E.

156, Mica schist, much silica, and little staurolite—quarried; dip, 35° S. 30° E.

Beyond this the rocks are covered for a quarter of a mile with gravel. Then there is an indurated argillaceous schist, with many interlaminated seams of quartz (No. 157), at a fork in the road, dipping 85° N. 40° W., and also near a deserted house.

For purposes of immediate comparison, I will introduce here the description of a section along the state line across this whole area, extending from Winchester to Guilford (Fig. 71). The previous section terminates with No. 157, which is the point of intersection with the one about to be described. The figures are taken from the catalogue of Section I, as far as to Connecticut river.

66, White gneiss, near E. Lyman's, Winchester,—dip, 20° N. 40° W.

67, 68, Decomposing gneiss,—dip, 25° N. 40° W. just east of tributary from the north emptying into Perchog brook.

69, 70, Tourmaline schists, and

71, Gneiss, dipping 40° N. 30° W.

72, 73, Quartzites, vitreous and jointed,—dip, 85° N. 25° W., and, in a few feet, 75° N. 65° E.

The last named is on a hill constituting the high western bank of the Perchog river. The gneiss is seen to pass directly beneath this quartzite, both rocks retaining essentially the positions assigned above. It is therefore an excellent example of unconformity, as the quartzite is the younger rock.

74, Mica schist,—dip, 80° E. and 80° W. by school-house; the same beyond.

75, Coarse granite vein in 74, by S. H. Smith's.

76, Mica schist, siliceous, half a mile west, —dip 50° N. 30° E.

77, Micaceous quartzite,—dip, 45° N. 45° E. near C. Stebbins's.

With this (No. 77) are layers carrying nodular veins of quartz,—ferruginous and argillaceous strata. Nos. 74–77 are clearly the mica schist of the Coös group. This is the last specimen obtained in Winchester.

78, 79, 80, Quartzites, near W. Coombs's, Hinsdale, near Connecticut river, and dipping 80° N. 30° E.

Next succeed the quartzites adjoining the river on the west side, 60° N. 20° E., and at the railroad cut dip one third as much. The rock is mostly quartzite, with mica schist layers of different degrees of coarseness. The south end of the cut is gneissic, and there is a trap dyke here also. In the road adjoining the cut is mica schist, dip N. 18° E. In the field west is a large development of hornblende schist, dip about 48° east.

Higher up are beds of micaceous quartzite, not very abundant, dipping N. 60° E. These are followed by grayish-green hornblende rock, partly actinolitic. A breccia was also noted between masses of hornblende. The several bands following are these, in order: quartzose gneiss, hornblende, quartzose gneiss, hornblende, mica schist, dipping 40° S. 50° E., of considerable thickness; hornblende schist, at the height of land, argillaceous and staurolitic schists, dipping 50° S. 58° E., and 45° S. 72° E. This brings us to No. 157, an indurated schist, where the first road west of South Vernon crosses the line. The relative thicknesses of these several beds may be ascertained by referring to the published figure.

The eastern ends of these two sections are a mile apart, but they come together at No. 157. Hence we may learn how the breadth agrees upon the lines so near together; and it is surprising to learn that the predominating rock along the state line is but slightly represented upon the other, but the dips are everywhere the same. Two narrow bands of hornblende rock are cut on the southern line, both of them combined hardly five hundred feet wide; on the other, at least one third part of the strata consists of this material. The western bands seem to correspond with each other, while we may say the eastern has narrowed extremely in proceeding southerly, or else it is covered by quartzite and mica schists. The latter is probably the better view, since the hornblende expands very much to the south in Northfield and Gill.

Following our section along the state line, we find next a considerable breadth of staurolite mica schist, thicker-bedded and more uneven from contortion than a similar rock in Bernardston (No. 158). On the small hill west of the road crossing the state line, the dip is 45° easterly (No. 160). In the deeper valley beyond, not traversed by a public road, the dip is north-east (No. 161). This valley marks the place of an anticlinal, the rock on the west side, and up to the summit of the steep hill-side (No. 162), dipping 65° S. 20° W. This whole hill, known as Pond mountain, consists of the same staurolite rock. The crystals are very small, and in other respects differ from any found elsewhere in this Helderberg area.

The rock for the three quarters of a mile succeeding has not been examined. That next seen is at the crossing of the Bernardston road over clay slate, where we have, first, by continuing the strike a short distance, 50°, then 5° S. 20° W. and 75° W. Then we have on the west side of Bald mountain the dip 15° S. 50° E., and above Shattuck brook, in the valley of Fall river, 50° S. 40° E.

The quartzites are supposed to be continuous from South Vernon to the north-west part of Gill, passing through the south-east corner of Bernardston. At the railroad crossing, in the south-west corner of Northfield, the quartzite (No. 14) dips 25° S. E. immediately adjacent to hornblende schist (No. 16) supposed to have the same dip. Near Purple's house, in the east part of Bernardston, we find a gneiss (No. 13) and a conglomeratic feldspathic quartzite (No. 65), with well-defined quartzites, all dipping about 30° S. 30°–40° E. Thirty or forty rods north-west of this house are ledges of hornblende schist, dipping 70° S. E., extending very near to Purple's quarry. A section line from No. 16 to No. 139 (Purple's quarry), a part of Fig. 72, shows the same order of rocks as along the state boundary. The same order may be obtained farther south-west. The eastern mass of hornblende occupies much of Gill; and its junction with the quartzite appears at the crossing of the north line of the town at Unadilla brook, and at a fork in the road about a mile east of Otter pond. No. 15 represents quartzose gneiss, a rock physically like quartzite, and shown by Prof. Dana to have feldspar in it. The dip is 15°–25° S. E. On the road north-westerly from No. 15 are outcrops of hornblende schist, graduating into sienitic gneiss, dipping 15° S. 40° E. (No. 17). In passing west, the next rock is the principal mica schist range (No. 138). The quartzite range continues from this last sectional line, underneath a wide expanse of gravel, to the neighborhood of Otter pond in Gill. About half a mile's width of it may run between this pond and Fall river, dipping south-westerly. It then passes out of sight beneath the Trias. At No. 68, west of Grass hill, the dip is 30° S. 40° E., agreeing with the usual dip of this formation, but near Fall river, along the line of strike, it has changed to north-west. This fact may indicate the presence of an anticlinal, not commonly observable because inverted. This affords data for believing this quartzite is the repetition of the bands, soon to be mentioned, north of the village of Bernardston. All authors have assumed the identity of the South Vernon range with that connected with the fossils. If so, the connection is through folding and not by continuity, since the strikes are different, as exhibited upon the map. For the benefit of any persons disposed to doubt the reality of the connection, it may be said that all the gneissoid quartzite of this region occurs along the eastern range, from Otter pond to South Vernon, and is not found at all in connection with the western range; also, the gneissoid quartzite is intimately associated with hornblende schist, and is related to the Vernon gneiss; and all these more crystalline layers are situated east of the pimpled mica schists with staurolite. The fossiliferous locality is two miles distant, in the direction of the dip from the nearest part of the South Vernon range. I have separated areas of this gneissoid quartzite along the state line and east of Bernardston village, upon the map, calling them Bethlehem, or the equivalent of the Vernon area. I presume most of the quartzite, from which these smaller areas have been separated, is essentially the same. It is noticeable that hornblende occurs upon both sides of this range of quartzite and gneiss, just as it encircles the Vernon and Hinsdale area of gneiss.

The quartzite next the crinoidal limestone usually dips 25° S. 35° E. The strike very nearly points to a school-house on the east side of Fall river. A short distance south the dip is more southerly. It occurs also a quarter of a mile to the north of the limestone (No. 64), and is vertical, with westerly-dipping slates on the east. On crossing the valley, a quartzite is found (No. 69) behind the first dwelling above the school, running into the hill as if it were making for the corresponding rock in the west part of Vernon. The strike is about N. 50° E., and the strata are vertical. It may be followed for half a mile (No. 63). Part of the way it presents a precipitous slope, with many reticulated quartz veins. The *débris* at the base of the cliff is too great to allow a view of the limestone, if it exists, in the place corresponding to its position on the west side of the valley. The rock is largely white and bluish-gray, not very granular, mostly vitreous. On crossing towards the back road to Vernon the quartzite and slate dip south-easterly. Quartzite also appears south of the school-house, at No. 67. There are no other indications of the presence of this rock in the north part of the town.

There is a second range of quartzite behind the limestone, towards West mountain, possessing an easterly dip. I find, among observations made in 1858, that there is a quartzite, dipping 60° westerly, some twenty rods north of the limestone. There is also a westerly-dipping breccia a few rods west. These may be spoken of again in the description of the section upon this hill. After protracting these quartzites west of Fall river, upon the map, none of them seem to connect directly with the band east of the stream back of the school-house.

Little is known of the extension of the Perchog Brook (Winchester) quartzite southward. I have noted it as having a westerly dip near the north line of Northfield. The Massachusetts map represents a range of it reaching to Miller's river, through Northfield and Erving. Starting from the place where it is known to occur in Winchester, at a saw-mill near F. Doolittle's, just in the edge of Winchester (Nos. 90, 91), there is a quartzose conglomerate, carrying a little galena.

5. Coös Mica Schists.

We have at least three prominent varieties of these mica schists. 1. An ordinary mica schist, argillaceous, and containing crystals of staurolite. 2. Very siliceous mica schist, without staurolite. 3. Even bedded slate, with and without staurolite. In this latter variety, this mica is abundant in small, brown prisms, showing their faces where the strata have been broken. Though resembling phyllite (chloritoid), it is likely the mica is a phlogopite. Small red garnets are often present in great abundance, so that when freshly fractured the surface of these slates is covered with small pimples and pits. We have often, in the field, distinguished between the Coös and Cambrian slates, by observing the presence or absence of these pimples. The distinction is not complete, since the Guilford and Vernon slates are often much pimpled, yet belong to the older series.

In Hinsdale and Winchester the mica schists carry beds of granite, both coarse and fine grained. Other beds are of nearly pure quartz, of mechanical origin.

Wantastiquit mountain is mainly composed of these mica schists which are thought to overlie the quartzite range in the north part of Hinsdale, already described. The strata on Bear hill dip easterly at a high angle; and the position all through the eastern part of Hinsdale is essentially the same. These beds of granite show themselves in climbing Bear hill from the north. Ashuelot river has cut through the ridge at Hinsdale river, but it rises in Foxden mountain to fall again southerly in the south-west corner of Winchester. The dip is usually to the east. At Hinsdale depot the dip is 60° E. By R. Smith's, three fourths of a mile south, it is 70° N. 56° E., and it is nearly due east between the last two. More than a mile south of the depot it is also to the east, by S. Doolittle's (No. 177). There is a granite vein east of school-house No. 6, besides the one already mentioned in Section I.

After crossing into Massachusetts the dips of the mica schists change to the west, as No. 167; half a mile south of the line, a soft wavy rock, inclined 80° N. W. A short distance further the schist is sandy, decomposing like siliceous limestone, almost vertical. East of Northfield village, to the north and east of Mill brook, the mica schist is considerably quartzose, dipping easterly. At Nos. 168, 170, the dip is irregular to the north-west. It is about the same at 169. Returning by a more southerly route along Mill brook, we have, first, a northerly and then a westerly dip. No observations have been made farther south.

A branch from this range crosses the Connecticut to South Vernon from about school-house No. 6 of Hinsdale. Between the Whithed cemetery and the railroad crossing above school-house No. 4, of Vernon, are several exposures of staurolite mica schist dipping 40° S. 50° E. and east. The most northern and southern exposures have the first position named. There is some hornblende rock between the most northern ledge and the Vernon gneiss. Just in the edge of South Vernon is some mica schist, the thinning out of this area towards the railroad junction.

Next we find the Bernardston area barely connecting with the mass just described, through Nos. 165, 166. As alluvium covers the valley of the outlet from Lily pond, we cannot be absolutely certain whether the quartzites or the mica schists occur here. Before erosion, both may have been here. Across the road from the limestone in gneiss (No. 11), mica schist dips 50° S. 25° W. Next we find it on the state line section, mostly dipping easterly, east of the road, and showing an anticlinal on Pond mountain. From this mountain south-westerly to Fall river the rock is mostly the pimpled mica slate. East of Bald mountain the dip is south, then south-east. Near the end of a branch road (Nos. 128, 129) there is a hard, siliceous rock, not well defined. The dip is usually small to the south-east over all this area. It is last seen to the south-west, about a mile north-east of Bernardston village.

The relations of this group of strata are best seen in a section (Fig. 71) from about the mouth of Couche's brook, a tributary of Fall river from the west, across the supposed eastward repetition of the Williams quartzite to Purple's slate quarry, and beyond. The Cambrian slates are believed to dip about 50° S. E. along the west end of the section, beneath the alluvium of Fall river. The quartzite seems to stand vertical, and then to dip south-east. The wrinkled schists cover it at the school-house, and dip 35° S. 40° E. On the ridge west of Purple's slate quarry the dip is about 12° S. E. At the quarry the dip is about 20° S. E. About a stone's throw to the south-east succeeds hornblende schist, dipping 70° S. E. At the house are the gneissic quartzites, dipping about 30° S. E. At No. 68 the dip is 30° S. 40° E., and the hornblende beyond is supposed to lie in about the same position.

Our observations seem to establish a direct continuity of exposures of these pimpled staurolite mica schists from the east foot of the Williams hill, overlying the quartzites to Chesterfield, and consequently with the extensive area of the Coös groups reaching to Haverhill. Hence it confirms the first part of the previous conclusion of Prof. Dana,* that the "Coös group, which is but the northern continuation of the same [Bernardston] series, is, if correctly traced out, also Helderberg." The reference here is to the mica schist division of the group.

6. Helderberg Limestone.

There is but a single exposure of this limestone, and therefore I will carefully describe the position of the rocks associated with it. It occurs upon the east slope of a hill a mile north-west from Bernardston railroad station, and not over a fourth of a mile distant from ledges of the Triassic sandstone. We enter through a gateway of Mr. Williams's from the carriage-road, and encounter immediately a small knob of the blackish, pimpled clay slate, dipping 30° S. 48° E. This is the western edge of the Coös slates; and in the field farther north it occurs with a high dip to the north-west. Next succeeds the quartzite, dipping at first 29° S. 35° E., and then 25° S. 50° E. This is at a quarry. A hundred feet to the south of the section line, and nearer the limestone, the quartz is more vitreous, and dips 52° S. 40° E. In the field north of the section, in

* *Amer. Jour. Sci.*, iii, vol. vi, p. 349.

1858, I noted a quartzite dipping 60° N. W.; and in 1874 I observed a ledge, presumably the same, standing vertically. Earth covers the immediate junction of the quartzite and limestone; but as the latter dips apparently beneath it, though at a small angle, it is so represented upon the section. Yet the higher dips of the quartzite so near the limestones on both sides may warrant one in suspecting the possibility of some irregularity which should change our views of the relative ages of the rocks. The limestone may be twenty-five or thirty feet thick, the place being shown at No. 94. It abounds with fragments of crinoidal stems often an inch across; one end is frequently larger than the other. I have, also, specimens of coral from it, quite obscure, which have never been submitted to a paleontologist. From the decomposition of the limestone a considerable limonite has been formed, which was once manufactured into pig iron. The limestone consists of carbonate of lime, 98.38; peroxide of iron, 0.62; silica, 1.00=100.00.

A short distance west of the limestone occurs a brecciated rock, composed of fragments of quartz and slate, dipping apparently 25° W. This is succeeded by a dark-colored quartzite having the same position. This is followed by quartzite of the usual variety seen to the east, with a dip rather more southerly than that. The length of the section, protracted sufficiently to include the westerly band of quartzite, is eighty rods.

The observations from which our figure is constructed are mainly those taken by my father in 1857 and by myself in 1858, and published in the Vermont report. Prof. Dana has published a somewhat similar figure in his sketch, to be mentioned presently. I do not speak of two narrow argillaceous seams adjacent to the limestone, mentioned in 1858, as they did not seem prominent in any later visits. I have examined the section several times since 1858, once in company with Prof. Dana. Some further remarks about this limestone, in its relations to the adjoining strata, will be appropriate after alluding to the opinions of my predecessors.

Later Rocks.

The map shows an extension of the Triassic sandstone up the valley of Fall river, reaching nearly to the limestone quarry. The slates have probably been excavated across their edges transversely to form the basin for the sandstone, though the north-westerly dip of the quartzite, near Otter pond in Gill, is suggestive of the existence of an underlying synclinal. The area of the sandstone is much restricted from its representation on the Massachusetts map, in consequence of the discovery of the harder rocks in Gill. The north end of the Trias in Northfield is composed of a very coarse conglomerate, and is regarded as the uppermost member of the series.

There are several lenticular-shaped drift hills in Gill and Bernardston, noted upon the map, which may be regarded as ancient glacial moraines, and therefore devoid of ledges. They constitute a feature in surface geology hitherto overlooked; and their presence here makes it certain that no ledges will be found upon their surfaces. Prof. Dana speaks of seeing a ledge of gneiss upon one of these drift hills (D D′ of his map), which must be a loose fragment, though of large size. Another class of drift deposits occur along the railroad east of Bernardston village, which, equally with the moraines, obscure our knowledge of the ledges; but enough of the outcrops are visible to make clear how the solid strata in the neighborhood of the fossiliferous band are to be grouped. The alluvium is not represented except where it is so abundant as to conceal the underlying ledges, and make it uncertain what formation properly belongs there.

Catalogue of Specimens from the Helderberg Area.

In the museum the specimens are labelled 1001, 1002, etc., to 1192, but upon the map the figures commence with 1, 2, etc. In all other respects the map resembles those drawn heretofore to illustrate the Coös, White Mountain, and Ammonoosuc districts.

BETHLEHEM GNEISS.

Vernon.

1, Gneiss, with much mica and pyrites.
2, 5, 8, 12, 58, Granitic gneiss.
3, Gneiss, very talcose.
4, Hornblendic gneiss.
6, Gneiss resembling Montalban.
7, Gneiss, with dark mica.
9, 10, Gneiss, very siliceous.
11, Limestone.

Bernardston.

13, 15, 65, Gneiss, very siliceous.

Hinsdale.

20–27, 29–36, 39–43, 45, Granitic gneiss.
27a, Feldspathic gneiss.
28, Ferruginous gneiss.
37, 38, Conglomerate gneiss.
44, Gneiss, very siliceous.

HORNBLENDE ROCK.

Northfield.

16, 18, Hornblende schist.

19, Epidotic hornblende schist.

Bernardston.

17, Hornblende schist.

Hinsdale.

46–48, 50–52, Hornblende schist.

49, Epidotic nodule in 48.

Gill.

52 a, Hornblende schist.

QUARTZITE.

Vernon.

53–56, 57, 58 a, 59, 62, 70, Quartzite.

57, Conglomerate.

Bernardston.

14, 63, 64, 67–69, 93, Quartzite.

66, Quartzite, with mica blotches.

Hinsdale.

71–77, 81, 82, 86–88, Quartzite.

78, 83, Bluish quartzite.

79, Feldspathic quartzite.

80, Sandstone.

Northfield.

89, Conglomerate.

Winchester.

90–91, Conglomerate.

92, Quartzite.

HELDERBERG LIMESTONE.

94, Large crinoid, Williams's quarry, Bernardston.

CAMBRIAN SLATES AND SILICEOUS BEDS.

Vernon.

95, 98, 102, Argillaceous schist.

96, 97, Ferruginous quartzites.

99, 101, 103, Quartzite.

100, White quartz in 99.

Chesterfield.

104, 105, Quartzites, opposite Brattleboro'.

Guilford.

111, Conglomerate.

112–114, Conglomerate, with greenish mineral.

116, Sandstone.

117, Talcose conglomerate.

118, Reddish quartz.

119, Conglomerate.

120, Compact quartzite.

CAMBRIAN.

Bernardston.

106, 107, 127, Clay slate.

108, Argillaceous schist with 107.

131, 132, Wrinkled slate.

Guilford.

109, Clay slate.

110, Novaculite.

Vernon.

121, 122, 125, Argillaceous schists.

124, Blackstone.

COÖS SLATES AND SCHISTS.

Bernardston.

128, 129, Siliceous micaceous rock.

130, 138, 140–142, Pimpled slates.

133–137, Argillaceous schists.

139, Staurolite slate—Purple's quarry.

Vernon.

163–166, Staurolite mica schist.

Northfield.

167–171, Mica schist.

Section along the road from West Northfield to the state line, and thence to the second road crossing the line.

143, Quartzite.

144, 145, Micaceous quartzite.

146, Gneiss.

147, Argillo-mica schist.

148, Hornblende schist.

149, Micaceous quartzite.

150, Breccia.

151, Argillo-mica schist.

152, Gneiss.

153, Compact hornblende schist.

154, 155, 156, Staurolite mica schist.

157, Indurated argillaceous schist.
158, Mica schist, with staurolite.
159, Indurated schist.
160, 161, 161 a, Staurolite schist.
162, Clay slate—second road crossing the state line.

Hinsdale—south of the village.

172, 173, Quartzite.
174, 175, 177, 180, 181, Mica schist.
176, Staurolite schist.
178, Mica schist, coarsely crystalline.
179, Mica schist—pyritiferous.

Hinsdale—north of the village.

182, 184, 186, 189–191, Staurolite mica schist.
183, 185, 187, Mica schist.
188, Argillaceous schist.

Chesterfield.

192, Granite, with plumose mica.

History of Exploration.

This sketch will not be complete without extensive reference to the writings of my predecessors in this field. The first notice of this limestone I have seen in print is in the *Report on the Geology*, etc., of Massachusetts, published by my father, in 1833, page 295. He says of it,—

Since the first edition of the first part of my report was published, I have had the satisfaction of discovering organic remains of the family of encrinites in the bed of limestone in Bernardston. From the highly crystalline character of this rock, I had been led to suppose it older than the encrinal or transition limestone; and that it formed a bed in the argillaceous slate, which appears to be one of the oldest varieties of that rock. But its organic remains settle the question of its position; and, differing in dip and direction from the slate, I have been led to doubt whether it really forms a bed in that rock. The slate in the vicinity runs more nearly north and south, and the dip is nearly 90°; but the limestone runs N. E. and S. W., and dips S. E. not more than 20°. Besides, the rock that is found above the limestone appears to be mostly composed of quartz, and probably ought to be called quartz rock. It does not lie in immediate contact with the limestone, nor is the slate visible immediately beneath the limestone. Upon the whole, I am of opinion that this limestone lies beneath the oldest variety of the new red sandstone series, which has been described, and upon the argillaceous slate, in an uncomformable position. * * * *

The encrinal remains in the Bernardston limestone are usually quite imperfect; but the transverse septa and the central perforation are generally distinct. Plate XIV, Fig. 47, exhibits an end view of one encrinus, about an inch in diameter, and a view of another lying horizontally in the rock.

No additional facts respecting the limestone appear in the final report of 1841. It is noticed in a brief paper *On the Geological Age of the Clay Slate of the Connecticut Valley, in Massachusetts and Vermont*, presented to the American Association for the Advancement of Science, in 1851 (2 vol., p. 299). The substance of the paper is, that this limestone has been discovered to underlie a portion of the slate, and hence is thought to be of the same age with it. The fossils were shown to James Hall, who believed they might belong to the period of the Onondaga limestone of New York; at least, that they are not more ancient than that rock.

Thus we fix the age of this clay slate as a part of the Devonian system, unless there is some mistake in the observations or the opinions as to their character. If this result be admitted, it does not follow that all the rocks of the Green and White Mountains are no older than fossiliferous rocks, as some maintain; for the slate formation in the Connecticut valley is manifestly a newer rock than those which succeed, either on the east or the west. Perhaps it is a portion of the Hudson River slate, which once arched over the intervening Hoosic mountain, and which has been subsequently worn away, except in this deep valley. * * * I have met nowhere with rocks more thoroughly crystalline than those which constitute most of the White Mountain ranges. Gneiss, mica slate, and hornblende slates, just such as you find in the central Alps, constitute most of the White Mountain ranges. * * * We shall be cautious in admitting a conclusion [that the New England rocks are as new as the paleozoic] which goes to the very extreme of metamorphism, without decisive evidence. We should at least wait till the White Mountains have been more carefully studied.

Not far from this same year, the locality was visited by James Hall and Sir Charles Lyell, but none of their publications add anything to what has been already stated in this historical sketch.

A fuller account, with a section, is given in the geology of Vermont, based upon my father's and my own observations made in 1858. They have been given essentially without change in the preceding description of the section (Fig. 72).

The fullest description of this region hitherto published was prepared by Prof. J. D. Dana, and has been already alluded to. The facts of his paper do not differ materially from my own, as given above, and I will not quote his statements of the distribution and positions of the strata, but present his conclusions. I feel very grateful to Prof. Dana for the interest he has taken in this field. He perceived the true relations of the Coös group to the mica slates of Bernardston before any one else; and it is a pleasure to me to be able to confirm this conclusion by actually tracing the Bernardston slates, ledge by ledge, to Chesterfield, and so on to Haverhill, and finding them to be the same with what I have called the Coös group in New Hampshire. If the Bernardston slates belong to the

Helderberg series, it is certain the principal part of the Coös series must go with them.

1. This Helderberg series in central New England comprises a large part of the common kinds of metamorphic rocks, gneiss, of several varieties, undistinguishable lithologically from the oldest; hornblende rock and schist; sienitic gneiss; coarse mica slate; staurolitic slate.

2. A large part of the rocks that have been distinguished as of the "Montalban" or "White Mountain Series" in New Hampshire, and regarded as of pre-Silurian age, are here included, and are hence nothing but altered Helderberg sediments. It is therefore far from true that "the crystalline rocks of the Green Mountain Series," and "the whole of our crystalline schists of eastern North America, are not only pre-Silurian, but pre-Cambrian in age." *Hunt.*

3. The passage of quartzite into gneiss is exhibited in different ways. The presence of mica in the quartzite is one of the steps; but at the locality marked *q* [15] on the map, part of the quartzite is very finely banded with white and gray. The white portions are feldspathic, as is proved by their fusibility before the blow-pipe; while the light gray are quartz, and some short darker lines are micaceous. Thus this region, like that of Berkshire, demonstrates that gneiss and quartzite are rocks of the most intimate relations,—as intimate as mud and sand along sea-shore flats. Part of the feldspathic layers widen at intervals into forms an inch or more thick at the middle, but they are generally nearly even.

4. Hornblende rocks of the purest kind and of great extent are here so intercalated with quartzite and mica slate, and so often graduate into one or the other, that all must have been alike a result of the metamorphism of sedimentary beds. It is not possible that these hornblende rocks, constituting part of a Devonian or Upper Silurian formation, should have come from the metamorphism of beds of a pre-Silurian, chemically-deposited, meerschaum-like hydrous silicate.

5. The Bernardston, South Vernon, and Northfield beds being of Helderberg age, the Coös group, which is but the northern continuation of the same series, is, if correctly traced out, also Helderberg. Hence, in the era of the Lower Devonian, the Connecticut valley, from the latitude of Bernardston northward, was an arm of the sea, extending down from the great Devonian Gulf of St. Lawrence. Crinoids require the best of ocean water, and thus they had it in central New England.

6. The Bernardston beds have been supposed to be Lower Devonian or Upper Helderberg, on the ground of Hall's opinion, and also that of Billings's, recently obtained. But both of these paleontologists speak of it only as the most probable conclusion from the fossils thus far found;—they may belong to the Lower Helderberg or later part of the Upper Silurian. According to Prof. Hitchcock, a slate containing imbedded crystals of mica, just like that of Bernardston, occurs near Lake Memphremagog, where there are fossil corals of unquestionable Lower Devonian types; and, as the same slate follows the Coös series through to that region, the lithological resem-

blance suggests identity of age, though not proving it without a further stratigraphical study of the region between.

7. At Littleton, also, fifty miles south-south-east of Lake Memphremagog (S. 24° E.), there is a limestone, half metamorphosed, containing Helderberg corals,—one of the important discoveries of Prof. Hitchcock, to whom I am indebted for guidance over the region. The limestone is associated with quartzite and clay slate, and also with a series of chloritic rocks, partly feldspathic, including chloritic slate and a kind of protogene, in which a pseudophite-like mineral is disseminated in small grains; and it appeared to me that all were conformable. If this conformability is sustained by further observations, we shall have here the additional lithological fact that chlorite rocks, including protogene, may constitute metamorphic beds of Helderberg age.

8. The facts which have been presented sustain the statements made on an early page of this article, that lithological evidence of geological age is to be distrusted. If, when used by one who has made it a special study, it leads to the conclusion that true *Helderberg* rocks in the White Mountain series are of Cambrian or earlier age, it is surely a bad reliance. If it also makes out that Green Mountain rocks are of Huronian age, or of some pre-Silurian period, when in reality belonging to the later part of the *Lower Silurian*, geologists may well be afraid even of its suggestions, unless it have sure stratigraphical support. "Huronian" areas have been defined in various parts of the country and the world on the basis of this evidence alone; and in such cases who knows anything whatever with regard to the real age of their rocks? It is probable that the rocks considered characteristic of the Huronian occur also among true Laurentian terranes; it is certain that they do in formations later than the Lower Silurian.

Finally, what reason is there in chemistry or geology why crystals of andalusite and staurolite should have been made only in pre-Silurian times? Andalusite consists simply of silica and alumina, and staurolite of the same, along with iron. These three ingredients are now and ever have been the most abundant of all the mineral constituents of the globe. With or without the iron, they are the materials of all clay deposits; and clay deposits, from the decomposition of granite, gneiss, and related rocks, have been forming all over the globe, and increasing in amount, ever since these rocks began their existence. They are therefore the very last minerals that should be thought of as pre-Silurian "fossils." Were zirconium, or any other of the rare metals a constituent in the species, there would be some reason for suspecting their restriction to the more ancient formations, since later sediments would contain only traces of them. But silica, alumina, and iron belong to all time. These remarks apply equally to chlorite, in which these three ingredients occur, with only a little magnesia besides, and water.

9. The epoch of disturbance, in which these Helderberg rocks of the Connecticut valley were upturned and crystallized, was probably that closing the Devonian, when, as Dawson and others have shown, extensive upturning, plication, and crystallization of Devonian and older rocks took place over New Brunswick and Nova Scotia. It was

the most prominent epoch of mountain-making on this eastern border of the continent, after the Lower Silurian. Facts are against any earlier epoch; and the only other probable suggestion is, that the time was after the Carboniferous age, when the Alleghanies were made. Hence the various Helderberg rocks of the Connecticut valley have their actual date, as crystalline or metamorphic rocks, either from the close of the Devonian or that of the Carboniferous era. The conclusions which have been presented are based on a foundation of facts, certainly as far as the region of Bernardston, Vernon, Northfield, and Hinsdale is concerned, where my own observations were made; and, judging from the descriptions of Prof. Hitchcock, they appear to be sustained as regards the Coös range to the north. *Amer. Jour. Science*, iii, vol. vi, pp. 348–351.

Several other conclusions of a hypothetical character, relating more especially to southern New England, follow the above, but do not need to be quoted here.

Views of J. P. Lesley. Under date of October 27, 1858, Mr. Lesley wrote me, saying he had obtained large crinoids and a possible *Cyathophyllum* from this limestone, which had been sent to Prof. Hall for determination. "My impression, from the whole aspect of the ground, was, that I was on old and familiar ground, namely, V, VII, and VIII, with us,—Clinton and Helderberg,—but such impressions are never to be trusted. The limestone may be Onondaga, and have a *Cyathophyllum.*"

Conclusions.

Now that no further field-work is possible, I will state fully what conclusions seem to be warranted in regard to the order of all the formations in this Helderberg area; how far their age can be determined from the presence of the crinoidal limestone; and what may be learned by a comparison of the rocks in the Helderberg and Ammonoosuc areas.

1. The porphyritic gneiss of Winchester is encircled by strata of the Bethlehem group. Therefore the first is the older of the two, and, as we shall see by further comparison, the oldest formation in the Connecticut valley, as well as in all New Hampshire.

2. The Bethlehem gneiss in Hinsdale and Vernon is encircled and overlaid by hornblende schist. The same has been observed in five or six other areas, so that the relations between these two groups of rocks in the Connecticut basin may be regarded as thoroughly understood. Hence, whenever the hornblende seems to underlie the gneiss, we know that it has been inverted.

3. Quartzite encircles the hornblende. Hence, as the relations of the

hornblende and Bethlehem gneiss are well understood, the innermost being the oldest, it follows that the quartzite is newer than the hornblende schist. It may be there is more than one quartzite in this field; but none of the authors who have written about these rocks have assumed the existence of quartzite of more than one age.

4. There was probably a long interval between the period of the deposition of the hornblende and quartzite, so that there is an unconformity between them; and the presumption is, that the quartzite west of the hornblende in Vernon lies upon the latter, both strata dipping easterly, and the former may not be inverted. The possibility of inversion here has been suggested heretofore. The clay slates of West mountain and Guilford are universally admitted to underlie the quartzite unconformably. Therefore we have both the period corresponding to the stratigraphical break, and the time occupied by the deposition of the clay slates, to represent the interval between the quartzite and hornblende schist. The quartzite has also been mentioned as unconformably over the hornblende east of Otter pond in Gill. The superiority of the quartzite to the gneiss, in the absence of the hornblende, is well shown on the Perchog river in Winchester (Fig. 71).

5. It is well agreed, also, that the Coös slates overlie the quartzite. This appears from the section at Mr. Williams's (Fig. 73); from the relations of the quartzite east of Fall river to it (Fig. 72); and from many sections that have been described in the other Connecticut areas. Mr. Huntington has come to the same conclusion in his essay upon the rocks between Charlestown and Chesterfield.

From these conclusions, others of importance follow.

6. The Coös slates, starting from the Bernardston plain, cross transversely the clay slate, quartzite, hornblende schist, and Bethlehem gneiss before reaching the Chesterfield deposits of the same age, which extend uninterruptedly thence to Haverhill, embracing the typical area of this name in Hanover, Lyme, and Orford. Hence it is the newest of all the several series named.

7. It follows that there are important inversions in this whole field, where no one would suspect their existence without a previous knowledge of the facts now set forth. Perhaps the most singular is that of the Coös slates between Fall river and South Vernon. They dip at a very

small angle, yet must be inverted along their eastern border (Fig. 71); and they may possibly fold over the quartzite by the school-house opposite Williams's (Fig. 72). The quartzite range is also inverted;—it lies between two hornblende bands, all three dipping south-easterly. Hence it must constitute an inverted synclinal. There is the possibility, however, that there may be a band of the Bethlehem gneiss between these hornblende areas. I have so called them upon the map, but would prefer the conclusions of Prof. Dana, that we must not rely too strictly upon lithology; and, as by his conclusion (3) gneiss and quartzite are rocks of the most intimate relations, we may say that the very quartzose gneiss of this range is not of Bethlehem but of Coös age. As once before intimated, the hornblende schist of Northfield may be regarded as the repetition of two bands of the same rock to the east, and of the Leyden and Shelburne Falls groups farther west, though some of them may be apparently monoclinal. Furthermore, many of the easterly-dipping mica schists in Hinsdale and Winchester may be regarded as inversions, particularly near their eastern border. I cannot now state all the overturns existing in this area.

8. It is not so easy to be sure of the repetitions of the quartzite, yet the following seem probable: On the east we have the range from the Perchog river in Winchester through Northfield. This must pass under mica schists, and come up in the range at Doolittle's saw-mill, at South Vernon and West Northfield, which passes south-westerly into Bernardston and Gill. These ranges are connected naturally and obviously, the dips not being inverted. The next repetition is the range near a school-house, a mile north of Bernardston. Though it seemed to point directly to the quarry back of Williams's, the discovery of the northward continuation of the latter makes any connection between them improbable, save by a synclinal fold beneath the valley of Fall brook. Then, if there is but one band of quartzite, there must be a repetition of it upon the Williams section (Fig. 73). The dips that have been observed show a tendency of the rocks to conform to this position. The north-westerly dip of this rock in the north-west part of Gill indicates a connection between the Williams Hill range and that east of Fall brook (Fig. 74). We find here, also, that all the dips along the eastern border of this largest range are not inverted.

9. Next will follow the most singular of all our conclusions, the proba-

bility that the crinoidal limestone occupies a small valley in the quartzite, and therefore would be newer rather than older. In other words, it may be the newest rock in this Helderberg section, resting upon the quartzite, instead of underlying it, as is commonly represented. Whether it may not crop out somewhere between the quartzite and Coös slates, remains to be seen. There is nothing in its relations, if correctly interpreted, rendering this an impossible position. The quartzite and slate in the field north stand vertically and dip west. Though the limestone at the quarry seems clearly to dip under the quartzite, we must not forget that the state of things is entirely different close by. That this limestone should bear the structure of an inverted synclinal may seem strange, but it is not any more singular than many similar exposures of Chazy limestone in the Champlain valley, as shown conclusively by the presence of fossils. Lesley's views seem to confirm this opinion.

This view agrees with the interpretation given heretofore regarding the related rocks in the Ammonoosuc area. There the quartzite underlies the limestone in many exposures. In that region the staurolite slates nowhere touch the Helderberg. In fact, a conglomerate associated with the crinoidal layers contains fragments of a rock supposed to have been derived from the development of Coös schists not very far away, but separated by a well-marked Huronian ridge. There is nothing in the relations of the same two rocks in Bernardston to prevent us from interpreting them in the same way, *i. e.*, to regard the slates as much older than the limestone.

10. Granting that the staurolite slates of Bernardston are the southern end of the Coös group, it does not follow that the latter are of Helderberg age, as Prof. Dana supposes; for we have first to prove that the former are so intimately associated with the limestone as to be necessarily of the same age. These slates nowhere touch the limestone, so far as known. They are separated by the quartzite.

11. Nevertheless, the Coös rocks are the newest in the whole Connecticut valley north of Massachusetts, unless it be this fossiliferous limestone. Provided some intimate connection can be made out between them,—and there is plenty of ground to work over in search of the paleontological evidence,—they may all be regarded as Helderberg. There is nothing incongruous between a Helderberg Coös series and the doctrines laid

down in previous chapters regarding the great antiquity of most of the New Hampshire rocks.

12. In case the Coös schists are to be regarded as of Helderberg age, the whole of the Calciferous mica schist must be taken with them. These occupy about a third of the area of Vermont, and such reference would add much to the breadth of Paleozoic areas in New England. This was very nearly the view of Logan, of twenty years since, who supposed that this formation belonged to the Niagara group.

13. There is no connection whatever between the Coös and Montalban groups, as is inferred by Prof. Dana. If we grant the former to be Helderberg, it does not bring the latter any higher up, since all the White Mountain rocks have been shown to underlie them unconformably.

14. There is no interstratification of the chloritic rocks at Littleton with the Helderberg. There may be a few small bunches of chlorite in the limestone. Chlorite is a mineral that may exist wherever rocks have been elevated and permeated by fluids transporting the proper chemical reägents. Its presence does not indicate a high degree of metamorphism. The chloritic rocks do not come anywhere near the Bernardston series, so that it is clear they do not belong to the Helderberg series, even upon the most comprehensive definition of them.

15. It is probable that the epoch of elevation of the Helderberg rocks along the Connecticut valley occurred in middle Devonian times. We find at Memphremagog lake the upper Helderberg limestone, and also elsewhere in northern New England, but no later groups. In the east part of Maine I have found Helderberg strata, elevated at a considerable angle, overlaid unconformably by Hamilton beds. It is presumable that this epoch of elevation in Maine may correspond with that in this valley. I am persuaded it was an epoch of elevation of the greatest importance, perhaps more so than any other that has manifested itself in New England. (See page 263.)

16. Interpreting the facts as above to harmonize with what seems well established about the older New Hampshire rocks, it is clear that we may still eliminate the thoroughly crystalline schists from the catalogue of Paleozoic formations; and, conversely, the Helderberg rocks have not been very much metamorphosed, even if we refer the Coös rocks to that age. Staurolite and andalusite may be found anywhere, because their

constituents are universally common, as explained by Prof. Dana; so that their presence does not argue a high degree of metamorphism.

APPENDIX TO CHAPTER IV.

The Huronian System.

On page 267 I have promised at this place to discuss the claims of the Huronian system to recognition. It will be done briefly, while our comparisons must extend over a very wide territory.

In the large geological map of the United States, prepared in conjunction with Prof. W. P. Blake for the Smithsonian Institution, and exhibited in Philadelphia at the Centennial Exposition, seventeen areas of the Huronian system west of the St. Lawrence river are represented, irrespective of those along the Atlantic border.

The first use of the word Huronian I find is in the *Esquisse Geologique du Canada*, prepared by T. Sterry Hunt for the Paris Exposition of 1855. It is represented as being a series of grits, schists, limestones, conglomerates, and diorites, reposing unconformably upon the Laurentian, and lying beneath the Silurian. It is said to hold about the position of the lower Cambrian of Sedgewick. The area from which the name was derived lies upon the north shore of Lake Huron. A section from the Laurentian outcrop on the main land opposite Drummond island, and running a little north of west to Lake George, would pass in succession through all the members of the series. I find these overlaid by the St. Peter's (Chazy) sandstone, according to Logan.

The following is a section of the Huronian rocks from this typical locality, as derived from the geology of Canada, 1863, and the accompanying atlas, wherein the distribution of the several members is clearly represented with colors.

	Feet.
l. White quartzite, chert, and limestone,	2,100
k. Yellow chert and limestone,	400
i. White quartzite,	2,970
h. Red jasper conglomerate,	2,150
g. Red quartzite with greenstone; ripple marks,	2,300
f. Upper slate conglomerate,	3,000
e. Limestone, with diminutive contortions,	300
d. Lower slate conglomerate, with greenstone,	1,280
c. White quartzite,	1,000
b. Green chlorite slate,	2,000
a. Gray quartzite,	500
	18,000

This typical locality does not enable us to restrict the limits of the system so closely as may be done upon the south side of Lake Superior, in the northern peninsula of

Michigan. The underlying rock is the same, but it is covered by the "Copper series," a group of strata devoid of fossils, and situated beneath the Lake Superior sandstone, which is now commonly esteemed as the equivalent of the Potsdam. The Huronian is therefore older than the fossiliferous Cambrian.

Huronian System of Michigan.

The latest studies in this region have been made by Messrs. Pumpelly, Brooks, and Wright, and are described partly in the report upon the geology of Michigan, and partly in special papers, by Major T. B. Brooks, in the *American Journal of Science*. I accept these latest studies as the best. The system is divided into twenty parts, and I give in parallel columns the specifications concerning their nature in the two best known districts, Marquette and Menominee. The Huronian is said to be distinctly unconformable to the Laurentian.

Marquette Region.	Menominee Region.
	XX. Granite and gneiss.
XIX. Mica schist, with staurolite, andalusite, and garnet; quartz, in bunches, and rare hornblende seams.	XIX. Mica schist, with staurolite and hornblende schist—rarely gneiss—chloritic schist; granitic dykes.
Quartzite, and probably soft slate.	XVIII. Quartzite, with chloritic, micaceous, and argillaceous schists and slates.
XVII. Anthophyllitic (?) schist, usually magnetic and manganiferous.	XVII. Chiefly hornblende schist and related greenstones and chloritic schist.
XVI. Banded ochrey porous quartz schist.	XVI. Chiefly clay slate, often ferruginous; also hydro-magnesian schists; micaceous quartz schists; hematite schists; rarely hornblende rocks and greenstones.
XV. Blackish argillaceous slate, rarely micaceous, occasionally with garnets.	XV. Gabbro or diabase, with greenstones; ferruginous and actinolitic schists.
XIV. Gray arenaceous quartzite; quartz conglomerate.	XIV. Unctuous hydrous magnesian schist; sericite, quartzite, and chloritic greenstones.
XIII. Hematite and magnetic ores; banded jaspery schist, and beds of chloritic and hydro-mica schists.	XIII. Chloro-argillaceous slate, chloritic schist, diorite, carbonaceous slate, and anthophyllitic schist.
XII. Red quartz schist, with banded micaceous iron; quartzose limonite ores.	Hornblende rock and chlorite mica schist.
XI. Diorite, hornblende schist, chlorite schist, chloritic-looking mica schist; rarely hornblende gneiss.	Micaceous clay slate (phyllite), with seams of quartz; carbonaceous slate.
X. Hematitic and limonitic schists, often manganiferous; siliceous schists; garnetiferous, anthophyllitic schists.	Whitish dolomitic marble, with crystals of tremolite and wollastonite.

IX. Hornblendic rock, diorite, and diabase.	Clay slate, quartzite, mica schist.
VIII. Ferruginous quartzose flags; clay slate and quartzite.	Hornblende schist.
VII. Hornblendic rocks.	Hydrous magnesian schist and probably ferruginous clay slate.
VI. Ferruginous quartzose schist, clay and chloritic slates.	VI. Hematite schist and siliceous flag ore; ferruginous clay slates; hydrous magnesian schist; rarely granite dykes.
V. Quartzite verging into protogene; beds of dolomitic marble; novaculite; rare chlorite and mica schist; sienite, diorite, diabase, hornblende schist, conglomeratic quartzite and quartzose iron ores; talc schist.	V. Dolomitic marble; rare beds of quartzite and hydrous magnesian schist.
	IV. Arenaceous magnetic mica schist.
	III. Soft schist, not made out.
	II. Quartzites, arenaceous, micaceous, and actinolitic. Ripple-marked.
	I. Protogene gneiss; hydrous magnesian schist; schistose conglomerate; quartzite and diorite.

Major Brooks devotes much attention to Nos. XIX and XX of the Huronian as they occur in Wisconsin, just over the Michigan line.* Though the rocks resemble the Laurentian, he is satisfied they occur above all the other eighteen Huronian members, while lying unconformably beneath the copper-bearing series, which he calls *Kewenawian*. Readers of our New Hampshire geology will recognize the resemblance between these youngest Huronian rocks and our Coös or possibly the Montalban series. The position at the summit of the Huronian is in exact agreement with the place of our Coös group. This resemblance is sufficient to attract the attention of observers, and to give new interest to the determination of the New England groups.

Brooks estimates the thickness of the Menominee groups (exclusive of XX) at 12,000 feet, and only half that amount in the Marquette region. Steatite and serpentine are rare in these Michigan rocks.

The Huronian in New Brunswick.

Under the name of Coldbrook, Messrs. Matthew and Bailey describe rocks of this age near St. John, in New Brunswick. They are the following:

Upper Coldbrook.

b. Red and greenish-gray argillites, 170 feet.

a. Red sandstones and conglomerate.

6. Gray feldspathic sandstone, beds chloritic schists, conglomerate.

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* *Amer. Jour. Sci.*, iii, vol. xi, p. 206; also vol. xii, p. 194.

Lower Coldbrook.

5. Greenish-gray clay and micaceous slates, with slaty dolomite.
4*b*. Feldspathic and dioritic sandstones, with chlorite and epidote.
4*a*. Sandstones, chloritic schist, diorite, and especially petrosilex.
3. Fine gray dark diorites.
2. Pinkish or white felsites, and feldspathic quartzites, } half a mile thick.
1. Diorites, ... }

In other sections of the province the red felsites and dolomites are both more prominent than in the Coldbrook series above.

Views of Thomas Macfarlane.

Allusion has been made (vol. i, p. 532) to the views of this gentleman, erroneously said to be *James*, who is well known for his book on the *Coal Regions of America*. Mr. Thomas Macfarlane thinks he was improperly referred to by Dr. Hunt, and has taken the pains to state his views concisely in the *Canadian Naturalist* for 1871. He commences by remarking upon the incongruity of Logan's map, in representing by a single color the metamorphic Quebec group of Eastern Canada, the Calciferous sandstone, and the upper copper-bearing rocks of Lake Superior. I will quote from what he says respecting the Huronian and Cambrian rocks of Canada, which of course applies equally well to our Connecticut Valley Huronian, their southern continuation.

"In referring to the gneissic series of the Green Mountains, Dr. Hunt makes mention of my having, in 1862, 'ventured to unite it with the Huronian system.'* I am not aware of ever having done this, nor do I think that there are even good lithological reasons for assuming the identity of the two series. In the paper referred to by Dr. Hunt, in which I instituted a comparison betwixt the rocks of Norway and Canada, I endeavored to point out the resemblance between the rocks of Tellemarken, or the quartzose group of the *Urschiefer*, and Sir W. E. Logan's Huronian series, as developed on the north shore of Lake Huron. As differing from these, I expressly distinguished the Dovrefjeld slates, the schistose group of the *Urschiefer*, and pointed out their resemblance to the semi-crystalline schists of Vermont and Eastern Canada. The lithological differences betwixt the Tellemarken rocks and the Dovrefjeld slates in Norway are just as decided as between the Huronian series and the Green Mountain schists in North America. Enormous beds of quartzite, and perhaps felsite and peculiar conglomerates, characterize the Huronian, while micaceous, chloritic, and argillaceous schists and serpentines distinguish the Green Mountain rocks. It may be that these differences are not sufficient to justify us in regarding them as belonging to different formations, but they would seem to afford grounds for distinguishing them as groups. Therefore in my paper on the subject † I have separated the quartzose from the schistose division of the *Urschiefer*, the former and not the latter being identified with the Huronian. If it were considered advisable to distinguish the Green Mountain

* *Dr. Hunt's Address*, p. 33. † *Canadian Naturalist*, vii, 161.

rocks as a separate formation, it would seem to me most advantageous for the science to use the term Cambrian for this purpose, as has already been done by eminent geologists, and as I propose to do on the present occasion.

"THE CAMBRIAN SYSTEM. In studying the various geological formations which present themselves in Canada, it is impossible to avoid comparing their architecture, lithology, and mineral contents with the same or similar formations in European countries. Any one who has had an opportunity of observing them will at once perceive that not only do the Dovrefjeld slates resemble our eastern townships rocks, but also that the primitive and transition rocks of Saxony have much in common with them. Moreover, in examining the manner in which the eastern townships rocks succeed each other, the analogous order of the schists of the Erzgebirge at once presents itself to the mind, and suggests ideas as to the respective ages of the corresponding rocks in Canada.

"When the traveller in the Saxon Erzgebirge mounts the steep escarpment which borders that range of mountains towards Bohemia, passes northward up the valley of Joachimsthal, and stands at last on the ridge overlooking to the south the valley of the Eger, with Carlsbad in the distance, he has entered the primitive region of Saxony, rendered classical in geology by the labors of Werner and his successors. If the journey is continued northward, by Annaberg, Elterlein, and Lössnitz, to Stollberg, gneiss, mica schist, and clay slate formations are passed over successively, and at last unequivocal sedimentary and fossiliferous formations arrived at. The order of succession of these schists of Saxony afforded the foundation for the law, long ago propounded by Werner, that mica schist forms the lower, and clay slate or its substitutes, chlorite and talc schist, the upper part of the *Urschiefer*. Further, since the mica schist, in those districts where the primitive formations are present in all their completeness, is found to be supported by gneiss, it follows that in the architecture of these oldest rocks the three groups of gneissic, micaceous, and argillaceous schists succeed each other in ascending order. It must not, of course, be forgotten that in some instances one or the other of these groups may be absent;—those which are present, however, always show the order of succession here indicated.* This is observed not only in the Erzgebirge, but also in the Fichtelgebirge, the Südeten, the Riesengebirge, Scotland, Ireland, Norway, and Hungary.

"Turning now to south-eastern Quebec and the states adjoining it, we find that following the line of the Grand Trunk Railway north-westward, the succession of primitive and even transition strata occurring in the Saxon Erzgebirge is repeated. After leaving the granite and gneiss of New Hampshire, we cross the mica schist district of Compton county, and then chlorite and clay slates from Sherbrooke to Richmond. From the latter place, through the townships of Durham, Acton, and Upton, green and grayish slates, graphitic slates, grauwacke sandstone, and gray limestone, in strata more or less highly inclined, are traversed. All this time the country becomes less and less hilly, the rocks less and less frequent, until near Britannia mills, or, still keeping in a

* Naumann, *Geognosie*, ii, 155.

north-west direction, near the village of St. Helene, the wide-spread alluvium of the St. Lawrence valley is reached, occupying an area of several thousand square miles, in which very few rock outcrops are observed. This area is said to be underlaid by the Utica and Hudson river formations, which again are said to overlie conformably the Trenton and Chazy limestones, and the Calciferous and Potsdam sandstones. All these rocks form part of a series of sedimentary strata occupying certain areas in the valley of the St. Lawrence, lying horizontally or nearly so, and supposed to be of Lower Silurian age. The Potsdam sandstone is the lowest member of this group of strata, and is regarded as the oldest Silurian rock, and possessing even greater age than the mica schists and clay slates of the eastern townships. Indeed, in the attempts which have been made at determining the age of the latter rocks, it has always been the rule to begin with the Potsdam sandstone as the oldest rock, and to assume that those to the eastward (regardless of their lithological characters) followed each other in ascending order. Any one who has studied the structure of similar regions in Europe, such as those above mentioned, can scarcely fail to come to the conclusion that the opposite of this assumption is the truth; that the oldest rocks are those of New England, and that, as we come north-westward, we pass over more and more recent strata. This view would be maintained in spite of the prevailing dip to the south-eastward, which can only be accounted for by assuming, with Emmons, that the strata have been overturned,—this, and indeed the plications of the whole series, having been caused by some enormous pressure from the south-east.

"In distinguishing the Green Mountain series, Dr. Hunt seems to have been unable to leave the beaten track, in which he had previously travelled, and to regard the more eastern crystalline rocks as the older instead of the newer. He still adheres to the idea that the Green Mountain rocks, because they apparently underlie the White Mountain mica schists, etc., are the older rocks. In referring to the Laurentian system, it has been shown how entirely inconsistent with European experience this supposition is.

"In the preceding section the opinion has been expressed that Dr. Hunt has gone too far in asserting the pre-Cambrian age of the Green Mountain schists. In maintaining their pre-Silurian age, however, he merely adopts a view advocated by myself as early as 1862. In describing the Dovrefjeld slates, and comparing them with similar rocks in the Quebec group and Green Mountain series, I made the following remarks: 'Different views prevail, as to their age, in different countries. In Cornwall they are considered Devonian; in Scotland, Lower Silurian; and in Bohemia, as in Norway, pre-Silurian. In Belgium, Rhenish Prussia, Westphalia, and Nassau, they are by some geologists regarded as Devonian, and by others as belonging to an older formation. In East Russia, on the western slope of the Ural Mountains, they are supposed to represent Lower Silurian strata. A dissimilarity of views will probably continue to prevail as to the position of these rocks until the question is decided as to what value, in the absence of fossils, the petrographical characters of a group, taken in connection with its stratigraphical position, should have in determining its age. Perhaps there prevails at present too much of a tendency to attribute extraordinary influences to metamorphic agencies. So soon as the true limits and effects of metamorphism are recognized, it will probably be acknowledged that whatever view may be entertained as to their origin, the schistose rocks above referred to *underlie the Silurian and all unaltered or metamorphosed fossiliferous strata.*'"

The Huronian of Quebec.

In consequence of the changes of opinion respecting these rocks in the more western area, or that represented upon Plate I and mentioned upon page 12, it is difficult to estimate the proper succession and thickness of the several members. Sir W. E. Logan has described them under the general name of Quebec group, with three divisions. He has grouped together a large series of fossiliferous Cambrian and metamorphic rocks, assuming that the one was the equivalent of the other. I have endeavored to separate the fossiliferous from the metamorphic portions, with the assistance of Dr. T. Sterry Hunt, upon Plate I, though it may not be so easy to decide between the bands as belonging to the one or the other series. On page 12, I have stated that the western band of Huronian extends to the end of the peninsula of Gaspé. That is an error. After eliminating the fossiliferous portion, the metamorphic area is found to reach only about as far east as the city of Quebec, and it is properly represented upon the map, and there is also a small isolated area near the end of the peninsula. The line of the Bayer and Stanbridge anticlinal is the proper division between them.

Logan's classification, as derived from the report upon the geology of Canada for 1866, is the following: The lower or Levis series consists of limestone, black shales, gray shales, dolomites, and conglomerates, amounting to 6,145 feet for the maximum thickness. This carries numerous graptolites and other fossils distinctly belonging to the region of the Calciferous and Chazy.

The middle or Lauzon division is marked by a predominance of green, red, and purplish shales, with thickness ranging from 100 to 6000 feet. Two brachiopods occur in it. The metamorphic portion is bounded by two magnesian bands, dolomite, soapstone, or serpentine. Logan supposes the soapstone and serpentine are altered dolomites. These two bands are accompanied by beds of metallic ores, particularly of copper. Of the three synclinal areas, the most western is regarded as unaltered, and the two eastern as true Huronian. The second synclinal carries chlorite and epidote, which are wanting in the first or Paleozoic basin. Other rocks are talcoid schists, greenish micaceous sandstone, nacreous slates, etc. The third synclinal is like the second lying east of the Green Mountain range. The upper or Sillery division, unaltered, consists of greenish (slightly calcareous) sandstone, passing into fine conglomerates, about 2000 feet thick. The metamorphic portions are chiefly epidotic and chloritic schists and quartzites.

From this series, as proposed by Logan, we must eliminate all the fossiliferous portions, and invert the order. The fossils known to occur in the unaltered formations agree to this reversal, and we find the Sillery and Lauzon groups correspond to the older Cambrian of England, and the Levis to the Skiddaw slates, or the lower part of the Cambro-Silurian of America. This view renders it unnecessary to regard these fossiliferous groups as at all connected with the proper Huronian, or the rocks of the two eastern synclinals; but it shows that inversion is the rule for these rocks near Quebec, and therefore the rocks east of the Sillery are older. This is in agreement with the recently quoted view of Mr. Macfarlane, and has been also insisted upon by Dr. Hunt.*

Separating the eastern part of the area called Quebec group by Logan, we may clearly understand it to be older than the fossiliferous Cambrian of any part of the world, and therefore to be named Huronian, unless we adopt the suggestion of Macfarlane. He is probably correct in referring this eastern portion of the Quebec group to the upper division of the Urschiefer, in distinction from the lower, which may be the same with the Michigan rocks. But instead of calling the upper division Cambrian, it is better to say *Upper Huronian;* and, if further examination confirms the suggestion that none of the upper division is to be found about Lake Huron, we may call that the *Lower Huronian.* Where it is not possible to define between the upper divisions, it will still be proper to use the general term for the whole. Our statements respecting these rocks in New Brunswick indicate the presence of the felsites of the lower division with the more argillaceous upper group.

The Vermont Huronian.

The Vermont Huronian, save that along Connecticut river, is the southward continuation of the Quebec group of Canada. It is divided into two parts by the central ridge of the Green Mountains, which continues a few miles into Canada.

Macfarlane follows the report on the geology of Vermont in regarding the Green Mountain ranges as older than the adjacent Upper Huronian. We have in that early publication (1861) insisted that these Green Mountain rocks underlaid the green schists upon both sides (see p. 31), and they are consequently older. The name Green Mountain gneiss, as applicable to this formation, was in use in 1846; and therefore the use of the same geographical designation by Dr. Hunt, in 1871, for the Huronian, is both inappropriate and improper, on account of prior usage. The Green Mountains are not Huronian at all, though flanked by it upon both sides in the northern half of Vermont. They belong to the Montalban series. Adopting the principle of inversion, as applied to the members of the Quebec group, we find they overlie these Montalban gneisses in the proper order of succession. As Macfarlane says, those who once accepted the theory of the metamorphism of New England seem to retain erroneous notions of the age of the successive mountain ranges, calling the Green Mountains newer than the Adirondacks, and the White more recent than the Green. They are both nearer the Laurentian than the Huronian, in respect to age.

* *Chemical and Geological Essays*, p. 613.

Huronian in New Hampshire.

We seem to have in the Connecticut Valley area at least three groups,—the Lisbon, Lyman, and auriferous conglomerate. To this should be added the Swift Water series, giving a thickness in all of 10,269 feet. The volume of these rocks is greater in Coös county. The rocks present a greater similarity to the lower Huronian than those of the Vermont area next the mountains.

We have yet to consider a great thickness of rocks in the south-eastern part of New Hampshire, consisting of quartzites and mica schists. These seem to us to be related to the Upper Huronian, and may be thus described in the later chapters of this book. These extend into Massachusetts, where are also developed very plainly the felsites of the Lower Huronian. The porphyries of the White Mountain district resemble them, and would be classed as Huronian, I suppose, by Dr. Hunt.

Huronian of the Atlantic States.

These same rocks occur at intervals in Connecticut, New Jersey, Pennsylvania, Maryland, Virginia, North Carolina, South Carolina, Georgia, and Alabama. Lithologically, they agree with the areas mentioned in New England. Observers do not agree in referring them to the Huronian. Geologists are beginning to study them, and therefore will gradually accumulate the means for their final and correct determination.

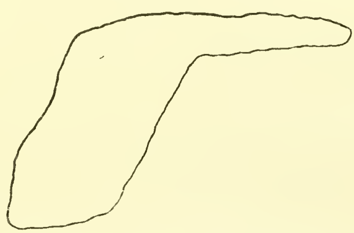


Fig. 75.—SECTION OF DISTORTED PEBBLE, LEBANON, ONE HALF NATURAL SIZE.

CHAPTER V.

THE GNEISSIC AREA FROM LANDAFF TO THE SOUTHERN BOUNDARY OF THE STATE.

BY J. H. HUNTINGTON.

THIS area embraces the entire western part of the Merrimack Valley district, and its western limit corresponds with that of the dry land in the Labrador period, as marked on a map in Volume I, opposite page 528. The rocks that bound it on the west are the quartzites and mica schists of the Coös group. On the east the limit is generally the porphyritic gneiss, except towards the south, where it embraces the whole of Cheshire county. The line that bounds the area on the west runs nearly parallel with the Connecticut river; that on the east is not so direct, yet it has the same general direction as that on the west.

Along the western border, at intervals where the newer rocks are included in this district, there are mountains of considerable elevations, as in Orford, Dorchester, and Grantham. Elsewhere the country is high above the sea-level, and rises in hills of varying height. East of this the common gneiss forms the central part of the area, and in places extends to the western border, the country nowhere rising into hills of very great height; but in parts of Warren, Wentworth, and Dorchester the country is generally high, while in the eastern part of Unity and in Lempster, it forms an elevated plateau-like area. East of the common gneiss, a fine-grained gneiss,—forming a transition state into mica schist, and generally carrying fibrolite,—is the rock of some of the highest mountains in this district. East of Baker's river we have Mt. Carr and the ridge extending southward, that terminates so abruptly in Rattlesnake mountain west of Rumney. Southward we have high hills and mountains: Plymouth mountain, in Plymouth; Mt. Crosby, in Hebron, from the summit of which we have such a fine view of Newfound lake; Tenney hill, immediately north, and the high land in Groton; then we have, south, the deep valley of Cockermouth brook, and the high hills between this and the north-east branches of Mascomy river, and south of these the porphyritic gneiss of Mt. Cardigan. The water-shed then descends to the famous notch in Orange cut by the Northern Railroad. In Grafton, the country everywhere is high; Isinglass hill, Alger's hill, where the immense beryls are found, Ford hill, a little south-west of the last, and Prescott hill, are the most noticeable points;—they vary in height from 1600 to 1800 feet. The ridge which we have followed, if it appears in Springfield, except in the extreme northern part, is not prominent above the general level of the country. It appears, however, again southward, in a high ridge in the east part of Goshen; also, in Lempster mountain, and still farther south in Surry mountain. The country in the south-east part of Cheshire county and along its southern border is everywhere high land, having an average of at least a thousand feet above sea-level. Well marked hills are not very numerous; hence Monadnock is one of the most prominent mountains in the state, as the view in every direction is unobstructed. In the east part of Winchester, in the west part of Richmond, thence northward in Swanzey and extending into Keene, are round hills and mountains composed cheifly of gneiss. The depression in this area seems to have the general direction of north-west and south-east, though there are others not so well marked in other directions. It is to be noted, however, that they pass through nearly all the varieties of rock. The following are the prominent groups of rocks noticed, in what appears to be their order of superposition, beginning with the lowest:

1. *Porphyritic Gneiss*, for the most part, forms the eastern boundary of the area we propose to describe; but it has outliers in the south which extend to the western part of the district.

2. *Bethlehem or Protogene Gneiss*. This rock varies somewhat in texture and composition in this area. That in Enfield is very closely allied

to that in Bethlehem, and it has been often described. South, where it occurs in Grantham and Unity, and in the more extended area in Cheshire county, it is generally finer-grained. The feldspar is often reddish, and it sometimes contains hornblende; the chlorite is in places abundant, but elsewhere there is little, or it is wanting altogether. In general, however, its lithological characters are such that the rock is easily recognized.

3. *Common or Lake Gneiss.* In the north part of the area it has uniformly a remarkably coarse texture, and is composed largely of quartz and black mica, and generally the mica is quite abundant.

4. *Ferruginous Concretionary Schist.* This is largely developed in the south-east part of Cheshire county. It is a siliceous schist, nearly everywhere pyritiferous, and frequently contains brilliant garnets in imperfect crystals. It is sometimes plumbaginous, and, as in Nelson, it contains extensive beds of plumbago or graphite.

5. *Fibrolite Schist, sometimes gneissic and passing into common mica schist.* It is often thick-bedded, and is characterized by having immense veins of coarse granite along its entire outcrop.

6. *Quartzites and Quartz Conglomerates.* These are evidently of the same age as those of the Connecticut Valley district.

7. *Intrusive Rocks and Veinstones.*

Laurentian Series.

Porphyritic Gneiss. The lithological characters of this rock have been so often described in preceding pages, that it is not necessary to repeat the description here. It is characteristically developed in Ellsworth, to the north-west of Stinson pond; in Rumney, at the north end of Stinson mountain; on Mt. Cardigan; also, in Sunapee, Stoddard, Marlow, Chesterfield, Winchester, Hinsdale, and Rindge. In Canaan there are crystals of feldspar; but the general character of the rock is that of the common gneiss. The area north-west of Stinson pond is in the forest; and on both sides of it we have fibrolite schist. In Ellsworth it outcrops on Moulton brook, where the road crosses it at H. & D. Sanborn's mill. The strata appear to be vertical. Here, also, we have mica schists and a fibrolite on the west. Both outcrops, however, are some distance from the mill. Going east, the next outcrop of porphyritic gneiss is near G. Avery's, in the road, probably sixty rods west of the house. Here it comes in contact with the fibrolite schist. It is nearly vertical, but at one point it dips N. 70° W. 78°. South-west of Avery's, in the edge of Rumney, partly in this rock and in a "trap" dyke, there is a mineral vein that carries galenite. From what I was able to see, it appears to be a very promising lode.

On the north end of Stinson mountain there is an outcrop of porphyritic gneiss in the pasture farthest up that side of the mountain, and it is entirely surrounded by the schist. In the south part of Groton the gneiss has a few crystals of feldspar, but it does not seem to be the characteristic porphyritic gneiss. Farther south, in Alexandria, there is no doubt about the character of the rock, and it is entirely east of the fibrolite schist. The small area of gneiss in the west part of Canaan that contains crystals of feldspar probably belongs to the common gneiss, since in its general foliated texture it does not differ from that rock elsewhere. From the line of Canaan and Orange, the western boundary of the porphyritic gneiss runs a little to the east of south through Grafton and Wilmot to Pleasant pond in New London; then it turns a little to the west, and in Sutton it turns almost directly west, and goes to Sunapee lake. At Sunapee Harbor, and on the hill immediately south, we have the porphyritic gneiss associated with a rock that resembles the White Mountain gneiss, and the dip is easterly 70°. North of Sugar river, Straw's ledge in Sunapee is porphyritic gneiss. In the vicinity of Sunapee lake we frequently have fine-grained granitic gneiss that evidently belongs to this series of rocks. South, on the road from Goshen to Washington, opposite J. Glinn's, we have a fine-grained gneiss enclosing bands of porphyritic gneiss; thence south-east, towards Washington centre, there are gneisses and pyritiferous and mica schists; but the rock in the south and east part of Washington is chiefly porphyritic gneiss, and a band extends into the north-east corner of Marlow. Its north-western limit is near Sand pond, and the line separating it from the rocks on the north-west runs south-west, probably between F. M. Lewis's and school-house No. 3, thence bending a little north, and extending to a point near the upper part of the letter L of the name of the town on the country map; thence it sweeps round to the south-east, nearly to the road south of Bald mountain. Its south-eastern limit would be marked by a line extending from the south-east base of Bald mountain, and crossing the road running north through Marlow, a mile and three quarters above the village. There are ledges near the road, and it is almost the only rock on the road from C. D. Symonds's to Ashuelot pond in Washington. It is the rock of Huntley mountain, south of Sand pond, and it is probably continuous to Bald mountain, and this appears to be its south-eastern limit. The rock north-west of the porphyritic gneiss is mica schist, containing imperfect crystals of andalusite; on the south-east and south we have gneiss, at first fine-grained, but coarse as we go southward.

Going southward, the next area of porphyritic gneiss is included in the towns of Chesterfield, Swanzey, Winchester, and Hinsdale. This area is wholly in the topographical district we are describing. It forms the high, rough, and rugged portions of the towns where it is found. Its northern limit is about a mile and a half south of Spofford lake in Chesterfield. It soon widens and sends off an outlier into Swanzey. It extends south into Winchester, and has its southern limit about three and a half miles from the state line. As a whole, the area is oval in shape, and in a line east and west it extends from near Kilburn pond in Winchester to within a mile of the Ashuelot river. The road from Chesterfield to Winchester, except for the first mile, passes over a country where this is the underlying rock. On the road from Chesterfield to Ashuelot village, there are many outcrops. Near its northern limit, not far from D. L. Sanderson's, there are many ledges; and on the road near Crouch's saw-mill, in the south-east part of Chesterfield, there are numerous outcrops. In Swanzey, near H. Albee's, is a porphyritic gneiss; and here it has a fibrolitic schist interstratified with it, but in a way that seems to show that the schist is the newer rock. Some of the boulders of porphyritic gneiss here contain fibrolite, which has not been seen in this rock elsewhere. This band of gneiss extends north to school-house No. 6, and as far south, at least, as the road that runs past M. Riley's. It is possible that this band may be separated from the rock west, in Chesterfield, by a band of schist. Where the porphyritic gneiss is found on the road directly west of Winchester village, the crystals of feldspar are flesh-colored,—a characteristic that is not common in this rock. Where the Ashuelot river has cut a deep, broad ravine through this rock, the stream is rough and rapid; and as the many boulders with which the channel is lined resist the current, and the water is poured over and around them, the noise of the rushing and tumbling of the waters equals some of our fierce mountain streams. South of the Ashuelot river, on the road that runs west from Ashuelot village, the porphyritic gneiss extends to the edge of Hinsdale. South-west of Ashuelot village there is an outcrop, near the house of C. Wise, and this is near its southern limit. The rock in this area, as well as that in Marlow, is nearly everywhere stained with iron. Near the central part of Fitzwilliam there is a limited area of porphyritic gneiss. At Dr. S. Cummings's, we find a characteristic variety. West, near the railroad, and just north of the granite quarries, there are several outcrops, and the one north of the Richmond road and east of the railroad is quite extensive. Some boulders on the road from the station to the village enclose rounded masses of the dark gneiss that is quarried on the Richmond road and below the station. There may also be an outcrop on the east side of South pond. From the State Line station on the Cheshire railroad, going north, we have White Mountain gneiss, dipping north-westerly; this is followed by a fine-grained gneiss, and this in turn by a band of well-marked porphyritic gneisses which extend to Sip Pond hotel, while northward are granitic gneisses of the White Mountain series.

In Jaffrey, south-west of Gilmore pond, near A. Emery's, there is a small area of prophyritic gneiss. In Dublin, south of Monadnock pond, there is an isolated hill near W. Phillips's, where the crystals of feldspar are much smaller than those found elsewhere in the porphyritic gneisses; here they are not much more than a quarter of an inch in thickness, and three quarters of an inch in length. The same rock outcrops near P. Morse's, and it is associated with a pyritiferous schist, but interstratified with it there is a dark, fine-grained gneiss. The dip of the porphyritic rock is N. 8° W. 35°, and the pyritiferous schist is unconformable with it. The rock in the south-east part of the town has many of the lithological characteristics of the porphyritic gneiss, though the large crystals of feldspar are wanting, and it resembles the gneiss of Bradford. In the north-east part of Dublin, and extending into Harrisville, the gneiss is porphyritic. At J. Gilchrist's are many ledges, and there are outcrops along the branch of Contoocook river to the outlet of North pond. Its western boundary extends from near the forks of the road above school-house No. 9, a little west of north, to D. French's, south of Long pond; thence it extends northward through Nelson, and in the north part of the town it outcrops near M. Wilson's. It then extends north through the central part of Stoddard, thence into Washington, and probably dips under the common gneiss, to come up again in the narrow Marlow range. In the east part of Stoddard, as well as in the east part of Washington, there are not only numerous ledges of porphyritic gneiss, but in many places there are boulders of immense size. In the study of this rock we have found in Ellsworth that there are areas of it surrounded by fibrolite schist, and that on the east it is unconformable with the schist; that in Orange, the relation of the two rocks are not certain, as they do not come in contact; that in Sunapee, we have detached masses, on both sides of which are micaceous and granitic gneisses of White Mountain series,—and the same fact has been observed in Fitzwilliam; that in Marlow, it has, on the south and south-east, gneisses that cannot be referred to either of the well-marked divisions of the rocks; that in Chesterfield and Winchester, it has at least on one side the common gneiss; and that in Jaffrey, Dublin, Nelson, and Stoddard, it is associated with a siliceous pyritiferous schist, that is found not unfrequently in basins of the porphyritic gneiss. The fact that rounded fragments of a dark gneiss are found in the porphyritic shows that the porphyritic rock in Fitzwilliam is either intrusive, or that in the process of metamorphism these fragments were not obliterated, and that the dark gneiss—which is very limited, but resembles some varieties of the Bethlehem gneiss—is the older rock.

The Bethlehem or Protogene Gneiss, and the Common or Lake Gneiss.

The common gneiss enters this topographical district from the north, and its western limit coincides very nearly with the western boundary of the Atlantic or gneissic period, as represented on a map in Vol. I, opposite page 516. It extends a little more to the west in Westmoreland; and although in Hinsdale the rock is a gneiss, it does not seem to be the common variety; and, as already noted, the rock from Chesterfield southward is porphyritic gneiss. The eastern boundary is for the most part definite and easily traced, and the rock bordering on it is a fibrolite schist. It extends southward through the east part of Landaff, through Benton along the side of Moosilauke, far up its western slope, through Warren along the steep slope of Mt. Carr, and extending south it crosses the line between Wentworth and Rumney near its southern terminus; then it follows near the line of Dorchester and Groton, then runs just east of the west line of Canaan, thence southward, near the west line of Grafton. In Springfield it is not so well defined, but is probably about a mile west of the old Sulloway tavern. In Sunapee it is not far from Union church, on the road from Sunapee Harbor to Newport. In Goshen it runs nearly parallel with the road that goes south through the east part of the town,—generally a little to the east of this road. From Goshen it turns westward, and runs south along the west slope of Lempster mountain, thence south-east nearly to East Alstead. Though the boundary is not well marked through Alstead, yet in Surry it is again well defined. Southward, the boundary becomes more indistinct again; and the rock on the east verges into the micaceous and granitic gneisses of the White Mountain series, and the line turns somewhat to the east, running almost directly to South Keene; thence southward, and crosses the Cheshire railroad just above Marlborough depot, when it goes south near the line of Swanzey and Troy. After it reaches Richmond, it turns suddenly to the south-west, and strikes the line of Richmond and Winchester a mile and a half north of the state line, and leaves a small area of White Mountain gneiss in the south-east part of Winchester. Between this line through Richmond and the porphyritic gneiss in Winchester, we have for the most part the Bethlehem or protogene gneiss, though it differs from the gneiss in the northern part of the area we have described. We find also several areas of protogene, which are contemporaneous with or older than the common gneiss.

Protogene Gneiss. This is found along the western border of the common gneiss in Haverhill and some of the towns south. It is quite unlike that found in Grantham, Keene, and some of the adjoining towns. In the latter the feldspar is often flesh-colored, and sometimes it largely predominates. We find elsewhere a large proportion of quartz; then we have a greenish mineral, probably chlorite,—certainly not mica. If the chlorite is wanting, mica, when present, is in minute scales, and collected in patches through the rock. The protogene gneiss, known as the Bethlehem gneiss of the northern part of the topographical district of the

Connecticut valley, has been already described, so we shall notice only that which is found east of the main range of the quartzite.

The lithological characteristics of the northern variety of the protogene or Bethlehem gneiss have been pointed out so often that it will not be necessary to repeat them here. When this rock occurs east of the quartzite, it is not always easy to tell where it ends and where the common gneiss begins. A characteristic variety of the Bethlehem gneiss is found in Hanover and Canaan, to the east of Moose mountain; and a fine-grained variety extends northerly into Lyme. The whole forms an oblong area, the northern limit being near the saw-mill north of the old Holt tavern, and its southern, near the village of Enfield. On the south it is compact, rather thick-bedded, contains quite a large proportion of flesh-colored feldspar, and it is quarried in the north-east corner of Hanover and in the south-west corner of Canaan. Northward, especially in Lyme, it becomes quite friable and crumbles easily, and it is separated from the protogene area westward by a band of quartzite. The watershed between the Mascomy river and Goose Pond brook is probably the limit of this area eastward in Canaan. Other areas of the protogene gneiss that occur along the north-west border of the common gneiss, that have not already been described, will be noticed with the common gneiss.

In Grantham, west of Croydon branch, we find a reddish protogene gneiss that is quite different from the protogene gneiss northward; it is much finer-grained, is cut by numerous joints, and in it here and southward there are intrusive bands of quartz. It extends from the road north of D. S. Hastings's southward to the road running north-west from Croydon east village. The principal band, however, of this rock begins in Surry, across the ravine south of George Joslyn's, and extends through the edge of Keene and Westmoreland into Chesterfield to the forks of the road south of J. Putnam's. The first prominent outcrop is south-east of G. Crain's: at first there are few quartz veins; then south the rock seems to be almost entirely quartz; but west of C. Wright's we have ledges of protogene; and east of school-house No. 4 we find in basins of this rock the mica schist which is so common to the north-west. The reddish gneiss,—for the protogene character of the rock is not always apparent,—is cut by the railroad in the south-west corner of Surry, and below, at the first crossing in Keene. In the latter cut we find, going west,—(1) gneiss; (2) quartz bands, with well defined walls (the rock is very much jointed, and resembles a dyke); (3) we have a chloritic rock; (4) we have the intrusive quartz repeated. In the Surry cut we have hornblende schist, which terminates abruptly at the line of a fault, and there is a slight change in the inclination of the strata. The inclination of the fault is about 70° easterly. At the line of the fault we have a band of quartz twenty or thirty feet wide. The inclination of the strata of the hornblende schist is very nearly the same as that of the gneiss; so we have simply a downthrow of the rocks at the east end of the cut. It is the best defined of any fault that we have found, and it is shown in Fig. 80. Here, as in this quartz elsewhere, there are some fragments of gneiss included in it. Gneiss begins abruptly against the quartz, and going west the inclination of strata is apparently quite variable,—generally, however, about 15° westerly, but more inclined as we go west. There are several quartz veins penetrating the gneiss, and in one of these pyrrhotite was found. On Gray's hill, a little west of south from the Surry cut, the protogene gneiss is found on the summit and westward, and it is probably continuous from the railroad. It is here cut by the intrusive quartz veins;—the strata seem to be nearly horizontal, and resting on it are hornblende and chloritic schists. The protogene gneiss occupies the entire western part of Keene, except where it is covered by other rocks. It is also found on the western slope of the hills east of the central part of the city of Keene, just west of the road along Beech hill. Hence it is altogether probable that this rock underlies the drift across the valley of the Ashuelot from West mountain to Beech hill.

Besides the rocks on Gray's hill there are outcrops a mile south-east of the Wilson farm, half way from school-house No. 12 (of the county map, now No. 7) to the railroad crossing, near D. B. Stearns's, at G. Perry's, and on the hills both north and south along the Chesterfield road from Keene west of the railroad. On West mountain there are extensive outcrops; but the reddish protogene rock disappears in the north part of Swanzey, but the rock southward does not differ very much from some varieties of the protogene northward. From the eastern slope of West mountain, in the broad valley of the Ashuelot, we find only drift until we ascend the hills on the east side of the valley, where there is a decomposing gneiss, probably the common variety of this section in the Bethlehem gneiss. A section across the valley shows the protogene, and the rocks associated with it. In Westmoreland the gneisses occupy nearly the whole of the south-east part of the town. The principal rock is the protogene gneiss; but the boundary between it and the common gneiss has not been determined. The limits of the gneisses westward, and the principal places of outcrop, will be noticed further on; but the rocks of the south-east part of Westmoreland deserve especial notice. The following is the succession of rocks from Samuel Gordon's, just south of the Barker place, to A. Parker's; and it seems more than probable that they occur here in their natural order, without having been overturned, and without having been pushed very much one over the other. The older rocks form a basin in which these were deposited. Going north from Samuel Gordon's, we have (1) protogene gneiss,—dip, N. 74° W. 22°; (2) hornblende schist, containing nodules of epidote,—dip, N. 19° W. 12°; (3) at J. Tilden's, a foliated and wrinkled gneiss,—dip, N. 9° W. 10°; (4) at D. Hyland's, quartzite,—dip, N. 10° E. 16°; (5) forty rods north of Hyland's, a wrinkled mica schist, with staurolite, dipping N. 80° E. 8°. At Parker's there is a hornblende gneiss, resting on a protogene gneiss, which dips N. 60° W. 25°. These rocks are entirely surrounded by protogene gneiss. A section showing the relation of these rocks can be seen in Fig. 79.

Protogene gneiss occupies the north-east part of Chesterfield, and it is succeeded on the south by porphyritic gneiss, and on the west by argillaceous and mica schist and quartzites. North-west of the gneiss there are staurolite, siliceous, chloritic, and other schists. On the south-east there is mica schist, generally fine and even in texture, while with the gneiss there are hornblende schists and quartzites.

Common or Lake Gneiss. The common gneiss occupies the central and south-western parts of Landaff. The gneiss varies greatly in texture. In the area between Easton and E. E. Merrill's it is coarse and granular, with an abundance of black mica; but south of Cooley hill it is somewhat finer, and at the forks of the road from Easton and the old road from the McConnell place, it is followed by mica schist. Where the Easton road crosses the Wild Ammonoosuc there is gneiss, and it outcrops three fourths of a mile east of Danville. Northward, on Cobble hill, we have a hard, greenish rock, probably diorite. It is so jointed that the stratification cannot be determined with any certainty. North of Cobble

— ILLUSTRATIONS OF CHAPTER V. —

BY J. H. HUNTINGTON.

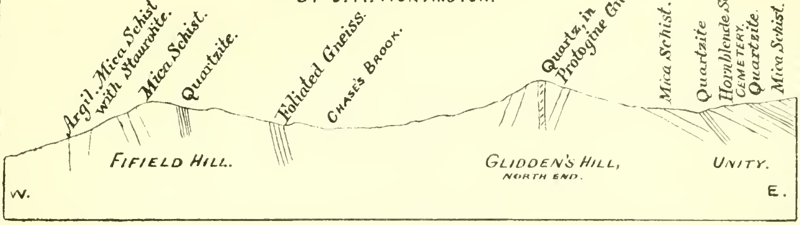


FIG. 76. SECTION FROM THE WEST SIDE OF FIFIELD HILL TO UNITY CENTER.

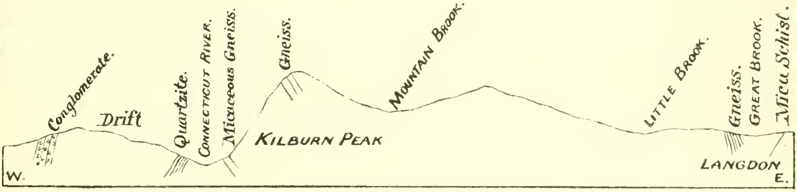


FIG. 77. SECTION FROM HILL WEST OF S. H. No. 13, WESTMINSTER, VT., TO LANGDON VILLAGE.

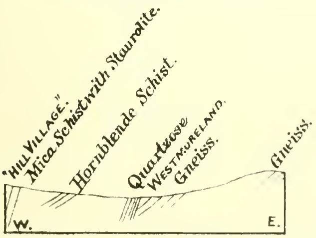


FIG. 78. "HILL VILLAGE" TO C. BUTTERFIELD'S, WESTMORELAND.

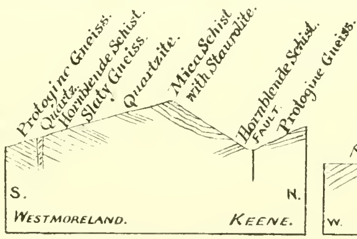


FIG. 79. S. GORDON'S TO J. WILLIAMS'.

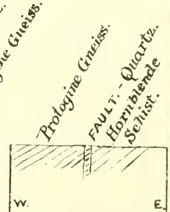


FIG. 80. SURRY SUMMIT, CHESHIRE R. R.

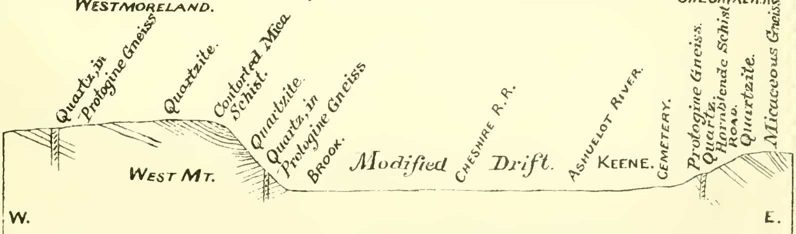


FIG. 81. SECTION IN KEENE, ACROSS WEST MOUNTAIN AND ASHUELOT VALLEY.

VERTICAL SCALE, 1500 FEET TO AN INCH.
HORIZONTAL " , 1 MILE " " "

HELIOTYPE

hill, on the road turning to the left, about fifty rods east of J. T. Gale's, in the gneiss, is a vein containing iron. This is crossed by a coarse quartz vein. Near the house there is a fine-grained gneiss, which seems to pass into a granular quartzite; and in this is a large vein of quartz. Near J. Clough's there is a fine-grained gneiss; and west of Green mountain there seems to be a granitoid gneiss. To the north there is a fine-grained, thick-bedded gneiss as far as the south side of Pond hill. South, three quarters of a mile from Clough's, we cross a band of quartz; then we have gneiss,—a dark, fine-grained variety. Still south, at an abandoned iron mine, we have gneiss, which extends into the edge of Bath and outcrops on the hillside east of J. Mann's. Along the road, on the north side of the Wild Ammonoosuc, the first gneiss that is seen has a more distinct, foliated texture than is common to the great body of the gneiss in this section, and the quartz in it seems to be more abundant. The thickness of this band is, however, quite limited. The gneiss, which is fine-grained, continues nearly to D. N. Page's, where we have a band of quartzite, and this outcrops nearly half a mile north of Page's. The gneiss outcrops again east of Page's; and at L. W. Hubbard's we have a chloritic rock. At Mrs. W. Grant's we find quartzite and a dark, fine-grained gneiss; then, eastward, there is gneiss, as already noted.

In the north-west part of Benton the prevailing rock is gneiss, between the quartzite and Tunnel brook. East of the quartzite, near D. Howe's, we have a narrow band of hornblende gneiss that contains nodules of epidote. This band may be the source of those immense crystals of epidote that have been found in the south part of Benton and in Warren. East of the hornblende rock we have gneiss, and it extends south to the height of land. East of the road south of the height of land the rock is coarser than the gneiss in general, and has some of the characteristics of the porphyritic gneiss. West of the same road, the mountain ridge between it and the railroad is protogene gneiss. It is also the rock of the railroad cut at Warren summit. From the western slope of Moosilauke the common gneiss extends southward, and there is an outcrop at the saw-mill on Baker's river, near J. P. Boynton's, and near Dr. D. C. French's; also, at the saw-mill below. At both saw-mills the water has worn deep channels in the rock.

Above Warren village, at S. Flanders's, we find common gneiss; and north, near A. Whitcher's, the rock is fine-grained, and the stratification is remarkably distinct. A mile and a quarter north, on a road west, near J. Whitcher's, is a thick-bedded, very light-colored gneiss; and south, near N. Libby's, there is hornblende gneiss. West of the railroad, beginning at Webster Slide mountain and extending west to the Cross iron-ore mine in Piermont, and south-west to Ore hill, the rock is a fine-grained gneiss, sometimes forming a transition state into mica schist,—and everywhere it is more or less ferruginous. A band of this rock extends southward into Wentworth. Gneiss is found between Ore hill and Tarleton pond, and there is an outcrop near J. H. Kelley's; that on the road west of Ore hill may be more allied to the Bethlehem than the common gneiss. At Warren village we find common gneiss; and on Hurricane brook there is the same coarse variety as at the saw-mills on Baker's river. The fine-grained gneiss and quartzite west are the mineral-bearing rocks of this section of the state.

In Wentworth a very large proportion of the rocks is common gneiss; but we have besides a fibrolite schist on the ridge of Mt. Carr, which crosses the north-east corner of the town; a mica schist, which runs to the north from near N. Coolidge's and outcrops at the outlet of Lower Baker pond; and west of the mica schist, at T. Simpson's, we have the Bethlehem gneiss. The last two disappear a mile and a half south of Simpson's; and the common gneiss extends entirely across the south part of the town. On the south-east, it extends beyond the border of Wentworth into Rumney. A fine-grained gneiss outcrops at E. Currier's; and west of this we have fibrolite schists. On the west, the common gneiss extends into Orford a fourth of a mile west of E. Lamprey's.

In Dorchester the prevailing rock is also common gneiss. Its western boundary runs from near E. Lamprey's in Orford to a point just west of McCutchins pond, thence to Norris pond and to the west of its outlet, and thence it probably runs to the south line of Dorchester, near Clark's pond. In the north-west corner of the town it has on the west quartzite and the chloritic hornblende schists of Smart's mountain; at J. Clough's, a hornblende rock and a fine-grained gneiss or mica schist; and south of the outlet of Norris pond, the friable, brittle rock that resembles protogene gneiss. On the east we have only the fibrolite schist. It runs along in the edge of Groton, crosses over into Dorchester a mile north of the stream near Mrs. R. P. Holt's, then runs south nearly parallel with the line of Groton, and strikes the corner of Orange. Included within these lines common gneiss is the only rock, except a feldspar porphyry on the new road east of Norris pond, and a breccia, with porphyry, on the east side of Pollard hill. The dip of the strata here, as in Wentworth, is easterly.

The gneiss of Canaan has not that uniformity of texture that we find in the gneiss of Dorchester and Wentworth. While the protogene gneiss in the west part of Canaan is coarser than that northward, the other gneisses become finer-grained and more variable in texture; besides, we have hornblende schist that appears, in some instances, to be interstratified with the gneiss. Sometimes these hornblende bands are continuous for some distance. One is seen on Indian river, near East Canaan, continuing west, parallel with the railroad. It turns north, extends along the west side of the Pinnacle, and northward, crossing the road near J. P. Barber's. That which outcrops near R. Hayward's is probably a continuation of this, and possibly that at R. Atwell's;—at least, we find that the coarse gneiss which we have in Dorchester and northward, is east of the line of the outcrop of this hornblende schist, and that the rocks intervening between it and the protogene gneiss are generally fine-grained granitic gneisses, and probably form the upper division of the Bethlehem group. These rocks extend south, and occupy a large part of Enfield; for directly south from Canaan the Bethlehem gneiss disappears, and it is only in the extreme east part of Enfield that the common or Lake gneiss is found. These fine-grained granitic gneisses in the north part of Grantham are replaced by the Lake gneiss. It is difficult to tell anything about the stratigraphical relations of this granitic gneiss, since the arrangement of the constituents of the rock gives little or no indication of stratification. In Canaan, on the west, we have the Bethlehem gneiss; but south, in Enfield, we have argillaceous schists, mica schists, and quartzites. The line that separates the schists from the granitic gneiss runs—from a point half or three quarters of a mile east of the northwest corner of the town—south-east; but after it passes Lily ponds it turns a little to the west, then suddenly to the east, and forms a curve around the Lake gneiss in the north part of Grantham. As a whole, this area of granitic gneiss is oblong. It is about twelve miles in length, and has its greatest width in Enfield, where it is about five miles wide. In Canaan, however, west of Hart's pond, it is not more than two and a quarter miles wide.

Confining the Lake gneiss to the gneiss of a coarse granular texture, it is narrow in the north part of Canaan, but to the south it becomes wider, and opposite Hart's pond it extends into Orange. South of East Canaan it contracts again, and nearly the whole is crowded into the south-west corner of Orange. The rock at Orange summit is a coarse granular gneiss; and though there are occasionally feldspar crystals, yet the amount of feldspar in the rocks as a whole seems to be much less than is usual in the Lake gneiss. Following this rock, on the east, everywhere in Orange we have fibrolite schist. The common gneiss extends along the entire western part of Grafton. It has quite a uniform texture, and is a mile in width along the northern border, and two miles in width on the line of Springfield. Typical varieties of this rock are found, particularly in the vicinity of Grafton pond. It does not extend far into Enfield; but near the south-eastern corner of the town the northern and western boundary turns to the west along the line of Enfield and Grantham. It outcrops in Grantham east of the Butternut pond, where it is coarse and granular. To the south-west, it can be seen on Grass Pond brook, near G. Colburn's. These outcrops are near its north-western limit; and from near Colburn's the western boundary of the gneiss extends along the east side of Sugar hill, thence southward along the east base of Croydon mountain. East of this line, except the protogene gneiss and quartz, the common gneiss is the only rock in the town. We have not yet determined the exact eastern limit of this rock in Springfield. The rock in many places has feldspar crystals scattered through it, which sometimes make it difficult to distinguish it from the porphyritic gneiss to the east; though where the rock has been examined its foliated texture is always more marked in the gneiss of the west part of Springfield than in the porphyritic. In Sunapee, along through the west part of the town, we find the typical Lake gneiss, and on the west we have the White Mountain schists and gneisses. There are many outcrops of the common gneiss on the road west and south of Ledge pond, on Young's hill, to the south of Sugar river, and in the hill south of H. Crowell's, near Union church. The strata have an easterly dip, and the inclination is much less than that of the rocks farther north. In the north part of the town the inclination is 15°, but it increases southward, and near G. B. Wilson's it is 45°.

In Croydon, except the mountain range on the west, and the protogene gneiss and the quartz, all the rocks are the common or Lake gneiss. In the south-east corner of the town the inclination of the strata is less even than in Sunapee; but we have here what is not common in this gneiss, namely, coarse granite veins. There is one south-west of J. Ryder's; and near H. Clark's there is one where the crystals of mica are two inches across. Near Rock Bound pond the common gneiss has a westerly dip—a thing quite rare. There is quite an area west of Croydon branch, where the gneiss resembles the protogene more than the common gneiss; but west of this, as near W. Stockwell's, the common gneiss has an easterly dip of 20°. Along the road from Croydon Flat to Brighton, the strata seem to be horizontal, though the jointing may have made the stratification obscure. The gneiss extends southward, and occupies the whole of the town of Newport, except a strip about two miles wide along the western border. The line separating the gneiss from the schists and the quartzites is very direct; it crosses the road near N. Gould's, east of D. C. Story's, near T. M. Cutting's, east of Mt. Tug, and between L. P. Tenney's and S. Wright's. The common gneiss is found on the high hills in the east part of the town, and specimens were obtained between Newport village and Kelleyville and near A. D. Pike's. We found here, as in Sunapee, that the inclination of the strata is nowhere very great. There is a large amount of drift along the Goshen branch and moraines east of school-house No. 12. In Goshen, there are prominent outcrops of the common gneiss, on the stream north of Mill Village, on Dodge hill, east of the Goshen branch, and at the Four Corners. From Chandler hill, northward, there is a fine-grained rock, which, in some places, is pyritiferous; and south of A. D. Bartlett's there is granitic gneiss. This small area belongs to the Montalban series, and is an outlier from, or connected with, that in Sunapee.

In Unity, the common or Lake gneiss is found in the entire east part of the town, and extends west nearly to Unity Centre. The line that separates the gneiss from the schists and quartzites extends southward from Newport, and crosses the road near S. Pierce's, just west of S.

Messenger's. We then follow it southward, near J. Kimball's and west of Cold pond. The rocks have everywhere an easterly dip. They vary somewhat in strike, but are quite uniform, generally running north and south, and have the coarse granular texture of the common gneiss. In the gneiss near E. Cutting's there is a coarse granite vein; and we also have a quartz schist associated with the gneiss at the forks of the road near S. Walker's. The band crosses the road near J. G. Smith's. It is quite uncommon to find the quartz schist running across the gneiss, as here, and it shows clearly its unconformability with the gneiss, and its more recent origin. Going eastward from A. C. Sleeper's, we have (1) mica schist, with a dip of S. 50° E. 15°; (2) a quartzite, with a dip of S. 70° E. 20°; (3) a mica schist, with staurolite, dipping S. 20° E. 20°; (4) gneiss, with a dip of S. 30° E. 20°,—showing not only that the schist and quartzite have been inverted, but that the gneiss has been pushed over them. The common gneiss extends southward from Unity and Goshen into Acworth and Lempster. It occupies a strip a mile and a half to two miles in width in the east part of Acworth. A line bounding it on the west extends south from a point west of Cold pond, around the west base of Coffin hill. It crosses the road near J. Davis's, and runs near Mitchell pond and school-house No. 7. Keeping east of the road across Grant hill, it crosses Cold river near Wyman's saw-mill, and continues southward around the west side of Gates mountain. In Lempster, it occupies the whole of the north part of the town, but it keeps to the west of Lempster mountain. In the south-east corner of the town we find the schist and gneisses of Lempster mountain, and the porphyritic gneiss to the south-east of these. The common gneiss sends out an outlier on the road near William Gee's; but the schist is found on the road by Beaver pond; so we have a very narrow strip of gneiss, if any, in the extreme south-west corner of the town.

South of Acworth and Lempster this great band of common gneiss, which we have followed southward from Landaff, loses, in a great measure, its well defined limits. As the isolated area of gneiss that extends from the Connecticut to the north-west part of Alstead, and which has been described upon page 410, passes into the micaceous gneiss of the White Mountain series on the south, so here, as we go southward from the northern boundary of Alstead and Marlow, the character of the rock, as the common gneiss, except in a few small areas, is almost obliterated, and in its place we have micaceous and hornblende gneisses; and at the same time the fibrolite schist assumes more the character of a well defined gneiss. When it is known that these rocks have again their characteristic forms, in Surry, it leaves little doubt that all these rocks—the common, the hornblende, the micaceous, and the fibrolite gneisses, including the fibrolite schist—belong to one great series. From near L. Honey's in Acworth the common gneiss extends into Marlow, and its southern boundary is probably just below Trout pond. Near H. Priest's we again find the common gneiss; but as we go northward we have mica schist, at C. W. George's in Acworth. The rock has the character of a fine-grained gneiss at G. H. Gassett's. At J. Buckminster's and S. E. Mann's we have mica schist. Frequently in this vicinity we find bands of hornblende schist. In the north-east corner of Alstead, near J. H. Shepherd's, we have a fine-grained gneiss again. Going towards Marlow, and turning north by the cemetery, we find bands of hornblende schist; but between the cemetery and Gustin pond is the boundary between these rocks and the fibrolite gneiss. At the forks of the road, east of A. Mack's, and in Alstead, at A. Kent's, we have mica schist, the dip being easterly, and nearly the same at both places. We have mica schist, also, north, near Mrs. Whitcomb's; and in the coarse granite veins here there have been several openings made for mica. In the vicinity of Warren pond we have common gneiss. An outcrop at J. Caldwell's, south-west of the pond, has an easterly dip, and it seems to pass into a mica schist. In the northern part of the town, on the south-east side of Cobb's hill, there is a fine-grained gneiss, which has generally a westerly dip, though the strata are often curved, so that in places they are inverted. One outcrop, where it runs into the hill, looks like a section of a cone; and here we have schists on both sides of the gneiss. This has been noticed in a preceding chapter.

South-east, near the road up Warren brook, between J. P. Forrestall's and L. Way's, there is gneiss again with an easterly dip, and about a mile above Way's there is mica schist. South-west, at Mrs. Emerson's, on the road north of Alstead centre, the rock is a quartzose mica schist, and the dip is exceedingly variable. On the road south-west from the centre, we have mica schist to the line of Walpole, except at George Pratt's, where there is a gneiss rich in quartz. South, at J. H. Moriarty's, there is gneiss also rich in quartz, and a dark arenaceous schist. From this point south-east, on the road to Surry as far south as R. E. Smith's, and also in the road east from E. Slade's, the schists are like those of the Coös group. But fifty rods north-west of T. A. Bolster's, there is a greenish quartzose rock in which there is hornblende; this is interstratified with a dark gray gneiss and pyritiferous schist. On the road south from Bolster's, we have the wrinkled argillaceous mica schists of the Coös group. In the south part of Alstead, on the Surry and Alstead road, we have a wrinkled and contorted mica schist. Just below Robbins's there is a broad band of coarse granite, mostly feldspar; and on both sides of this there is a mica schist, common elsewhere in Alstead. At a turn in the road, three quarters of a mile north of Robbins's, there is gneiss rich in quartz, and above this mica schist. At the forks of the road near E. H. Flint's, there is hornblende schist; but east, to J. B. Cady's, we have gneiss; north from Alstead centre to Ellis's there is also gneiss, and east of these two points there is mica schist; but with this, at J. Blood's, there is hornblende schist. As we go southward, on the road from Blood's, we come to the micaceous gneiss of the White Mountain series, and there is a well-marked outcrop near the southern border of the town, at J. N. Hodgkin's. On a road farther east, that runs south from Warren pond, we have, at D. W. Sawyer's, a micaceous gneiss of fine foliated texture, forming a transition state into mica schist,—and this is the character of the rock south to the line of Gilsum. Near J. A. Kidder's it contains coarse granitic veins that have been worked for mica; and there has been a small excavation by the side of the road at Gleason's. A quarter of a mile west of S. Goodhue's, mica has been quarried at intervals for many years, and the rock is in places a genuine gneiss, and frequently contains fibrolite. Along the top of a ridge there is an immense coarse granitic vein, in parts of which there are masses of glassy, translucent quartz. On the road north-east from Gleason's the rock is generally a micaceous gneiss. At D. Knight's, there is an opening that has been made for mica; also, one at H. R. Knight's. On the road the rock is more like mica schist, contains garnets, and is often pyritiferous. North-west of the house there is a coarse granitic vein, and then the rock resembles the gneiss of Marlow, which will be described under the division of pyritiferous schists. At A. Whittemore's, in Marlow, west of Grassy brook, we have a fine-grained gneiss. On this road, from the line of Marlow to the village, the micaceous gneiss was not seen. As we go south from the west part of Alstead into Surry, the rocks have a more definite character, although the typical variety of the common gneiss has not been seen in any extended outcrop. There is gneiss east and south-east of the village. Even here the rocks are more allied to the protogene than the common gneiss, and they are probably varieties of it. We find gneiss on the road to Mine ledge, and on the road south it can be seen at E. Woodward's; from thence to Keene there are no ledges of any kind; neither are there any ledges on the direct road from Surry to Keene. As there is some doubt whether there is any outcrop of the typical variety of the common gneiss in Keene, the rock is described under protogene gneiss, which is the prevailing rock. In the central and south-east part of Westmoreland we have a gneiss that is, at least, closely allied to that in the northern part of this district, and northward. Specimens of the reddish variety of protogene gneiss from Surry and Keene can hardly be distinguished from some specimens of the gneiss obtained in Jefferson, near the Mt. Adams house.

The northern and western limit of the gneiss, including the protogene, is as follows: A line drawn from a point just north of school-house No. 4, in Surry, to the tannery north-west of Westmoreland village, would represent the boundary on the north-west. This, continued to the south-west nearly to the molybdenite mine, then sweeping round into the edge of Chesterfield, just north of L. Pierce's, would represent it on the west;—the line then extends to the north part of Spofford pond, crossing it, and runs south of A. Chandler's; then round to Factory village, crossing the outlet of the lake, striking the stream again by the lower mill, crossing the road near E. R. Wellington's, and turning southward to the forks of the road east of school-house No. 14: this represents its south-western boundary. South of the east part of this line, between the gneiss and the porphyritic gneiss, we have an oval area of mica schists, quartzites, and conglomerates. The area in the east part of Westmoreland is noticed under protogene gneiss. The gneiss outcrops at the harness shop near D. Warren's, on the top and east side of the hill west of Mrs. Carlisle's, at J. L. Paine's, at O. Leonard's, and J. Briggs's, Jr. South of the village, at the Curtis mine, and as far south as Spofford lake, south-east at E. Pierce's and Jas. Comstock's, south-west of Comstock's nearly to Factoryville, and along the east side of Pistareen mountain, there are many ledges. At the south end of the mountain the rock appears to be intrusive, and is composed largely of feldspar. South of Spofford lake there is a slaty gneiss, unlike anything found elsewhere, unless there is a small area north of the Barker place in Westmoreland, and west of Mine ledge in Surry. It is cut by numerous cleavage planes, and dips to the south. Nowhere is the hornblende gneiss so persistent as in Westmoreland, but it is associated with the mica schist rather than with the common gneiss, and quartzite is also found in many places. The succession of the rocks here is as follows: Gneiss is everywhere the underlying rock; hornblende schist follows the gneiss, and mica schist the hornblende. At Westmoreland, however, as shown in Fig. 78, there is a quartzite or quartz between the gneiss and the hornblende schist.

Between the area of gneiss in Surry and Westmoreland and that in Swanzey, where gneiss occurs, it is of the protogene variety, and in Surry and southward to the state line the gneiss is a well defined variety of the Bethlehem gneiss. It appears on Mt. Cæsar, in the Ashuelot mountains, on the line of Swanzey and Winchester, on Attleboro' and Second mountains in Richmond, and in the south-east part of Winchester. In the north-east part of Swanzey the rocks are for the most part concealed by drift. Going west from Marlborough depot into Swanzey, near A. T. Lane's, is a gneiss that has some of the characteristics of the common variety, and it contains a coarse granite vein that carries magnetite. Some of the crystals are an inch in thickness. On Mt. Cæsar the strata seem to dip westerly 10°, though generally the strata of this rock are nearly vertical. North, at L. Dickenson's, the gneiss is more micaceous than elsewhere; and the dip is about the same as on Mt. Cæsar. Northward, to the town line, there is drift, generally a fine gravel. Southward, at Unionville, there is gneiss; and in the south-east corner of the town, and in the edge of Troy, there is a granite composed largely of quartz. East of Swanzey pond, near L. W. Darling's, there are extensive outcrops of gneiss; and in the extreme south-west corner of the town, between Winchester and Richmond, the rock is altogether gneiss. On the north-west side of Franklin mountain it has been quarried to some extent, and a very desirable stone is obtained. It was used in the construction of the Episcopal church at Keene.

On a road, now discontinued, south of Franklin mountain, there are several outcrops of gneiss; and a boulder was seen, containing iron ore, evidently from this rock. At R. Weeks's, on the road south from school-house No. 8 in Swanzey, the rock may be intrusive. Where this road enters Winchester, at Naramore's mill, there is an interesting outcrop of gneiss. The strata are nearly vertical, and dark bands are very distinct. The mineral giving these bands their dark color is probably hornblende, though there may be some tourmaline present. To the south-west, near W. Hartwell's, these dark bands are also found. South-east, on the road to Richmond, at B. Corliss's, and from school-house No. 3 to Sandy pond, the rock is chiefly granite, but occasionally there are dark gneissic bands. In Winchester, on the western slope of Second mountain, there is gneiss nearly vertical, but dipping westerly. On the north-west side of Stone mountain there are many outcrops with dark bands, as at Naramore's mill, and this rock extends south to Peaked hill, where the strata are vertical. Going west from the summit of Peaked hill, we have a micaceous gneiss, and this extends northward along the west slope of Stone mountain, two thirds of the way from the summit to the base. In this rock, on Stone mountain, there is quite an extensive vein of rhodonite. The locality can be discovered after finding a depression that in the spring is filled with water;—it is about five rods north-west of this depression. West of this micaceous gneiss, on the ridge of Peaked hill, we have a pyritiferous schist with an easterly dip, and in this are coarse granite veins. Near the road is a hornblende schist, the dip of which is variable. East of the micaceous gneiss of Stone mountain we have a fine-grained gneiss. It outcrops just north of the cemetery; and where it is seen between the cemetery and the village it contains a coarse granite vein. On the road south-east from William Follett's, gneiss is the prevailing rock; but on a road, now discontinued, south-west of Follett's, we have hornblende gneiss. This contains an iron ore, which was worked to a limited extent many years ago.

Gneiss. Dip of the Strata.

Landaff and Easton.

At J. T. Gale's, N. 70° E. 20°.

West of J. Clough's, N. 40° W. 50°.

Dark fine-grained gneiss, a mile north of iron mine, N. 60° W. 50°.

At iron mine, N. 80°.

Fine-grained gneiss, N. 34° W. 45°.

¾ mile west of D. N. Page's, N. 62° W. 70°.

West of Iron Ore hill, N. 30° W.

Fine-grained gneiss west of last, N. 40° W. 68°.

Besides several of these localities there are specimens in the cabinet from near E. E. Merrill's, J. McConnell's, W. L. Shattuck's, a mile above Dansville,—the last especially represents the common gneiss.

Benton.

East of D. Howe's, S. 80° W. 60°.

At saw-mill, Tunnel brook, N. 46° E. 40°.

Height of land, N. 70° E. 65°.

The strata dip easterly, also, along the section on the western slope of Moosilauke.

Warren.

At R. B. French's saw-mill, S. 30° E. 70°.

Up Hurricane brook, a mile above Clifford's, S. 50° E. 62°.

Wentworth.

Between J. L. Ellsworth's and Rocky pond, S. 22° E. 58°.

At S. Ellsworth's, S. 52° E. 50°.

Near W. Evans's, S. 82° E. 50°.

The specimens in the cabinet which are on the section that passes through Wentworth represent well the rocks of the town.

Dorchester.

1½ miles N. W. of W. Robbins's, S. 70° E. 64°.

Near McCutchins pond, S. 62° E. 55°.

At J. Cogswell's, S. 82° E. 35°.

At town-house, S. 55° E. 20°.

At A. Blodgett's saw-mill, S. 30° E. 25°.

At J. Blaisdell's, S. 53° E. 65°.

Outlet of Norris pond, N. 75° E. 60°.

Canaan and Orange.

Protogene gneiss, ½ mile up Martin Meadow brook, S. 32° E. 40°.

At brick school-house, S. 56° E. 20°.

At S. Towle's, N. 32° E. 25°.

Fine-grained gneiss between school-house and Goose pond, N. 32° E. 25°.

At C. Bartlett's, N. 63° E. 20°.

Coarse granular gneiss, R. C. Ladd's, S 82° E. 32°.

Enfield and Grafton.

At D. Goodrich's, N. 82° E. 62°.

Line of Enfield and Grantham, W. 76°.

East side of East hill, N. 80° E. 46°.

Near M. S. Choate's, S. 53° E. 62°.

At W. C. Buffum's, N. 80° E. 30°.

Grantham.

At C. Colburn's, S. 43° E. 45°.

At O. B. Buswell's, S. 18° E. 25°.

East of Butternut pond, S. 78° W. 70°.

Croydon.

Rock Bound pond, S. 62° W. 15°.

At W. Stockwell's, S. 58° E. 20°.

Sunapee.

At S. Dodge's, S. 70° E. 50°.

At Charles George's, S. 68° E. 25°.

Near H. Crowell's, N. 82° E. 60°.

At G. B. Wilson's, S. 50° E. 45°.

Newport.

Near H. E. Hanson's, S. 12° W. 10°.

At Henry A. Jenks's, S. 10° W. 18°.

Near T. Scranton's, W. 12°.

At A. D. Pike's, S. 56° E. 10°.

At L. P. Tenney's, N. 82° E. 20°.

The massive character of the rock in some of the localities in Newport makes the dip of the strata very obscure.

Unity.

At N. C. Huntoon's, N. 80° E. 10°.

At S. Pierce's, N. 82° E. 15°.

East of A. C. Sleeper's, S. 38° E. 18°.

Acworth.

South of Coffin hill, S. 18° E. 15°.

At S. McKeen's, S. 53° E. 68°.

Forks of road east of school-house No. 10, S. 68° E. 15°.

Lempster.

At J. Carpenter's, S. 53° E. 15°.

At T. Pollard's, S. 68° E. 18°.

At Wm. Gee's, N. 38° E. 70°.

Marlow.

At L. S. Rogers's, N. 82° E. 48°.

At H. Priest's, S. 48° E. 25°.

Fork of road east of A. Mack's, S. 32° E. 60°.

East of village, S. 58° E. 80°.

At A. Whittemore's, S. 56° E. 50°.

Stoddard.

At C. D. Elliott's, S. 62° E. 88°.

Keene and Westmoreland.

South of reservoir, S. 70° E. 40°.

The protogene gneiss in the east part of Keene seems to have an easterly dip; but here and in Westmoreland, the dip is very obscure.

Swanzey.

The gneiss of Swanzey appears to be generally vertical, though there seem to be two exceptions, one on Mt. Cæsar, and the other at L. Dickenson's. At both places the inclination is 10° or 12° north-westerly.

Winchester.

At Naramore's mill the strata are vertical.

West slope of Second mountain, S. 82° W. 75°.

North-west of E. S. Adams', N. 82° E. 80°.

West base of Stone mountain, S. 70° E. 58°.

Peaked hill, strata vertical; strike N. 10° W.

Ferruginous Schists.

These schists are scarcely distinguishable, on the one hand, from the White Mountain schists and gneisses, and, on the other, from the fibrolite schists. So nearly allied are some of these rocks to the White Mountain schists, in many of their lithological characteristics, that they seem to pass, by insensible gradations, into rocks so like those that occur in the White Mountain region, that there seems to be little doubt but that all of the rocks we shall describe under the head of "Ferruginous Schists" belong to the White Mountain series. Neither is there any very marked distinction, save the presence of fibrolite, between these rocks and those we shall describe under the head of "Fibrolite Schists." In these ferruginous schists the large plates of mica are usually, though not always, wanting. They often contain beds of graphite, and are sometimes concretionary. The relations to the porphyritic gneiss show them to be among the oldest of our crystalline schists. The most northern outcrop where this rock is seen is on Mt. Prospect, in Holderness, and here it is associated with a porphyritic rock, which in some respects is unlike the porphyritic gneiss found elsewhere. It extends southward, and is the rock at Ashland village; also of Squam mountain to the east.

On the road north of Little Squam lake, near the town-house, we have the ferruginous schist, and with it the characteristic porphyritic gneiss; while south, on the road to Center Harbor, particularly at Mrs. T. Shepard's, we have distinct White Mountain gneiss. Elsewhere along this road, northward, the rock frequently contains mica, and is decidedly ferruginous, showing plainly that the ferruginous schist and the White Mountain schists belong to the same series of rocks. We have the same change in the rock, though not so marked, going west from Plymouth. South, through Bridgewater, the rocks are uniformly pyritiferous. If this is the same rock as the fibrolite schist or gneiss, then we have a line of outcrops from Mt. Prospect to the southern border of the state, including Ragged, Kearsarge, and Monadnock mountains. In the town of Goshen, east of L. Baker's, we have porphyritic gneiss, and with it there is White Mountain gneiss. East of this is the pyritiferous schist, which here contains graphite. North-west of Washington Centre there are outcrops of this siliceous pyritiferous schist; but it is in Cheshire county where these schists are most extensively developed. They occupy a large part of Sullivan, Nelson, Roxbury, Harrisville, Dublin, and Rindge, also parts of Marlborough, Jaffrey, Fitzwilliam, and Richmond. In Marlow there is a gneissic rock that does not come under either of the heads we have mentioned, and it may form a transition state into mica schist. There are boulders of it at the village, and an outcrop just east, where it is a fine-grained gneiss, and contains a gray fibrolite that has a fibro-lamellar texture. A mile below the village, and east of the road, there are many outcrops of gneiss. Here it contains nodular masses of quartz, from half an inch to three or four inches in diameter; and sometimes it contains amorphous masses of feldspar from half an inch to two inches in diameter. Elsewhere we find the crystals of the common varieties of porphyritic gneiss. Through the west part of Stoddard the rock is gneiss, and is exceedingly variable. On Stoddard heights it resembles a micaceous gneiss. Along the Ashuelot in Gilsum, as far south as the village, the outcrop examined was a coarse granite. In Sullivan, at Bear Den mountain on the west, and from near D. Seward's, at least as far as Moore's mill in Stoddard, the rocks resemble very closely the White Mountain gneisses. Between these points the rocks are generally highly siliceous and pyritiferous. Where the rocks are not ferruginous, as east of D. Seward's, the strata are often twisted into nodular-like masses. South-east of the church, on the road to East Sullivan, near Weathron & Cordney's, there is a coarse granite vein containing beryl. In Nelson the rocks are uniformly pyritiferous, except in the extreme eastern part of the town. In the north-east part of the town, at H. Wilson's, there is a bed included in the porphyritic gneiss. At A. Robbins's we find nodular concretions in the schist, which is here graphitic, and contains bright almandine garnets. In the vicinity of the Seabury graphite mine, the rocks are decidedly pyritiferous. Near the town farm, where large quantities of graphite have been obtained, the rocks are of the same character. At Page's, to the west, the cleavage is more marked than elsewhere in the town. Near Noah W. Hardy's the rock is generally the common pyritiferous schist, though there are bands that resemble gneiss.

In the entire eastern part of Roxbury we find that the rocks are ferruginous, and probably extend as far west as G. Nims's, on the road from the church to Keene. In the south part of the town they extend half a mile west of the forks of the road south of Horse hill. West of these rocks we have the White Mountain gneisses. In Roxbury, the ferruginous schist abounds in concretions. They are much more frequent than in this rock elsewhere, and they lie in all directions, with regard to the strata, sometimes directly across them. They are of various sizes and shapes. One was seen three feet in length, and not more than three inches in thickness. Usually they look like rounded pebbles, which some have thought them to be; but a fragment, two feet in length and not more than two inches in thickness, would hardly lie at right angles to the stratification of the rock, or even diagonally across the strata. The shape of some are peculiar, being thick at one end and tapering almost to a point at the other. This shows, also, that they can hardly be pebbles or boulders. Near the church, at the centre of the town, and on the south-west side of Horse hill, a person can have a fine opportunity for studying these forms. The Pinnacle, north-west of the church, is topped out with a coarse granite containing graphic granite and plumose mica. On the south of the Pinnacle and on Bassett hill we have the rock common to this part of the town. In the west part of the town the ferruginous schist appears to verge into the schists and gneisses of the White Mountain series; at least, there is no well-marked line of demarcation between them, except when we come to granitic gneiss, which is not found with the former. In Marlborough, except for a short distance on the road south-west of Cummings pond, the gneiss on the road west of Stone pond, and in the south-east part of the town, the rocks are either fibrolite schists or White Mountain gneisses. In the west part of Harrisville the rocks are nearly everywhere pyritiferous. At West Harrisville the cleavage is more distinct than is common in this rock. A mile to the east, where the rock is more gneissic, the strata are bent and contorted,—something not very common in this section. There is a small area of dark gneiss near the outlet of Breed pond. On the road from West Harrisville, and at James Derby's, the rock is also gneissic. To the east, at John Yadley's, the rock is very much jointed and decidedly ferruginous; but east, near S. Follett's, and on the hill south, near J. White's, the rock is less ferruginous, and has somewhat the character of hydro-mica schist. At Harrisville village the rock is gneissic, and resembles somewhat that in Marlborough village. A line drawn from near the outlet of Long pond to the inlet of North pond, and extended southward to the east end of Monadnock lake, would show the eastern limit of the ferruginous schist.

In Dublin, near P. Morse's, and north-west, we have the ferruginous concretionary schist. On a farm road running south from the road west of Thomas Fisk's, the concretions are numerous and distinct. These schists extend north-west, probably, to the line of Marlborough; but on the road south from J. Morse's to Marlborough the rock has more the character of gneiss. Near S. P. Frost's, at school-house No. 3, there are numerous ledges. Just north of Thorndike pond, in the south part of the town, is the only other locality where there are characteristic rocks of the ferruginous and concretionary schists. Most of the rocks in Dublin, including Beech hill, the great ridge of Monadnock, and quite an area to the south-east of the village, differ quite widely from these, and will be described under the head of fibrolite schists. In Jaffrey, except the north-west part, some outcrops on the road west of Jaffrey village, and two areas of porphyritic gneiss, the rocks are generally pyritiferous schists, and mostly without concretions. On the road to Mt. Monadnock, for some distance above the gate, we find pyritiferous schist; but east, on the road to Jaffrey village, there are several kinds of rock. Near the height of land there is a granitic gneiss quite uniform in texture; then we have a common gneiss with crystals of feldspar; this is followed by a highly contorted mica schist near an old mill; then we have the concretionary ferruginous schist; and between this and the village, the gneiss with crystals of feldspar. Three miles north of Jaffrey village, on the road to Dublin, there is gneiss with small feldspar crystals, and for a mile north-east we find pyritiferous schist; also on the road east of Thorndike pond. South-west of Jaffrey village, between J. Priest's and J. Spaulding's, we find gneiss; and then, except the porphyritic gneiss near A. Emery's, we have only drift to East Jaffrey, and there are no outcrops of rock on the road towards West Rindge. Following down the Contoocook, we find ledges of pyritiferous schist near the town line. On both of the roads running south-east from East Jaffrey we find nothing but drift, until we get nearly to Prescottville (Squantum). About half a mile north-west of school-house No. 1, there is a band of gneiss quite free from iron with the ferruginous schist; near Capt. E. Prescott's there is a band of coarse granite,—and the schist here, although decidedly pyritiferous, has the mica of the White Mountain gneisses. The rock at the village and at S. Rolfe's, half a mile west, is very much discolored with iron.

The rocks in Rindge are more uniform than in any other town in Cheshire county. The town is, however, largely covered by drift, which, in this southern section of the state, is quite different from that northward. In Rindge, particularly, boulders of large size are seldom found; the drift occurs in rounded hills, which are composed largely of gravel and pebbles. From the town line, on the road from Fitzwilliam, there are no ledges until we get near West Rindge (Blakeville). Fifty rods to the west of the station, the rock is a decomposing, foliated pyritiferous gneiss; and east, at a brook, there is a coarse granite vein. Going towards Rindge, near C. K. Stickney's, the rock resembles that west of the station, and here there is a coarse granite vein. Near the village there are many ledges; they are everywhere pyritiferous, and in places they resemble the White Mountain schists. South-east of Rindge, on the road by F. Wilder's, there is only drift to Monomonac lake. North of the east arm of the lake there is an outcrop of schist, but the rock here is mostly an intrusive quartzose granite. South-east of J. R. Bixby's we have a ferruginous schist, and also coarse granite veins; at A. Griswold's there is a coarse granite, and then drift south-east to the state line. At East Rindge there are many outcrops of pyritiferous schist, and north it can be seen near A. Giles's; also at school-house No. 7, with granitic veins. On the road to New Ipswich, at J. F. Hale's, there is a fine-grained gneiss; and a quarter of a mile east, south of the road, the strata are twisted and contorted. At S. J. Hardison's, and east to the town line, where the ferruginous schist appears, the dip is generally easterly, though the inclination is quite variable. Along the road north of Hubbard pond, nearly to L. P. Towne's, the drift is sand. The outcrops of rock on the road from Grassy pond to Rindge are ferruginous schist. The north part of the town is mainly drift, but there is a ledge near F. Gardner's. Between Rindge and the south-west corner of the town, the rocks, although somewhat ferruginous, are closely allied in many of their lithological characteristics to the White Mountain schists and gneisses.

In Fitzwilliam, near Wm. F. Ferry's on the east, and at H. Fisher's on the north-west, the rocks are decidedly pyritiferous;—elsewhere in the town we have andalusite and White Mountain schists, and porphyritic gneisses. In Richmond, except in the north-west part of the town, we have White Mountain schists and gneisses and pyritiferous schists; though here the two are hardly distinguishable from each other, and are probably only a continuation of the White Mountain rocks of Troy. They will be mentioned more specifically under the next head.

Fibrolite Schists and Gneisses.

This group of rocks consists of two bands. One is long and narrow; it extends from Landaff southward, and continues with some interruptions as far as Keene;—the other is found farther to the east, and its culminating point is Mt. Monadnock; from this it extends northward to Harrisville and south-east nearly to the state line. The rock is somewhat variable, but in Grafton county there is always a marked distinction between it and the common gneiss on the west and the porphyritic on the east. In Sullivan and Cheshire counties it seems sometimes to verge into the White Mountain gneisses. In the south-east part of Landaff the rocks that we have referred to in this group appear, but here they have more the character of mica schist than gneiss. In general they are thin-bedded, and split with an even cleavage into comparatively thin plates. Garnets are quite common, and we find a few coarse granitic veins. The band, as a whole, seems to have a synclinal structure ; and on the west we have hornblende schists and common gneisses, and on the east ferruginous schists. The great ridge running southward towards the summit of Moosilauke, between Tunnel brook and the great ravine west, is composed of a rock very similar to that in Landaff ; though, as we approach the summit of the mountain, the rock has more the character of a micaceous gneiss. The old bridle path from North Benton follows the ridge, and in many places there are ledges, the outcrops being more numerous than on any of the other approaches to the mountains. The whole width of the band, measured across Moosilauke, is not far from one mile and four fifths. This is not directly across the strata, since between the east and west summits the strike corresponds in places very nearly with the ridge. On the west spur of the mountain we find the rock not very unlike that on the east, except that the cleavage planes are not so numerous, and the rock appears to be thick-bedded and contains fibrolite. The mountain has a synclinal structure, and the relations of the rocks to those on either side are shown in Section VIII. The south-west side of Moosilauke is largely covered with drift, and the micaceous gneiss and schist extend nearly to N. Merrill's. As far as Warren is concerned, the fibrolite rocks are found along the entire eastern border of the town. They can be seen on the ridge east of R. K. Clement's, and there are many outcrops along Mt. Carr. On Hurricane brook, about a mile and a quarter above R. F. Clifford's, they succeed the common gneiss, and occupy the whole mountain east. The rock here is almost massive, and is composed mainly of quartz, mica, and fibrolite. On the ridge of Mt. Carr we begin to meet with those great coarse granite veins so common along the entire outcrop of this formation southward. Although the fibrolite rock has a high easterly dip on Mt. Carr, as we go eastward it becomes more nearly vertical, and in Ellsworth the dip is generally westerly. It extends to Ellsworth pond, and when it comes in contact with the porphyritic gneiss it rests unconformably on it. The porphyritic gneiss does not lie entirely to the east of the fibrolite rock, but there are several small areas where it is entirely surrounded by it. One is on Moulton brook, where the road crosses it at H. & D. Sanborn's mill; and there are two in Rumney,—one west of Stinson pond, and another on the north side of Stinson mountain. This is probably the extension southward of the large area at Ellsworth pond, most of the porphyritic gneiss being covered up by the fibrolite rock. As the areas of porphyritic gneiss to which we have referred are nearly equidistant from each other as far as the strike of the rocks is concerned, it seems altogether probable that they constitute a synclinal axis underlying the fibrolite rock; and it is possible that this may give us the data for determining the actual thickness of the latter.

In Rumney, except the small area of porphyritic gneiss, a fine-grained gneiss in the south-west corner of the town, an area of granite or granitic gneiss north of Quincy station, and a band of granitic gneiss north of Rattlesnake mountain, the rocks are mica schists or micaceous gneiss, and they contain either fibrolite or andalusite; the coarse granitic veins carry beryl. Graphite (black lead) is found in the drift north-west of the saw-mill near G. L. Merrill's, and probably came from these rocks. The high bluff of rocks west of the village, and the hills north of West Rumney, are andalusite schists; they are found south of the river; but the rock of Hawks mountain resembles more the common White Mountain gneiss. In general, the distinction between the rocks of Rumney, and the Montalban rocks as they occur in the White Mountains and east in Campton, is very slight. The andalusite schists consist chiefly of quartz, mica, and fibrolite, or andalusite. The mica is in smaller plates, and feldspar, except in the granitic veins, is not so common. In regard to the porphyritic gneiss, it is to be noted that in Rumney the band that enters the town from the north disappears beneath the fibrolite schists.

In Groton, in the north part of the town, except in the extreme western part, the rock is entirely fibrolite and andalusite schists. As we go south it divides, and one band goes south-east and extends into Hebron, where it is the rock of the ridge of Tenney hill and Crosby mountain; it outcrops on the road north of Newfound lake, and here we find some quite good crystals of andalusite. The other band goes south-west, towards the corner of the town. The easterly band does not extend much south of the north end of Newfound lake, but eastward it is the rock of Plymouth mountain, where the rock contains fibrolite. East of A. J. McClure's, and at the town-house, we have fine-grained granitic gneiss. In the south part of Groton, between the two bands of fibrolite schist, we have coarse gneisses, sometimes porphyritic. The westerly band of schist that extends south-west from North Groton, outcrops in extensive ledges near where the road crosses Cockermouth brook, and it extends west into the edge of Dorchester. South of Kimball hill, and at G. Thompson's, the rock resembles the more micaceous of the Montalban series. Coarse granite veins are quite common in Groton and Hebron, and some of these carry fine crystals of beryl and mica. In the narrow band of fibrolite rocks in the south-west part of Groton we no longer find the synclinal structure that we saw in the broader band northward, but all the rocks have an easterly dip. Section VI crosses the south part of Groton, and the dip of the rocks will be given, which will show the relation of the fibrolite schist to gneiss.

In Orange, a line drawn from near R. R. Smith's south to Grafton, passing near the outlet of Orange pond, will point out the boundary between the fibrolite schist and the porphyritic gneiss. Another line, drawn from near the north-west corner of Orange, and bending to the west so as to pass just through the border of Canaan, near W. Davis's, turning eastward to the forks of the road near S. H. Stevens's in Orange, thence southward to a point between the height of land and Tewksbury pond, will follow nearly the western boundary of the fibrolite schist. Here, as southward, we have the Lake gneiss on the west. It will be noticed that the schist is quite variable in width, being two miles and three quarters in width on the north, and for some distance southward, when it suddenly contracts, near the middle of the town, to a band a mile and a half in width; and on the southern border of the town it is not more than a mile wide. In this area most of the strata are nearly vertical, and in the narrower portions it has both an easterly and westerly dip. There are coarse granitic veins in several places, and fibrolite can generally be found.

In Grafton the band widens somewhat, and here we have the coarse granitic veins that have produced so much mica. The rock can be seen on the railroad near the outlet of Tewksbury pond, and on the hill between the pond and W. Aldrich's; and south it is the country rock of Isinglass mountain. Thence it extends south to Springfield, and has a width of about a mile and a quarter. Along its entire outcrop it has coarse granitic veins, and in these openings have been made for mica. Through the town we have the Lake gneiss on the west and the porphyritic on the east.

In Springfield this rock is not so easily traced, and in the north part of the town it seems to disappear altogether. Running southward from Aaron's ledge to Col. Sanborn's hill there is a band of rocks, but they are more micaceous than the common fibrolite rock, and as far as they have been studied no fibrolite has been seen, though the coarse granitic veins are common.

In Sunapee the rocks between the porphyritic and the common gneiss resemble those of the common White Mountain series. They can be seen at the village of Sunapee Harbor, on the road north at J. Newton's, and south at D. Winn's. Keyser hill, east of the narrow band of porphyritic gneiss at the village of Sunapee Harbor, is composed of White Mountain gneisses, sometimes granitic. The porphyritic band is probably an outlier of the great area to the south-east. The rock that outcrops near Union church, in the south part of the town, consists of fine-grained and micaceous bands, and is followed on the west by common gneiss. It is closely allied to the typical White Mountain gneisses, and extends southward into Goshen, where it outcrops along the west side of Sunapee mountain. North-east of Mrs. L. Blood's we have both the micaceous and granitic gneisses, though the former may be more allied to mica schist than to gneiss. Here we find a peculiar form of fibrolite, which is not seen north, but is quite common southward. It is sometimes greenish gray in color, is compact, and often has the semblance of crystals, the centre portions of which have been removed by weathering. East of L. Baker's we have prophyritic gneiss, then the band of mica schist, and in this is a bed of graphite, from which years ago tons of the mineral were extracted.

In the south part of Goshen, at J. Glines's, on the road to Washington, there is a narrow band of fibrolite rock intimately associated with the porphyritic gneiss. Southward the whole Lempster mountain range is mica schist or micaceous gneiss. It contains the compact fibrolite, and has coarse granitic veins that carry beryl and tourmaline. The strata have a high easterly dip, and there is common gneiss on the west and porphyritic gneiss on the east.

The band of mica schist in Marlow is less than two miles in width. Its northern limit is near Stone pond, and it is limited on the south-west by the porphyritic gneiss of Bald mountain. Half a mile south of Stone pond the compact fibrolite is very abundant, and is brought out finely by weathering. One of the best exposures is south-west, near S. Mathews's.

In Alstead the rock changes somewhat, being more compact and more gneissic in its character. In the south-east corner of the town it contains coarse granitic veins, where several mica quarries have been worked. The character of the fibrolite also changes, and is more like the common variety.

South-west, in Surry, we find Surry mountain composed of rock that is more like mica schist than gneiss; though it sometimes has the character of a micaceous gneiss, and sometimes, though rarely, contains fibrolite. On the west side of the mountain, east of the village of Surry, about three fourths of the way up, there is a vein, sometimes two or three feet wide, that carries galena, zinc-blende, and pyrrhotite. It appears also near the north end of the mountain, at nearly the same level. The southern extremity of Surry mountain is the limit of this band of the fibrolite rock southward. The rock of Bald hill,—which seems to be an extension of Surry mountain northward, although cut off from it by the deep valley of the Ashuelot river,—resembles very closely the White mountain gneiss, and probably belongs to the same group of rocks as Surry mountain. We have already referred to the rocks of Bear Den mountain when speaking of the pyritiferous schists, but they are hardly distinguishable from the rocks of Surry mountain, and evidently belong to the Montalban series.

Then, going south, in the east part of Keene and extending into Roxbury, and southward in Marlborough and Troy, we find the White Mountain schists and gneisses. In Keene, on Beech hill, and on the road east of D. Wood's, we have a micaceous gneiss; also in the hills south-east of South Keene.

In Roxbury, at school-house No. 3 and on the hills north, we find the same rocks. On the hill east, about a mile from school-house No. 3, we have a granitic gneiss, and this is succeeded by a pyritiferous concretionary schist. South of school-house No. 3 we have the famous Roxbury granite,—a granitic gneiss of the Montalban series. There are also quarries along the west base of Horse hill, where the rock is somewhat coarser in texture. On the road south, perhaps three fourths of a mile west of Cummings's pond, we have the concretionary schist.

In Marlborough this band of rocks becomes wider, and extends east along the north line of the town, taking the place of the concretionary schists of Roxbury, and probably resting on them. Going south-east from Horse hill in Roxbury, after crossing bands of White Mountain and fibrolite schists, we strike another band of concretionary schist, before we reached the line of Dublin, exactly like that in Roxbury; and this band may extend north through Harrisville and connect with the Roxbury schist west of Breed pond. If the schist that we find north-west of West Harrisville is not continuous north-east and connected with a similar rock in Nelson, then we have an oblong area of White Mountain and fibrolite schists extending into and partly surrounded by concretionary schists. On the south-east side of this area we have fibrolite schists, and they resemble more the schists of Monadnock than the common White Mountain schists. If these are connected with similar schist on the hill north of Harrisville, then we have a band nearly parallel to the Monadnock range, and separated from it by the concretionary schists. In the extreme north-east part of Marlborough, on the line of Harrisville and just south-west of the forks of the stream below West Harrisville, we find the compact fibrolite, so common in the schists of Marlow. This band of rocks outcrops to the south-west near L. Blodgett's, and the eastern limit here is between Blodgett's and school-house No. 6. From this point the line separating the two schists runs southward near Meeting-house pond, thence near the forks of the road north-west of D. Field's. The boundary here and southward is not so well defined as the southern limit of the band of concretionary rock west of Monadnock is, in the south-east corner of Marlborough.

The rock of the western and central part of Marlborough is White Mountain schists and gneisses. At the glen above the village there is an extensive exposure of micaceous gneiss. There is a great gorge, with a wall of rock thirty or forty feet in height, and pot-holes in the ledges where the water has poured over. The strata are nearly vertical, and there are granitic veins. South of the village is the granite quarry, and on account of the arrangement of the mica the rock appears to be bedded. It has two micas and two kinds of feldspar,—one beautifully striated. South, along the railroad, there are many outcrops of micaceous gneiss; the strata are nearly vertical, with nearly everywhere an easterly dip; while along the road south of the old church the dip is westerly, thus giving a synclinal structure to the Montalban rocks. Here, as elsewhere, these rocks frequently contain coarse granite in veins. They are quite numerous on the hills east of Marlborough station. On the west of these rocks we have a gneiss in the edge of Swanzey that resembles more the Bethlehem than common gneiss, while on the east, in Marlborough and in the edge of Dublin, we have siliceous pyritiferous schists.

Rocks of the Montalban series are the prevailing, if not the only, rocks of Troy, and many of them cannot be distinguished from those found on the summit of Mt. Washington. We have east of the village a granitic gneiss of this series that is quarried. The strata are generally nearly vertical, but the prevailing dip is easterly. The most important thing in connection with the rocks of Troy is that the Monadnock range meets Montalban rocks at such an angle as to show their unconformability. The western boundary of the Montalban rocks of Troy and southward follows very near the line of Troy and Swanzey, and from near the north-east corner of Richmond it extends in a curved line nearly to the village of Richmond; thence it extends a little south of west, and strikes the town line perhaps a mile south of Peaked mountain.

In Winchester there is a small area of these rocks in the south-east corner of the town, and they may extend in a narrow band as far north as the west side of Stony mountain.

In Richmond all the rocks south-east of the line we have mentioned belong to the Montalban series, with the exception, possibly, of the band of rocks that embraces the soapstone. The strata generally are nearly vertical, and have both easterly and westerly dips, while the strike is frequently north and south. In some places the strata are twisted and contorted, and so ferruginous as to disguise the real character of the rock. South-east of school-house No. 14 is a band of soapstone, included, in part, in hornblende schist. The soapstone is identical with that at Francestown, but on account of its limited area, and sometimes portions of it containing iron, it has not been worked with profit. When attempts were made to work it there were two openings, one nearly east from the school-house, and the other south-east from L. Harris's. The width of the bed was forty-two feet, and apatite, rutile, pinite, and iolite have been found,—the pinite in very perfect crystals. At E. Harkness's, near D. Martin's, N. Putney's, and several other localities, there are coarse granitic veins, and graphite above school-house No. 12. South-east from Richmond, in the town of Royalston, particularly at Royal cascade, we have the typical Montalban rocks. In the north-west of Fitzwilliam, adjoining Richmond, we have an extension southward of the Montalban rocks of Troy; there are outcrops west of S. W. Keith's, at M. Broad's, N. Howe's, and in many other places. Extending diagonally across the town we have a band of andalusite rocks, apparently an extension of the rocks from Monadnock. They outcrop on the road between Bowker pond and S. Drury's, south of R. Fairbanks's, on the railroad north of the Richmond road, and in the south-west part of the town at G. Richardson's. Except the granitic gneisses that are so extensively quarried near the village of Fitzwilliam, and a few rocks along the railroad, we shall have to regard this as the limit of the Montalban rocks, unless the pyritiferous schists of Rindge belong to this series.

The Eastern and Western Bands. The eastern band of fibrolite schist differs in many respects from the western, yet in some points they are alike. Most of the rocks of the eastern band are mica schist; but while many of the rocks of the western seem to be hydro-mica schist, yet there are some that are clearly mica schist. The compact fibrolite, common in the southern part of the western band, is also common in the eastern band, and is one of its marked characters. The fibrous variety is common to both. The rocks of the eastern band are very closely allied to, if not identical with, the range north that includes Mt. Kearsarge and the Ragged mountains. On the other hand there are many points of resemblance between this eastern range and some of the rocks we have described under pyritiferous schists. We have already alluded to an outcrop of rock north of Harrisville, which seemed to be a part of a band that extended south-east into Marlborough; but the Monadnock range has its northern limit at the northern extremity of Beech hill, where it has a dip almost directly north; but on the same hill south the dip is north-west. The rock seems more allied to hydro-mica schist than to the common mica schist, and it contains compact fibrolite. It is the rock directly east of Monadnock lake, and it occupies an area of country here at least two and a half miles in width. It is the rock of the country directly south of Dublin village nearly to Thorndike pond, and south-west it is connected with the ridge of Monadnock. There is an outcrop just south-east of the eastern extremity of Monadnock, and on the road still farther south the rock is more decidedly a hydro-mica schist than that found elsewhere in this range. Following the ridge of Monadnock, the rock is quite uniform until we get near the highest point of the mountain, when it becomes more compact, has fewer cleavage planes, and contains some chlorite. The fibrolite, though generally present, is not so abundant as on Beech hill, and it is the variety that was formerly called bucholzite. On the north side of Monadnock, probably a hundred and twenty rods a little east of north from the hotel, considerable quantities of graphite were formerly obtained, but the mine is now nearly or quite exhausted. The fact that graphite occurs here, would ally the rocks of Monadnock with the older rather than the newer rocks. On the north-west side of the mountain, and not far from a mile south-east of L. Darling's, the rock resembles the micaceous gneiss of the White Mountains, and it contains an abundance of the fibrous variety of fibrolite. The rock on the ridge extending southward from the summit of Monadnock is very similar to that on the ridge northward, and it crosses the road just west of the toll-gate, where it is a very narrow band, and nearly vertical. Southward, on Gap mountain, we have the andalusite schist associated with a rock probably intrusive, and also with a dark gneiss. The schist that outcrops in Fitzwilliam, west of S. Drury's, has a large proportion of andalusite, and where it was examined had no other rock with it; that south of R. Fairbanks's has a fine-grained granitic gneiss; on the east and adjacent to it, that near G. Richardson's has the strata vertical, and with it is a dark gneiss, similar to that on Gap mountain, and it is probably the same kind of rock as that quarried near the station.

Dip of the Rocks of the Montalban Series.

These include the ferruginous schists, the fibrolite schists, and the White Mountain schists and gneisses.

Easton.

At Easton village, N. 82° E. 60°.

On road towards Kinsman Notch (Bungay), N. 83° W. 60°.

Warren.

A mile east of R. K. Clement's, S. 28° E. 70°.

On Mt. Carr, at head of Hurricane brook, S. 48° E. 65°.

On crest of Mt. Carr, S. 38° E. 60°.

Wentworth.

On ridge of Mt. Carr, N. 80° E. 58°.

Other dips in Wentworth and in Ellsworth are shown on section VII.

Rumney.

On summit of Stinson mountain, N. 68° E. 60. North-west side, N. 78° W. 50°. West side, N. 75° W. 65°.

South-west side of Rattlesnake mountain, S. 65° E. 80°, and opposite.

Near cemetery opposite West Rumney, N. 87° E. 76°.

Near H. M. Swain's, S. 75° E. 55°.

Near J. C. Burnham's, N. 48° W. 75°.

Plymouth.

On the hill south-west of C. G. Batchelder's, S. 68° E. 64°.

Near C. Nutting's, S. 82° W. 65.

Near J. Nutting's, S. 85° W. 58°

Campton.

On Wolfe hill, above Blair & Sanborn's quarry, N. 70° E. 58°.

Near Capt. J. Cook's, N. 82° E. 70.

Holderness.

On Mt. Prospect, N. 57° W. 65°.

On north spur of Mt. Prospect, N. 68° W. 76°.

On Squam mountain, north of road, S. 84° W. 55°.

North of town-house, N. 72° W. 68°.

Near Mrs. T. Shepherd's, S. 38° E. 40°.

Bridgewater.

On the hill near S. Fifield's, N. 58°. W. 74°.

Near J. C. Barrett's, S. 76° E. 70°.

Hebron.

Near E. Woodbury's, S. 68° E. 70°.

Near Tenney hill, S. 76° E. 65°.

Groton.

North part of Groton, on road to Rumney, N. 36° W. 75°.

At school-house south, N. 58° W. 63°.

At North Groton the strata are often vertical, but west, they have an easterly dip, and east, they have a westerly dip.

At P. Chase's, N. 45° W. 65°.

At D. Esty's, S. 82° E. 80°.

Grafton.

At M. Kilton's, S. 60° E. 72°.

At mica quarry, N. 32° E. 80°.

At west side, S. 50° E. 75°.

At north, S. 63° E. 70°.

¼ mile south-east of J. Martin's, S. 78° E. 70°.

At Alger hill, N. 62° E. 75°.

At H. Bullock's, S. 38° E. 50°.

At Prescott hill, N. 82° E. 40°.

¼ mile north-east of T. Foss's, S. 65° E. 70°.

At Mrs. Arvin's, S. 62° E. 78°.

At Tewksbury pond, S. 33° E. 75°.

Orange.

At J. Eastman's, N. 82° E., variable.

North-west of J. W. Hooper's, S. 60° E. 70°.

At school-house No. 7, N. 40° W. 78°.

Opposite P. Stevens's, S. 6° W. 80°.

Sunapee.

Near Union church, N. 80° W. 76°.

Near D. Winn's, S. 82° E. 60°.

Goshen.

Near Mrs. L. Blood's the westerly dip is probably local, as elsewhere here, and at the graphite mine the strata have a high easterly dip.

Lempster.

At signal, Mt. Lempster, S. 76° E. 62°.

A mile north-east of same, S. 53° E. 50°.

A mile north of D. Hall's, S. 36° E. 75°.

Near T. Wellman's, S. 52° E. 72°.

Acworth.

Near L. Morse's, N. 80° E.—contorted and variable.

Second road north of Beryl mountain, N. 82° E. 15°.

North end of Beryl mountain, N. 66° E. 10°.

Near J. Buckminster's, S. 36° W. 46°.

Near G. H. Gassett's, N. 48° W. 50°.

Near C. W. George's, N. 80° E. 40°; half a mile south, S. 53° E. 15°.

Marlow.

Just south of Stone's, S. 50° E. 65°.

½ mile south of Marlow hill, S. 25° E. 70°.

Near S. Mathew's, S. 2° E. 70°.

At Gustin pond, 37° E. 60°.

Stoddard.

On Stoddard heights, at signal, N. 63° W. 75°.

Gilsum.

Near R. Nicols's, S. 68° E. 55°.

At school-house No. 1, N. 82° E. 32°.; also a fine-grained gneiss, S. 66° E. 70°.

Surry.

On west side Surry mountain, opposite the village, N. 80° W. 60°.

On Bald hill, S. 80° W. 62°.

South of Lily pond, S. 75° W. 70°.

½ mile north of the Austin place, S. 88° E. 70°.

At the Austin place, N. 82° W. 60°., and variable.

Roxbury.

Near school-house No. 3, N. 80° E. 40°.

Nelson.

At Page's, N. 53° W. 40°.

At N. H. Hardy's, N. 88° W. 45°.

At M. Wilson's, N. 68° E. 48°.

Marlborough.

Fifty rods south-west of Cummings pond, N. 55° E. 64°.

At the Glen, N. 48° W. 60°.

At J. H. Knight's, westerly.

South of brook near J. P. Smith's, N. 28° W. 46°.

Sulpher spring, westerly, nearly vertical.

At L. Blodgett's, N. 58° W. 60°.

At Wm. Tenney's, S. 82° W. 20°.

At Granite quarry, S. 65° E. 60°.

At T. Tollman's, S. 85° E. 65°.

At A. Bemis's, S. 80° E. 50°.

½ mile north of B. Morse's, N. 76° W. 55.

Troy.

At S. Tollman's, S. 68° E. 50°.

Near J. Bemis's, N. 62° E. 80°.

At W. Boyden's, N. 72° W. 62°.

At L. Wright's, N. 85° E. 70°.

At school-house No. 1, N. 68° W. 55°.

At M. K. Tapley's, N. 72° W. 60°.

Gap mountain, west side, north peak, N. 80° E. 70°.

Top of ridge, S. 78° E. 75°.

On south peak of Gap mountain, N. 70° W. 72°.

Dublin.

South-west of Monadnock pond, N. 28° W. 62°.

North end of Beech hill, N. 40°.

South-east side of Beach hill, N. 42° W. 30°.

South end of Beach hill, S. 35° W. 36°.

South of the east end of Monadnock pond, ½ mile south-east of L. Darling's, N. 68° W. to N. 12° E.—variable.

East side of Mountain brook, N. 12° to N. 36° W. 35°.

In the pasture on extreme north-east spur of Monadnock, N. 50° W. 18.

⅝ of way to north peak of Monadnock from the lake N. 80° W. 35°.

North peak of Monadnock, N. 72° W. 45°.

A mile north-east from summit of Monadnock, S. 84° W. 65°.

East of A. H. Fisk's, N. 46° W. 82°.

South of Wood's brook, N. 48° W. 70°.

Jaffrey.

½ mile north of summit of Monadnock, N. 82° E. 50°; summit, N. 36° W. 60°.

¼ way to Mountain house, N. 38° W. 20°.

½ way to Mountain house, N. 48° E. 25°.

Near toll-gate, N. 38° W. 60°.

Near J. W. Harris's, N. 62° W. 74°.

A mile north-east of Jaffrey centre, N. 36° W. 50°.

East of Thorndike pond, N. 43° W. 50°.

Saw-mill on Contoocook river, N. 85° W. 53°.

At Capt. E. Prescott's, N. 36° W. 55°.

Hill north-west of Haskell's, N. 63° W. 70°.

50 rods south of A. Baker's, N. 20° to N. 50° W. 62°.

Rindge.

At the village, S. 53° W. 70°.

South-east of J. R. Bixby's, S. 53° E. 20°.

At school-house No. 7, S. 48° E. 55°.

At J. T. Hale's, S. 8° E. 72°.

½ mile east and south of the road, N. 8° W. 50,—variable and contorted.

Near Gate's, S. 80° W. 45°.

South-west of village, and west of railroad, S. 75° W. 50°.

Fitzwilliam.

North of State Line station, N. 58° W. 45°.

At W. F. Terry's, strike north and south; strata vertical.

At G. Richardson's, N. 63° W., and opp.

On road west of S. Drury's, S. 8° E. 65°.

At M. Broad's and H. F. Hildreth's, N. 80° W. 40°.

Richmond.

At J. Hill's, N. 80° E. 60°.

At Z. Bowen's, N. 82° E. 40° to 70°.

At E. Harkness's, S. 58° E. 48°.

At M. Allen's, S. 68° E. 80°.

At W. Wright's, S. 80° W. 74°.

At A. Keton's, N. 75° E. 65°.

Winchester.

On Peaked mountain, N. 85° E. 75°, and vertical.

On Stone mountain, west side, N. 78° E., nearly vertical.

[NOTE. The quartzites and quartz conglomerates occurring along the western border of this district have been described in connection with those of the Connecticut Valley district, pages 416–421.]

INTRUSIVE ROCKS AND VEIN-STONES.

Quartz. There is a band of quartz that has its northern limit on Giles pinnacle in Grafton. Southward there are extended outcrops in Grantham, Unity, Surry, and Keene. This band of quartz has some marked peculiarities which distinguish it from all the other rocks that we have described. There are, however, two bands of rocks in the eastern part of the state that are its equivalents. The northern area, that in Grantham which forms the elevation known as Giles pinnacle, may be three hundred and fifty yards in length, and is probably five hundred feet in width. As the outcrop is surrounded by drift, this limit may be far too small, and the drift also prevents our knowing what rock the quartz penetrates. The nearest rocks, however, are common gneiss. The rock is not often a pure white quartz, but is generally of a dull yellow or of a reddish color. In many places it contains cavities that are lined with quartz crystals, and it frequently encloses decomposed feldspar. Sometimes there is a tendency in the rock to a banded structure, though this is not common.

The outcrops of the quartz in Grantham are not so prominent as those of Grafton. Here the quartz has been worn away nearly to the level of the other rocks, and everywhere that we have seen the quartz it rises above the rock it penetrates in proportion to its width. The character of the rock is very much like that of Grafton. It outcrops on the road that runs south-east from the Methodist church, and at D. S. Hastings's where it forms quite a hill, and on both sides of it we have gneiss. It can be seen west of N. Shaw's, and southward it crosses the road at the forks near W. G. Winter's, and below, at R. Winter's, there is a prominent ledge.

In Croydon, north-west of East Village, near W. R. Bartlett's, we find the quartz penetrating the protogene gneiss, and it contains iron ore both limonite and hematite. The masses are sometimes four or five inches in diameter. The quartz is several rods in width, and from the principal area it sends off veins into the surrounding gneiss.

The next outcrop southward that we have examined is on Quimby hill in Unity. In width it is much more extensive than the rock in Grantham. It is more compact, and has fewer cavities. There is also another outcrop on the hill directly south of Quimby hill. The drift conceals all the rocks except the quartz, but as there is a protogene gneiss east, it is more than probable that the quartz penetrates it here as in Grantham. We also find quartz at the south end of Perry mountain, and some of it is very white. It is here very near a band of quartzite. This quartz is probably the source of the very white quartz boulders scattered through Langdon.

In the south-west part of Surry there is quite an extensive area of quartz, and at Mine ledge it attains a greater width than anywhere else along the line of its outcrop: we have here nearly all the features that characterize the rock. At the extreme north end of Mine ledge, perhaps half a mile south-east of the house of E. Crain, Jr., there is a narrow band of the rock, with veins penetrating the protogene gneiss in every direction, making in many places a complete breccia. Southward the band of quartz widens, until opposite school-house No. 4 it is not far from six hundred feet in width. Just north of the road that passes through Mine ledge, in the quartz we find quite a quantity of iron ore, chiefly limonite, that forms botryoidal and mammillary masses on the quartz. From this circumstance this quartz hill received the name it bears, though the ore is not found in workable quantities. On the east side of the ridge there is a high and precipitous wall of rock, and opposite this, on the west, the ridge is quite steep. Besides the brecciated character of some parts of Mine ledge, we find not only in the rock here, but elsewhere, that the quartz encloses feldspar, generally partially decomposed, as though the quartz had been formed in a great fissure, and that the vapor or solution that carried the silica had penetrated the rocks adjoining, and absorbed all but a remnant of the feldspar.

Southward, on the railroad, instead of being concentrated mainly in one vein, there are several. In the cut below the crossing, in the corner of Keene, we find two veins with chlorite schist between: one of these veins has well defined walls. In the Surry or "mile cut" the principal vein of quartz is from twenty to thirty feet wide, is a breccia in part, and is on the line of a fault. On the east side it abuts against hornblende schist, while on the west there is gneiss, and in this there are several small veins of quartz. Both of the larger veins follow the line of an axis or a fault. South of the railroad, one band of quartz extends southward along the east side of Gray's hill, and soon disappears. Another band can be followed over Gray's hill and down on the south-west side. There is an outcrop of the quartz at A. Parker's and at the Barker place in Westmoreland, and also west of J. Hyland's, but all of these are comparatively narrow.

On the east side of the Ashuelot river, in Keene, there are several outcrops of the quartz,—one north-east of the cemetery, another south, and still another near South Keene. On the east side of West mountain, on the slope toward the Ashuelot, there are extensive outcrops. It is nearly continuous, and a brook near the line of Keene and Swanzey crosses it, but it does not extend far into Swanzey.

In Chesterfield, near C. A. Lincoln's, we have small veins of quartz; and at the forks of the roads south of J. Putnam's the veins have considerable width, and contain many cavities with quartz crystals. Here, as elsewhere, the quartz penetrates the protogene gneiss. This locality is the southern limit of this peculiar vein quartz, as far as we have been able to trace it.

From our study of this rock we conclude (1) that these veins are endogenous, i. e., the material of which they are composed was derived from the adjoining rocks and from the deeper parts of the fissure; (2) that the vapor or solution from which the silica was deposited was strongly alkaline,—so much so that in some cases it absorbed the silica of the adjacent rock; and that this was re-deposited with that already held in solution, enclosing portions of the feldspar of the county rock.

Granite. There are seven well-marked areas of granite in this topographical district. The boundary of each, however, does not seem to be so regular as that of the areas of granite in the central and eastern part of the state. Here, except that in Roxbury, the areas are much longer in the general direction of the strike of the rocks of the country than across it. At Sunapee and Fitzwilliam they differ not only from those east, but also from others in this district, by having several different kinds of rocks immediately associated with the granite.

Specimens of rock from different localities vary in the coarseness or fineness of their mineral constituents rather than in their composition;—at least, examining the specimens with a common lens, about all we can say is, that one is coarser or finer than another; but microscopic analysis may show much greater distinctions.

The most northern area is in Rumney. Immense boulders of the granite lie along the side and at the base of Rattlesnake mountain. These boulders are quarried; and it is wonderful how they have withstood the action of the atmosphere through the ages that they have been exposed to its influence. Many of them are scarcely affected by weather, showing that it is one of the very best of our granites. North of Quincy station there are ledges of granite, but the rock seems to be of a different character, more quartzose, and not so suitable for working.

Farther east, just in the edge of Rumney and extending into Plymouth, is Wolf hill; this is almost one mass of granite. It is in many respects unlike any of the other fine-grained granites, and seems to be metamorphic rather than intrusive.

In Sunapee the granite is confined to a small area bordering on Sunapee lake, south of Sugar river, but there are several kinds of rock in the immediate vicinity of this granite. Three quarters of a mile from the outlet of the lake we have a typical variety of the White Mountain schists; between this and the lake there is porphyritic gneiss; and with the granite at the quarry south-east of the Harbor there is a dark-colored gneiss that belongs to the upper division of the Bethlehem gneiss. Then on Keyser hill and towards the lake we find porphyritic gneiss again. When this locality was visited, the granite seemed to me to be intrusive, and, from my study of similar rocks elsewhere, we have had no reason to change our opinion. About a mile and three quarters south of the Harbor, and on a road running east and west, there is quite an extensive quarry, and the stone obtained here is one of the best for many purposes of any that is found in the state. It is fine-grained, the colors are bright, and the rock does not have the dull appearance characteristic of some of our granites. South-east of this last quarry, and near E. Woodward's, there is a very dark-colored granite composed largely of quartz and mica, which resembles very closely a granite associated with fine-grained granite on the Nulhegan river in Vermont. A little south-east of this, on the road nearest the lake, we find porphyritic gneiss.

In Goshen the amount of granite is very small, and the area is on the road in the east part of the town just north of Chandler brook. The rock is rather coarse, and contains a much larger proportion of white mica than most of our granites. There are no outcrops of other rocks in the immediate vicinity, though to the south-east we soon come to porphyritic gneiss, fibrolite, and ferruginous schists.

In Acworth, in the south-west corner of the town and north of Cold river, there is a very limited area of granite, and it is known as Osgood's ledge. The surrounding rocks are quite unlike those associated with the granites elsewhere. On the north and west we have quartzites and schists of the Coös group, while on the south we have rocks that probably belong to the Montalban series.

The granite of Roxbury occupies an area in the south-west part of the town, on the road running north-east from Cummings pond. Instead of extending north and south, as most of the granite areas do, it extends rather east and west. On the western slope of Horse hill, in several places, the rock has been uncovered and quarried to some extent. The joints are not so numerous as in many other quarries; the principal ones have a gentle inclination northward, and are from two to three feet apart, while along the face of some of the quarries scarcely a vertical joint can be seen. The rock here is somewhat peculiar in that it contains a few bright garnets. From hand specimens one would be disposed to think it was a vein-stone rather than the country rock.

The granite extends northward, and there is an outcrop south of the stream near G. Nye's, and probably this is its limit in this direction. Westward from Horse hill, west of the road and south of Roaring brook, is the Nye granite quarry; and a short distance south, but on higher ground, is the quarry of the Keene Granite Company. The rock from the two quarries does not differ very much, though that from the latter is somewhat finer in texture than that from the former. The rock has a brighter look, and the joints that run nearly horizontal are not so near together, so that blocks of immense thickness can be raised. About an equal amount of black and white mica, the bright colors of the feldspar and quartz, and its pleasing appearance when cut, make it one of the most attractive of our granites. Its use in the construction of the capitol at Albany shows that it is appreciated. The rocks on the north, east, and south, at least, are those of the Montalban series.

It is quite probable that the granite of Roxbury extends across the branch of the Ashuelot into Keene, since there is an outcrop of granite on the Lawrence place. The rock here is very much jointed, but was used in the construction of culverts and abutments of the Manchester & Keene Railroad. On the hill south-west of this ledge we have a dark granite similar to that found in Sunapee. The next area of granite going southward is in Marlborough, south of the village. This is in shape more like the common outcrops of Concord granite in the central and eastern part of the state, and it is surrounded by the schists or gneisses of the Montalban series. We suppose this to be a typical variety of the granites of this section of the state. It is composed of light gray quartz, of orthoclase and oligoclase feldspar, and has both black and white mica. The rock here appears to be stratified, on account of the seams of mica that run straight through it at an inclination easterly of sixty degrees.

But there are places here, as elsewhere in granite, that the mica occurs in patches about in the rock quite irregular, and more often bent than in straight lines. Sometimes it even occurs in nodular masses, so these lines of mica cannot be regarded with any degree of certainty as lying in the plane of bedding. A quarry in this rock is one of the oldest in this part of the state. A rock that withstands the weather and retains its freshness after years of exposure develops qualities that give it the highest recommendation as a building stone. That this rock has these qualities is shown in some of the county buildings in Keene.

In Troy the granite is largely covered by drift, but there are several places where it appears on the east and south-east of the village. The rock is fine in texture, and is a very desirable stone. The rock on the west is the schist of the Montalban series. Towards Monadnock there is a dark granite, and on Gap mountain it is associated with andalusite schists.

Southward, in Fitzwilliam, there is quite an extended area of granite. The northern outcrop is at the Fitzwilliam Granite Company's quarry, about three quarters of a mile north of the village. At the principal opening the rock is of a coarser texture than that found elsewhere, but for some purposes it is a superior stone. Just north of this, on the east side of the road, there is a very fine-grained rock, and this is in contact with andalusite schist. The most important outcrops of granite are on or near the railroad. It extends up the road about eighty rods above Angier's sheds, and, where it comes in contact with the schist, is one of the most interesting points for study. Below the Richmond road the railroad cuts the granite, and then south of the road we have extensive quarries which produce some of the best granite that we have. The immense blocks that are raised here show that the joints are not so frequent as in most of our quarries. The fresh, brilliant colors of the mineral constituents of this rock make it exceedingly desirable as a building or as an ornamental stone. On the hill south of the railroad station, and on its northern slope, is one of the oldest quarries in Fitzwilliam. The rock is cut by numerous joints, the planes of which correspond very nearly with the slope of the hill. This jointing enables the quarrymen to remove immense slabs that are only a few inches in thickness. In parts of the quarry, however, the joints are not so frequent, and large blocks for building or other purposes can be obtained. At the quarry on the eastern slope of the hill the joints are not so frequent, and, among the other desirable qualities of the rock obtained here, it is susceptible of a high polish.

With this light granite there is a dark rock that is extensively quarried. This rock we suppose to be a gneiss, and a more specific description than that already given will naturally come in the chapter on building-stones.

A section through the hill south of the station shows the dark gneiss on the south-east and the light gray granite at the quarries. But, a few rods north-west of the principal quarry worked by Mr. D. M. Reed, he has made an opening to obtain the dark gneiss; and here it is that we not only find the light gray granite in contact with the dark gneiss, but many veins of the granite penetrating the gneiss. The light gray granite is certainly intrusive here.

On the railroad, in a cut about ninety rods above the Richmond road, we have an exposure of the granite and the schist. On the right hand, as we enter the cut from the south-east, we find the schist nearly vertical, and extending to the bottom of the cut. But a few steps, and the granite suddenly appears, three or four feet above the rails, and it gradually rises until it reaches the surface of the ground. Except at the top of the cut the strata of the schist stand nearly vertical on the granite. After extending a short distance along the surface the granite is again capped by the schist, and soon disappears altogether.

Starting again from the south-east, on the left opposite the schist, the strike of which should carry it across the cut, we have nothing but granite, and we find the schist again only as we pass out of the rock cutting. Metamorphism may explain what we see here; but that the granite is intrusive is more probable.

Another interesting feature in the rocks here is, that below the Richmond road the porphyritic granite or gneiss is very near the light grey fine-grained granite, the intervening space being covered with drift. The porphyritic rock elsewhere seems to be stratified; but we have here, on the road from the station to the village, immense boulders of the porphyritic rock enclosing what appear to be rounded fragments of the dark gneiss, some of which are a foot in diameter. But whatever may ultimately prove to be the true character of these rocks, this section, from the variety of the rocks and their relation one to the other, will always be of interest.

Granitic Vein-Stones. Although there are many granitic veins in the east part of the Merrimack River Topographical District, yet there is one that can be called preëminently *the* granitic vein. It is nearly coextensive with the fibrolite schist, and follows mainly the axis of a great fold in the strata. It is important, as it contains the workable mica quarries of the state, and many interesting minerals. It is developed to a greater or less extent from Warren to Lempster. It first becomes noticeable on the crest of the ridge of Mt. Carr, where it contains rose-colored quartz. It probably follows this ridge southward, as it is found in Wentworth where the section crosses it.

North of West Rumney and east of J. Sawyer's, there is a vein that contains beryls, some of which are four inches in diameter. They occur chiefly in the feldspar, are of a yellowish color, and are not very brilliant. There are large boulders with granitic veins on the north-east side of Rattlesnake mountain, and these contain beryl. On the hill south of West Rumney we find the vein, and it continues southward in Groton. Near S. D. Southwick's some brilliant beryls have been found; some of the larger specimens are six inches in diameter. In the midst of the granitic vein at Southwick's there is a bed of arsenopyrite about a foot across. South, at H. N. Hall's, west of the house, the vein is composed largely of quartz; and some of the beryls found have their lateral axes two and a half inches in length. Following this vein southward we find large crystals of mica, some of the plates being fifteen or eighteen inches across. East of A. J. McClure's there is a granitic vein in granitic gneiss. From this vein some brilliant beryls and good crystals of mica have been obtained. A vein in the south-west part of the town, which is probably a continuation of the one at Hall's, contains plumose mica.

East, in Hebron, on the ridge running south from Crosby mountain, there is an extensive vein that carries beryl. Large crystals have been found, but they are generally of a dull greenish color. By patient search and some labor in this and the towns just mentioned, many brilliant crystals of beryl could undoubtedly be obtained.

The next outcrop examined was southward, in Orange, near P. Stevens's. Here the vein was formerly worked for mica. Beryls were obtained, and large crystals of tourmaline are still found; also mica, apatite, and albite, the variety Clevelandite.

Grafton is better known than any of the towns through which this granitic vein runs, and many years ago it became famous for its mica and its beryl. There is a vein on the ridge a little south of west from M. Kilton's, which extends northward; and south, on Isinglass mountain, is one of the oldest mica quarries in the state, it having been worked almost continuously for the last thirty-five years. Some of the strata adjacent to the vein were evidently changed contemporaneously with its introduction, where they come in contact with the vein rock, having been bent, and also changed in texture. We find here beryl, tourmaline, albite, apatite, and triphylite. On the east side of the ridge of Isinglass mountain, and north-west of T. Foss's, there has been an opening made for mica within a few years; and here large beryls are found. On Alger's hill, which is almost directly south from Isinglass mountain, and across a deep ravine, we find the granite vein on the crest of the ridge; and here the largest known beryls in the world have been found. One hexagonal prism from this locality weighs 2900 pounds, and measures four feet, three inches in length, with one diameter of thirty-two inches and another of twenty-two. A still larger crystal was partly dug out, but being left exposed to the weather it fell to pieces. It measured forty-five inches by twenty-four in its diameters, and was calculated to weigh two and one half tons. On a hill south-west of Hale pond recent excavations have been made for mica, and here formerly many fine beryls were found.

In Springfield the granite can be seen on Aaron's ledge, and it extends south-east towards N. Heath's. At J. W. Hill's mica has been worked, and the quarry is not yet exhausted. North of N. Heath's black tourmaline of remarkable size have been obtained. One crystal in the cabinet, with a perfect termination, is five inches in diameter; another, somewhat fractured, is about five and a half inches.

Southward, there are no marked granitic veins in Sunapee or Goshen, that we have seen, but in Lempster, north of the signal on Lempster mountain, there is one of considerable size that carries beryl.

The vein in Acworth that has been celebrated many years on account of its beryls, which have been widely distributed in this country and in Europe, seems to be in altogether a different line of fracture from the one we have followed, though the rock in which it occurs may belong to the same series. The locality is known as Beryl mountain, and is on the south side of Cold river, a mile south-west of South Acworth. The vein is composed largely of quartz, some of which is rose-colored. The excavation made for mica and beryl is on the north side of the hill, near the top. The opening seems like a fairy grotto, fallen somewhat to decay; for it has been made in the pure white quartz, and in this are set the beryl, several of which can still be seen. In 1830 Prof. C. U. Shepard visited this locality and obtained a part of a crystal, the whole of which he estimated to weigh two hundred and thirty-eight pounds. He supposed this to be the largest crystal noticed up to that time. The vein here seems to be confined to the immediate vicinity of Beryl mountain.

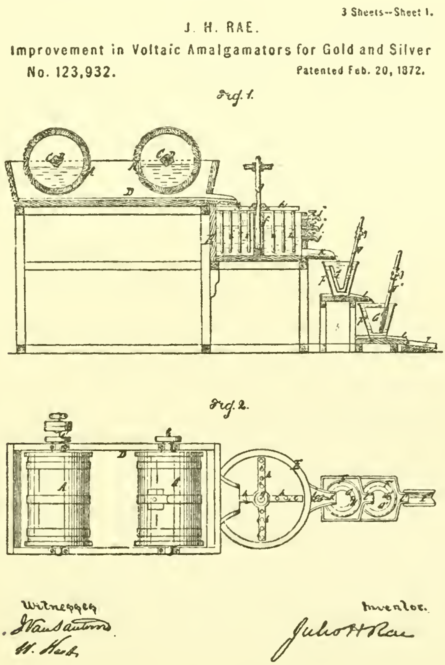
Southward, in Alstead, are several veins, but they are confined to the east part of the town. On the road south of Mrs. S. Whitcomb's there have been several openings made for mica, and black tourmaline is abundant with the mica. At D. Knight's there is an opening, and at J. A. Kidder's mica has been quarried. The most extensive excavations, however, are about half a mile west of S. Goodhue's. The vein extends south of where it has been worked for mica, and the quartz, often translucent, forms in this quite a distinct band by itself. An analysis of the feldspar from this locality by J. D. Whitney, gave silica, 70.84; alumina, 21.20; soda, lime, and oxide of iron, 7.97.

Fine crystals of beryl are found, and perfect crystals of tourmaline enclosed in the mica, and sometimes the tourmaline is found in the adjacent schistose rock. Southward, on Bald hill, in Surry, there is a coarse granitic vein, but it is not known to contain any minerals of special interest; and farther than Bald hill we have not been able to trace this vein.

There are other beryl-bearing veins, but they are generally small in size compared with those we have mentioned. There are some in Sullivan: one can be seen at Weathron & Cordney's. They are also found in

Marlow. There is one in Marlborough, at L. Blodgett's, where there are small but brilliant crystals, and another near the summit of Monadnock. These are among the most important we have seen.

There is one thing of special interest that we have noticed in regard to the position of the larger crystals of beryl. We find that all those above five inches in diameter have their vertical axes perpendicular, or very nearly so, to the plane of the horizon. If the strata were in their present position at the time of the formation of the vein, and the material of which it is comprised was derived from the adjacent rocks, this would seem to be the natural position of the crystals.



CHAPTER VI.

GEOLOGY OF THE MERRIMACK DISTRICT—SECOND PART.

THE description of the geology of the Merrimack district is presented in two chapters on account of different authorship. The dividing line between the areas described is the western boundary of the largest range of porphyritic gneiss, or that producing the high land between the Connecticut and Merrimack rivers. The geology of the territory west of this boundary has been already presented in Chapter V. The limits of the whole district have been stated in the chapter upon Topography. Speaking geographically, it may be said the area to be described in the present chapter is that of Merrimack and Hillsborough counties entire, with a few towns from Rockingham, Belknap, and Grafton. For convenience, the whole of the porphyritic gneiss of Ashland, Meredith, etc., and also the sienite of the Belknap mountains, will be described in the account of the Lake district, Chapter VII.

The formations occurring in the Merrimack district, as thus limited, are 1. Porphyritic gneiss. 2. Lake gneiss. 3. Montalban series, including the Concord granite. 4. Ferruginous schist. 5. Andalusite mica schist, with coarse granitic veins. 6. Rockingham mica schist. 7. Kearsarge andalusite group. 8. Merrimack group, including a little clay slate. There are no eruptive rocks in this area of sufficient importance to find a place upon the map.

1. Porphyritic Gneiss.

The largest area of this formation in New Hampshire is that commencing on the north in Groton, expanding at Grafton, narrowing in Wilmot, reaching its greatest breadth between Washington and Henniker, and coming to a point southerly in Jaffrey. It is sixty-one miles long, fifteen wide in its broadest part, seven and a half in Danbury and Grafton, and three and seven tenths in Wilmot. This area represents the height of land between the Connecticut and Merrimack rivers, which has been stated heretofore to constitute the first territory in the state that was redeemed from the primeval ocean. The normal structure of this mass should be anticlinal.

Besides this principal mass there are certainly eleven smaller areas. (1) Bean's hill mass, in Salisbury and Warner; (2) along Schodac brook, in Warner and Webster; (3) a smaller one in the same towns farther south; (4) Blackwater river range in Webster; (5) (6) the continuation of the same in the hill back of Tyler station, and near the village of Hopkinton; (7) the largest one next to the main ridge, in the north part of Weare; (8) north-west from Oil Mill station, Weare, perhaps continuous with the outcrops in the north part of New Boston; (9) a little known area in Pelham; (10) in East Concord; and (11) in Alexandria.

The western boundary of this larger area has been sufficiently well defined by Mr. Huntington on page 469. There are also a few small outliers west of it, as on the west side of Moosilauke in Benton, the north part of Rumney, three miles west of Sunapee lake, one about three miles north of Washington centre, the large range from the east part of Lempster to Marlow, a tract between Thorndike and Gilmore ponds in Jaffrey, and five small patches in Fitzwilliam, besides the oval district in Chesterfield and Winchester. These will not be farther alluded to.

The prevailing rock of this formation is the characterisic gneiss full of distinct crystals of feldspar. More than one species of feldspar may be present. The different areas are characterized by special features of size of crystals, their arrangement, or frequency of occurrence, so that it is possible to identify the source of boulders that have travelled several miles. Other layers consist of ordinary gneiss, ferruginous schists, and mica schists passing into quartzite. These associated rocks occasionally predominate, and the perplexing query often arises, Where shall we draw the line between this and the superior formations? Rocks repeat themselves in different ages, so that we have mica schists, etc., associated with the oldest as well as the newest formations, and it is not always possible from hand specimens to particularize the period. There are reasons for believing the porphyritic type of gneiss may not be the very oldest rock of the state, as instanced upon page 472. It was quite early remarked in one of the annual reports that this porphyritic rock seemed to have been thrust in between older strata. There are two areas of gneiss included within the territorial area of the older mass in Bradford, Warner, and Henniker. In other cases, an associated rock may be specified, though not delineated upon the map. It is a matter of regret that this principal area of porphyritic gneiss has been only slightly examined. Our studies upon it were mostly confined to the early years of the survey, before it was understood to be a stratified rock. Our observations of dip are therefore scanty, and its stratigraphical relations not well worked up. Then, latterly, also, the territory lay between the district being explored by two of us, and hence it was neglected.

Messrs. Whitney and Williams, in a description of the section from Portsmouth to Claremont, speak thus of this rock: "Large boulders of porphyritic granite are very numerous over the surface, from the West Parish of Concord to the centre of Warner, where we find the rock itself in place. It is a peculiar rock, having large crystals of feldspar uniformly distributed through its mass; they are often glassy, so as to furnish beautiful and striking specimens. This bed of granite extends across the state in a general N. E. and S. W. direction; it is from eight to ten miles in width, though often interrupted with veins of granite of various texture, often very coarse grained, and containing occasional beds of mica slate. * * * This rock continues, on this sectional line, about three miles west of Newbury, where it is replaced by mica slate." *Final Report, by Jackson*, p. 51.

In our second report a range was represented as extending from Waterville to Jaffrey, connecting across from Danbury to New Hampton, and not extending northerly from Danbury to Groton. Subsequent observations showed the existence of two instead of one principal range, and that no visible connection can be found between them. The intervening Montalban schists may be underlaid deep down by a synclinal basin of the older rock. The height of land in Springfield, New London, and Sunapee is represented on the map as consisting of the Lake gneiss, the porphyritic rock curving around it through Wilmot. I do not feel certain that we should not regard the Springfield gneiss as a part of the porphyritic group. Lithologically, it is more like the Lake division. Rarely crystals of feldspar are disseminated through it. The Montalban section of rocks carrying coarse granitic veins is also cut off by this Springfield gneiss.

We have four or five sections crossing this porphyritic range. At the north end, the formation is poorly exposed in Groton, on Cockermouth brook, and the positions are represented upon Fig. 82, Plate XXI. The strata are said to dip about 30° E., in the fork of the road east of Kimball hill. On the west the next ledges are of mica schist, dipping 50° and 60° N. 40° W. Hence, there may exist a strongly marked unconformity here. The rock through this valley in Groton contains many fine-grained gneisses ; also, ferruginous schist west of A. Fox's and the saw-mill, where the dip is 50° E. The rock is not seen in Hebron. This section, therefore, makes the dip of this rock in Groton essentially monoclinal. Farther north it is not seen, that is, for a distance of over nine miles, when we come to the Moosilauke-Kinsman range. It is probably exposed in the valley of Cockermouth brook, just at its northern extremity. The country north rises rapidly, and constitutes a high ridge about eight hundred feet above the porphyritic outcrops. This elevated mass of rock is probably a later formation, occupying a natural depression in the older rock. There may be an inverted anticlinal underneath the Kimball hill schists, in order to enable the porphyritic rock to present a proper face towards the easterly dipping gneisses of Dorchester.

The next section traversed is from the north end of Crystal lake in Enfield across Grafton and Danbury (Fig. 83). At the west end are strata of the fine-grained Bethlehem gneiss, with easterly dips. On the east side of East hill there is a gneiss somewhat porphyritic in aspect, dipping west. The rock is like this for two miles into Grafton, but the dip has changed to east. Then we pass the mica-bearing rock with its very coarse granite veins, dipping 53° S. 20° E. and 70° S. 80° E. This rock is believed to mark the place of a synclinal. The first ledges seen after leaving Grafton Centre are of genuine porphyritic gneiss, but I have no observation recording their position. The dips are believed to be easterly. In Danbury there is a south-west dip near S. Howe's, a mile north-east of the section. At the east end of the formation, half a mile north-west from Bog pond, the dip is 80° S. 70° E., and it is succeeded by a hard quartzite having the same position. The railroad cut in the ridge south of Danbury station is through this formation.

Next we cross through Wilmot (Fig. 84). This rock first appears on the east, between Potter Place and West Andover, standing vertically. Near the west point of Andover, in Wilmot, the dip of the well characterized rock is about S. 70° E. At Wilmot centre the stream falls over ledges of this rock, dipping 50° in the same direction. A mile west, by a saw-mill, there is a layer of hornblende rock, a great rarity in this formation. With it are the usual types of this rock, including layers with feldspar crystals three or four inches in length. These all dip like the last. By C. Rowe's, a little farther west, there is a magnificent display of these rocks, dipping the same way. Mica schists and porphyritic rocks with a dark base, having sparingly disseminated crystals of feldspar, occur here. By a small mill west of the "Gay stand," in the west part of Wilmot, the mixed porphyritic and common gneisses dip southerly. By our map this should be the western limit of the formation, but there is a porphyritic gneiss on the west town line, adjacent to Springfield. Our observations have shown the gradual increase of other varieties of rock in passing west from Wilmot, and therefore we may believe the characteristic feature may be almost gone, yet the age not change. Special conditions of deposition or metamorphism may have precluded the formation of the larger crystals in abundance. Along this section line the outcrops of ledge have been rare in the region west of the "Gay stand." Porphyritic gneiss is noted also about a mile east of the Springfield line. These dips recall the "fan-shaped stratification" spoken of by the older geological writers, perhaps resolvable into several closely pressed anticlinals and synclinals.

In the south part of New London there are large bands of porphyritic gneiss interstratified with the gneiss. The ledges on the south edge of Pleasant pond are abundant. There is a wide contrast agriculturally between the country of the porphyritic ledges south of Pleasant pond, and those southerly from New London centre upon the ordinary gneiss, the latter exhibiting beautiful farms, the former rocky pastures.

Sutton is nearly all underlaid by porphyritic gneiss. Near the north line, by C. A. Fowler's, the dip is 75° N. 75° W. The main road, through the hamlets of North Sutton, Sutton Mills, and South Sutton, abounds with porphyritic ledges. At the mills the descent is considerable. Between Kezar and Gile ponds there is an extensive meadow, and also below Sutton Mills. About South Sutton are steep conical hills, steepest on their south sides, as seen from the north-east. At the head of Long pond is a mass of compact flinty rock, dipping 80° N. 25° E., girt by the porphyritic rock on both sides. On Stevens brook this rock begins at the town line, and for two miles the ledges are nearly continuous. Sand obscures the ledges in the northern half of the town, on the road to Wilmot Flat from Stevens brook. It was surprising to us to find such a level road between Warner and Potter Place, through the Stevens Brook valley, in this mountainous region.

Another route, affording excellent views of this formation, is from Waterloo station in Warner along the railroad to Newbury summit. At Waterloo, north of the village, there are many ledges. Next they abound on the hill by Capt. S. Watson's. The dips may be north-westerly in them. Other outcrops are at a flag station midway between Waterloo and Melvin's Mills, and also at the mills. On a ridge south is a bed of the hard schistose rock usual in this group, standing vertically, with the strike N. 20° E. Other ledges crop out at Bradford mills, and quite abundantly along the railroad beyond, through Newbury. The dips on this route were not recorded. At the summit cut, near the south end of Sunapee lake, the rocks are finely shown. A dark micaceous porphyritic gneiss predominates, dipping 50° S. 65° E., and containing very irregular veins of coarse granite. Sketches of the veins show the mass composed of a coarse variety, full of beautiful minute garnets, and on both sides, adjacent to the walls, narrow bands of a finer grained granite. Next the vein the schists for a few inches' distance are often altered. Just north of the station the dark rock lacks the crystals of feldspar, retaining the same position. The formation is supposed to extend along the west shore of the lake to the north-west limit of the town, and also to make up the mass of Sunapee mountain farther south.

We have the data for a more satisfactory section from Washington to Contoocookville, across the very widest part of this porphyritic range, and shown in Fig. 85. The strata dip easterly along the western border of the rock. In Washington we have first a synclinal, an anticlinal, then a synclinal again at East Washington. The high hills in the south-west part of Bradford are thought to constitute another anticlinal, the dip of 30° S. 52° E. having been measured by A. Putney's. An anticlinal is put down for the highlands farther east, and the mica schist between Bradford centre and Bradford pond is reckoned as occupying an inverted axis. Ledges appear at the height of land, at the Baptist church, and along the west shore of Bradford pond. The last part of these dip easterly. Next, there is a considerable area of fine-grained gneiss supposed to belong to a later age, and occupying a basin in this older group. The east side of it is reached at Day pond, in the south-west corner of Warner, where high precipitous ledges of the porphyritic variety occur. Another micaceous schist, dipping 70° E. 80° E., occurs next on the Warner and Henniker line. Farther east, the dip is twenty degrees less. The whole width of this outlier is about half a mile on the town line, wider to the south. Next reäppear the porphyritic gneisses, continuous to the most north-eastern school-house in Henniker. The schist on the western border of the gneiss, east of the porphyritic, dips 75° S. 70° W. Thus this section also shows the fan-shaped stratification.

The occurrence of a curved line of hills in Washington, Bradford, and Henniker, is interesting. Lovewell's mountain is the highest and farthest west; the others are much elevated, and curve like a bow till the Contoocook river is reached. A trip from Bradford mills to Hillsborough Bridge showed porphyritic gneiss as far as Bible hill. Ledges were abundant near E. Cheney's, Bradford centre, and on the high hills in the south part of Bradford; and on Murdo hill, at the school-house near Loon pond, Hillsborough centre, and Peaked hill, in Hillsborough. Other localities of these rocks in Hillsborough appear at the Johnson place, and at the house of Miss Gibson, west of the lower village. It outcrops at the head of Long Falls, on the Contoocook river, dipping possibly 28° N. 52° W; about a mile farther north-east, two miles south-east from West Henniker, on the northern slope of a large hill, and at Henniker village, having the strike of N. 5° E., judging from the course of the longer axis of the feldspar crystals. The slates on the east dip towards the porphyritic gneiss.

In Warner, the Mink hills are all composed of this ancient rock. South of Bald Mink, a ledge of it, not necessarily typical of the mass, dips 20° W., and carries a vein of hyaline quartz, four feet wide. Ledges are

PLATE XXI.

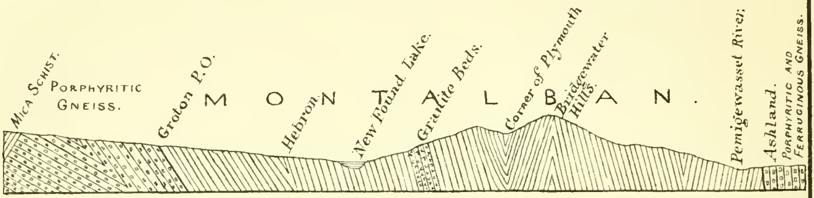


FIG. 82. SECTION BETWEEN TWO MAIN RANGES OF PORPHYRITIC GNEISS.

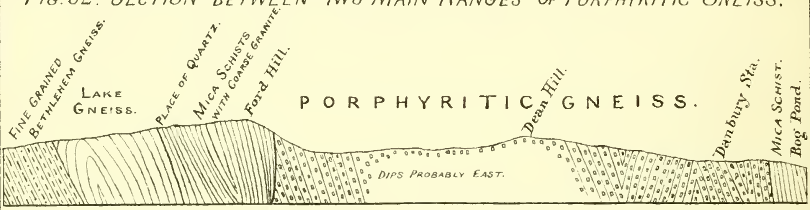


FIG. 83. SECTION FROM EAST ENFIELD TO DANBURY.

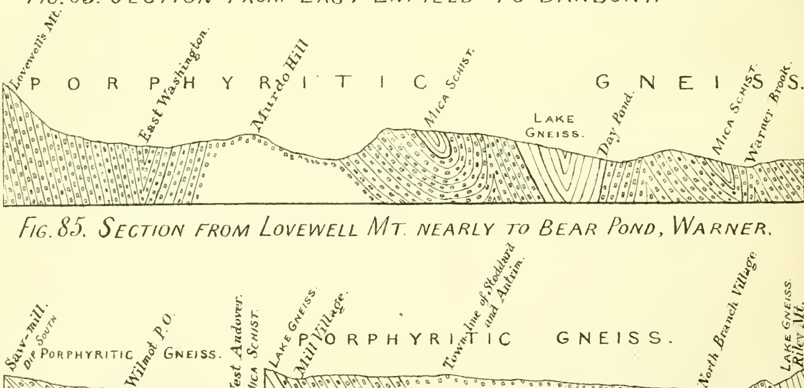
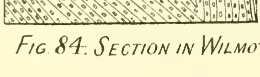


FIG. 85. SECTION FROM LOVEWELL MT. NEARLY TO BEAR POND, WARNER.



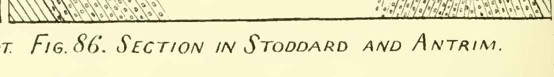


FIG. 84. SECTION IN WILMOT. FIG. 86. SECTION IN STODDARD AND ANTRIM.

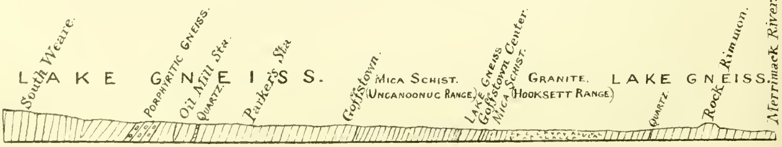


FIG. 87. SECTION FROM SOUTH WEARE TO MANCHESTER.

SCALE, HORIZONTALLY, $2\frac{1}{2}$ MILES TO AN INCH; VERTICALLY, 3000 FEET TO AN INCH.

HELIOTYPE

extremely common along the Mink hills, and the country west and south to the town lines of Bradford and Henniker. The road from the North branch in Antrim, across Windsor to Washington, shows chiefly ledges of porphyritic gneiss. The first hill climbed is very steep, and the strata may dip north-west. After reaching the crest of the hill, ledges are not abundant, the surface of the country being mostly covered by immense boulders of the same material, particularly between the southern school-house and Black pond. It is a characteristic feature of the porphyritic region that the surface should be conspicuously covered by large boulders of the same material with the underlying rock. Fertile tracts of land occur where the covering of drift has been finer than usual, or they have resulted from the filling up of low grounds. By Black pond in Windsor, the strata dip south-east. The road through the northern half of Windsor is over a smooth drift ridge, descending to a deep and wide alluvial peaty flat, below the outlet of White pond. This water flows north-easterly, tributary to the Contoocook, though not so represented upon the county map. In the edge of Washington, the profusion of boulders of porphyritic gneiss recommences, and the ledges appear at school-house No. 6. Near here are a few ledges of common gneiss, followed very speedily by the ordinary coarsely crystalline variety, which occurs several times on the road to Washington centre. Hills to the east, like Kingsbury, in Washington, and those in the east and north part of Windsor, seem to have the same underlying rock.

The next section (Fig. 86) extends from Stoddard to North Branch village, in Antrim, the strata appearing mostly monoclinal without any analysis of the dips. As in Washington, farther north, quite ferruginous schists flank the porphyritic gneiss on the west side, dipping 60° S. E., near Stoddard centre. At the mill village are the first porphyritic ledges, dipping in the same direction. These ledges are magnificently displayed near the east line of Stoddard. We have not passed directly over Tuttle hill, but followed the road to the north, down the North Branch valley, where we observed ledges of this rock at S. Dinsmore's and near the village. Its last outcrop on the section line is near Campbell pond, on the west side of Mt. Riley. Between the North Branch and centre villages are several outcrops of this rock seeming to dip N. W. The gneisses of Mt. Riley dip easterly, and therefore we represent a dip of the porphyritic variety conformable with it, thus necessitating the supposition of an anticlinal east of the northern village. The east part of the town of Antrim is occupied by a later gneiss, supposed to be encircled by the coarser rock, and to be that which crops out at first north of South Antrim and continues to Bennington, on the west side of the Contoocook. At Bennington the strata are about vertical, and the strike runs north-east and south-west. The rock at the mills in the village is well characterized. Hancock is entirely underlaid by porphyritic gneiss, and the whole breadth of the formation is represented by the town limits. To the south it narrows rapidly. A trip up Nubanusit river, into the east part of Dublin, showed only drift; but near the north-west corner of Peterborough there is a hard rock associated with porphyritic gneiss, dipping N. 50° W. The ledges were seen at intervals for two miles parallel with the north town line.

There is a spur of the porphyritic gneiss running from Peterborough into Greenfield and Francestown. An enormous boulder of it first attracts notice at J. Miller's, near the Greenfield line,—no ledges appearing from Peterborough village till we come to A. Green's. The country is flat, and covered with glacial drift much of the way, with a very few rocky outcrops. In Francestown the eastern limit of the porphyritic is reached near S. Duland's, the ferruginous seams there indicating a position of 50° N. 85° W. It is noticeable that this branch points towards the large porphyritic area in Weare, and an axial line is probably indicated by this circumstance. The areas of this rock farther south, in Jaffrey and Fitzwilliam, have been noticed in the previous chapter.

Upon Plate I there is a small area of this rock represented in Massachusetts, occupying the natural extension of the main New Hampshire range. The observations were taken from the Massachusetts report, where we find both our northern ranges noticed. The more western one shows itself in Northfield. The more eastern is said to be situated immediately east of a range of hornblende slate, which is made to extend from the Connecticut line at Monson directly north to Royalston. It will be noticed that Royalston adjoins Fitzwilliam; so that the connection between the Massachusetts and New Hampshire main ranges of this ancient rock is clear, and the general north and south course of the range is also continuous. My father thinks a strip of it may be found extending as far south as Long Island sound. He speaks of the fine development of this rock in the high hill east of Ware Village, extending southerly through Palmer. Those who ride over the Boston & Albany Railroad cannot have failed to notice this rock in Brookfield and Palmer. My father did not distinguish this formation upon the map, as he did not attempt to subdivide the gneiss, but has furnished data which enable his successors to trace out the formation.* The recognition of this porphyritic rock outside of the New Hampshire limits is of great importance, and it may furnish a clue to the structure of our New England geology.

Some observations of a trip through Winchendon and Royalston will further illustrate our position. Rindge has just been left, with its uniform ferruginous aspect. One mile west of Springville, in Winchendon, we observe the same rock in a horizontal position. One mile west of Winchendon the same rock, with coarse granite beds, dips 35° N. W. On reaching New Boston, a small hamlet in the south-west part of the town, ledges of porphyritic gneiss are perceived dipping west. A massive even-bedded variety succeeds, followed by the porphyritic, before coming to the village of South Royalston, dipping 85° west. This ancient band is nearly three, and perhaps five miles wide, cropping out in the direct line of continuity from the main backbone range of New Hampshire. On the west of South Royalston a gneiss like that of Winnipiseogee appears, dipping west, and within three miles the dip is reversed, giving us a synclinal axis. At Athol the rock is like the Montalban series, and dips westerly. The Lake gneiss comes up again in the New Salem, Shutesbury, and Pelham hills, with westerly dips. These may represent the southward continuation of the older rocks of the western part of Cheshire county. There is therefore a correspondence between the order of the formations in southern New Hampshire and northern Massachusetts, through Worcester and Franklin counties.

The Smaller Ranges. I will speak first of those about Warner. Bean's Hill, near Union church, in the south part of Salisbury, furnishes the beginning of an area of this rock a little over three miles in length. Tucker pond, Salisbury, and Bagley pond, Warner, with the west branch of Schodac brook, are situated upon it. The land stands out by itself, to some extent. There are three minor elevations upon it in Salisbury, and one in the very north-east corner of Warner. I do not find observa-

* *Final Report Geology, Mass.*, p. 628.

tions of the position recorded. On the main Schodac branch, where it crosses the Warner line, is a smaller area, about a mile long. It is bounded on both sides by ferruginous schists. Near Davisville is a third area, considerably smaller than the last, having an andalusite schist joining it on the west. All these areas are isolated from all connection with each other, or with the longer range to the east in the Blackwater valley. The smaller areas have a north-east course, the larger runs east of north, and all of them differ in direction from the Blackwater range, which courses a little west of north. They are separated by the Lake gneiss.

This Blackwater range begins near Webster post-office, and runs east of south, crossing the river in a band by a saw-mill and other buildings midway between the post-office and the south town line. It then continues in a high narrow ridge to the north part of Hopkinton, a distance of four miles, where it is covered up by the sand of the three converging rivers,—the Blackwater, Warner, and Contoocook.

This range is discernible in Hopkinton. It first crops out on the hill south of Tyler's station, on the C. & C. Railroad, with the dip 70° N. 65° E. There may be some veins of it cutting the adjacent ferruginous rock. Next is an outcrop of limited dimensions, a short distance north-westerly from the village of Hopkinton. These ranges point to the north end of the Weare area, in the south part of the town. Near J. & J., and E. G. Quimby's, we have porphyritic and common gneiss and mica schist, dipping 32° N. 85° W., with six feet width of white quartz. There are several exposures of porphyritic gneiss along the east and west road and the north part of Weare. South of J. Edmunds's the base rock holding the crystals is a clear, dark-colored, fine-grained mass. On two west roads farther south are other exposures. Near East Weare this rock dips 20° west. In the western part of this area, by D. D. Rowe's and S. S. Clark's, the dip is 20° S. 48° W. A little nearer North Weare it dips more westerly, and is succeeded by an overlying granitic gneiss with a small dip. This area is three and a half miles in its greatest diameter, and nearly as wide. The dips are all in the same general westerly direction, so that it must be an inverted anticlinal in its structure. A comparison of the trends of outcrops tends to the theory that the Greenfield spur from the main range may be continued in the North Weare, Hopkinton, and Webster areas.

In the south part of Weare, about a mile north-west of Oil Mill Village, is a small area of this rock, dipping 45° N. 50 W. Passing south-westerly into New Boston the same range crops out at J. E. Woodbury's, near the Weare line, with a north-westerly dip, and near Still pond, dipping 75° N. 60° W. The last has ordinary gneiss layers interstratified with it. These three localities are obviously connected, and constitute an ancient ridge parallel to the one previously mentioned.

There is an outcrop of limited extent east of the Merrimack river in Concord, near the "Mountain farm." The twin structure of the feldspar crystals is more obvious here than at any other known locality. The dip is north-westerly. It is associated with a rock like Concord granite, and a small trap dike is contiguous. I judge this outcrop to be unlike any of the others that have been noticed, and, if of the same age, belonging to a different or parallel range. It is quite near a quartz band, of which more will be said eventually.

The amount of the porphyritic gneiss in Pelham is not definitely known. When crossing the town on the line of Section I, I found in the valley, from one to two miles west of Pelham village, near J. Gage's, ledges of a porphyritic gneiss, but did not preserve a memorandum of the dip. It probably dips southerly. There is a record, also, of a single ledge of this nature by the high bridge over the Souhegan river, near the north line of Greenville. The dip of the associated rocks is 15° N. W. There is another a mile west of Pratt pond. Large blocks of this gneiss occur frequently in the valley of the Souhegan farther north, which may possibly have been derived from the neighborhood.

Conclusions. The facts stated thus far about the porphyritic gneiss authorize the following conclusions:

1. The central ridge has been subjected to such powerful pressure that both sides have been inverted frequently, and we observe the fan-shaped variety of stratification. A hasty generalization might state that this was the newest instead of the oldest formation in the state, because newer rocks apparently dip beneath it upon both sides. The same questions are raised here that have been discussed for many years in respect to the structure of the Alps in Switzerland. This main New Hampshire range may have formed a high mountain chain in past geological time, the more elevated summits having been eroded to furnish material for the building

up of the adjoining Lake and Montalban schists. We find here no examples of the modern type of synclinal mountains comparable with the Catskills or Greylock, since all such have been removed entirely by denudation. The ascent to the highest topographical line here is gradual from all sides,—something of the ge-anticlinal structure as set forth by Dana. From this elevated surface there is an occasional remnant of a later superimposed formation, like Monadnock and Kearsarge mountains. These features indicate a greater antiquity to the height of land in New Hampshire than belongs to the Green Mountains of Vermont. The latter still exhibit the anticlinal build. Should they be compressed still more, so as to produce inversions on both sides, and have their summits levelled down to the general average height of the mass, they would then be like the older New Hampshire range.

2. The repetition of the porphyritic gneiss in the smaller areas, and the occurrence of limited basins of gneiss and schist upon it, indicate the presence of anticlinal and synclinal lines, and thus aid in unravelling the stratigraphical features of the state. First of all, there is what might be called the Pemigewasset basin, a depression between the main range and that along Squam and Winnipiseogee lakes, allowing the accumulation of the Montalban series. Next, the Pelham area may be a remnant of an ancient ridge of this rock to constitute, with the main range, a basin for the deposition of the gneisses and schists of the lower Merrimack region. Third, smaller lines of upheaval or demarkation of basins are more clearly defined about the well established area; *e.g.*, there is the Peterborough and Greenville branch, continuous in the Weare, Hopkinton, and Webster outcrops. This gives us a basin for the deposition of the rocks between Greenfield and Salisbury. A smaller basin is that enclosed by the three Schodac areas of Warner, with the main mass in the Mink hills and Sutton. The gneiss outside of the Greenfield and Webster line is divided into two parts by the New Boston and South Weare line. There are two very obvious depressions in the porphyritic gneiss, about Bradford pond and in the west part of Henniker. Others must occur in the very large area between Wilton and Dublin, which farther explorations will bring to light. The depressions for the Monadnock and Kearsarge series must have been more extensive than any that have been mentioned. These lie partly upon this ancient formation, but as they involve others

of later origin, notice of their limits must be deferred. Opportunity may be afforded for the perfection of our general sections before the final completion of our explorations, in which case the reader will find in the atlas further details of structure in this ancient formation than appear from our descriptions.

We have not yet identified the Bethlehem gneiss in the eastern part of the Merrimack district. In the western part of the district three areas of a fine-grained variety are separated from the more characteristic rock, and delineated upon the map; and it is likely this kind of material, if not the other, might be found east of the porphyritic ridge. This distinction was made after the conclusion of all field work, so that it has not been practicable, as yet, to apply it to the eastern region. There is also a scarcity of hornblende in the Merrimack valley, the rock made use of in the Connecticut valley to mark the limits of the Bethlehem areas.

2. Lake Gneiss.

These rocks occupy about the same territorial area as the main porphyritic range just described. There are three principal lines of its occurrence, divided into many subordinate or isolated areas, which have been separated on account of concealment by overlying later formations. We find, first, the Northfield and Antrim line; second, the Dunbarton and Peterborough,—areas separated widely by a subsequent covering of rock, but connected directly with the next by an axial line; third, the Deerfield and Mason line; fourth, the Hampstead and Pelham. I will notice each of these in order.

Northfield and Antrim Range. The north-east end of this range is in several parts, or isolated areas, in Sanbornton, Tilton, and Northfield. West of Merrimack river, the principal exposure upon this first line is met with, occupying a large part of Salisbury, Webster, and Warner, and small portions of Boscawen, Sutton, Hopkinton, and Henniker. Next comes an area occupying the Contoocook valley in Hillsborough, Deering, and Antrim. Outliers on a parallel north-east line are in Francestown and Deering, having the Greenfield-Weare-Hopkinton porphyritic ridge for its eastern boundary. On the west side are the two outliers upon the porphyritic gneiss in Bradford, Warner, and Henniker. This line of outcrops is forty-one miles in length, and twelve in its greatest breadth. The most north-eastern of these areas in Sanbornton is five miles distant from the southern end of the typical district of this rock in Meredith. On the west side of Cawley's pond are many outcrops of gneiss. A little north are three embossed ledges, dipping north-east, and farther north they dip north-west. There is a hill of granitic rock, the highest land in the north-east part of the town, where the dip is north-westerly. The rock has been quarried for underpinning to a slight extent near O. Eastman's. It is not easy to say this does not belong to the mica schist series, particularly since granitic beds are found in the neighborhood, such as belong to the later series. I have specimens of gneiss from D. P. Tucker's, a mile north of Tilton village, with a north-west dip. At Tilton village the Montalban strata dip high to the south-east, and another exposure of gneiss occurs near C. Emerson's, in the north corner of the town, next New Hampton.

In Northfield, near D. M. Howard's, about a mile from Tilton, granitic gneiss dips 30° N. 65° W. Towards T. E. Poor's the ledges have the segregated aspect so commonly seen about Lake Winnipiseogee, and the dip is higher. There is gneiss, also, about the village of Northfield centre, but our information concerning this area is meagre.

The shape of the Salisbury area indicates the presence of an anticlinal in the eastern portion, as the newer Montalban schists wedge into it from the south along the valley of Mill brook, and from the north include Salisbury centre. The Montalban rocks of Franklin dip north-west to their very end, crowding closely upon these compact gneisses standing vertically and with a strike west of north along a line of hills near the east town line of Salisbury. The contrast between the two formations is well marked, and their relative positions indicate an unconformity between them. These hills are unnamed on the map, and are a mile and a half east of South Salisbury. At the village the rocks are more like the Montalban, and perhaps this eastern range should be isolated from connection with the gneisses west of the village, at H. Heath's and A. Wardwell's. These gneisses occur for two miles south of South Salisbury, on the road to Boscawen, with north-westerly dips. Ledges appear at the town line, and at C. Smith's in Boscawen. The ridge a mile and a half north of Corser hill, separating the Blackwater from its tributary through Great pond, is composed of this gneiss. South of Corser hill, outcrops appear at Mrs. M. French's, E. Little's, etc., but it is not easy to obtain satisfactory dip observations. Farther south, as at E. Shepard's in Webster, the strike is well defined, running S. 20° E., the strata being vertical. These are repeated by J. and Capt. I. Allen's, nearly a mile farther south. Other observations enable us to color this rock as a narrow strip east of the porphyritic ridge as far south as Hopkinton. In Boscawen village there is a gneiss, possibly of this age, dipping 60° E. It resembles the Concord granite, and lies at the north end of the village. There are many ledges of this gneiss in the Blackwater valley at North Salisbury, at the lower end of the bay. Others occur farther south, north of J. Wiley's, and at his house. The area makes a notch in the porphyritic rock in the south-west part of the town. Along the Blackwater valley many ledges are obscured by alluvium, and we have not had the opportunity to travel along the two long stretches of nearly parallel east and west roads in Salisbury. In Webster, and north of Long pond, the peculiar features of the Lake gneiss are clearly recognizable in its granitic aspect and the traversing by numerous segregated veins. Ledges are noted at the north end of the porphyritic ledge dipping S. 20° E.; at the mills by the crossing to Corser hill from the west; at the top of the hill west, overlooking Long pond, where are large veins of quartz; north of this pond; and by the water's edge, where several houses occur near together. In most of these cases the dip is obscure. At the last-named locality the strike is N. 30° E. The long hill south-west from Long pond shows many ledges resembling this formation as seen from the valley west.

In Warner observations are more abundant and satisfactory. West of the Long pond exposures in Webster we find the schists to the town line considerably ferruginous before coming to the isolated porphyritic area, and also west of Mud pond in Warner. Compact gneiss is abundant from this porphyritic outlier southerly as far as the alluvium of Warner river. Back of the school-house the layers are ferruginous,—less so at T. H. Bartlett's. The gneiss is of the normal variety at S. Bartlett's, on top of the high hill west of Schodac brook. Most of this hill is composed of drift. Between J. C. Flanders's and the lower Warner village granitic gneiss occurs with diverse dips, at first to the north-west, and near the village 80° S. E. Between the two villages the dip is 80° N. 20° E. A mile north-east from the centre the gneiss shows itself at the crossing of Willow brook. Other ledges occur on the hill west of Bagley pond, as at J. L. Mason's, dipping north-west at a small angle. Willow brook flows for more than a mile through swampy land in the north part of the town. On taking the road to Mt. Kearsarge, from Warner, we find gneiss at the point of starting, with a north-westerly dip. On top of the first considerable hill, at S. C. Pattee's, the compact gneiss dips 80° N. 30° W. There is more of this rock at the south-west corner of Salisbury, and at the crossing of French brook, near J. George's. This is the northern limit of the formation. It is succeeded by vertical masses of andalusite schists, with strike N. 30° E. Sawyer's hill and the south-west part of Salisbury are supposed to be underlaid by this same gneiss. The last mile of Stevens brook, in Warner, shows the same rock, more especially between the tributaries called French and Meadow brooks. There is a ledge at the Sutton line, also, which adjoins the porphyritic gneiss. Between French brook and the village of Warner the rocks are concealed by coarse alluvial and drift deposits, which are very extensive. Taking the road towards Bald Mink we first see gneiss with a north-westerly dip close to the river, then 70° N. 52° W., near E. W. Sargent's. The same rock continues to the height of land south of Bald Mink. Others are to be found constituting two hills,—one having three Davis houses upon it, and the other west of G. Foster's. The next is a little west of Levi Bartlett's. Others, perhaps the most south-eastern in this area, occur in "Joppa," between the school-houses, with a south-east dip. The rock is a mica schist, and at W. Danforth's there is a small bed of limestone associated with it. It is probable mica schists intervene between Danforth's and the locality of limestone west of Pleasant pond. The latter bed is associated with quartz, and has been burned once for the manufacture of quick-lime. The bed is twelve feet wide. The rock adjacent is a mica schist, dipping 70° S. 70° E. West of Tom pond, in Davisville, is a gneiss much like the Concord granite. These schists, with the quartz and limestone, will be represented upon the map as Montalban. Well defined gneisses often make their appearance on the hills on the south-west side of the railroad, between Davisville and Warner lower village.

The conclusion as to structure derived from these observations is the existence of an anticlinal line from the Bagley pond area of porphyritic gneiss across to the north-east point of the same kind of rock west of Bear pond. There are probably two similar axial lines in Salisbury.

Little is known of the area put down for Amy brook, Henniker, and extending into the edge of Warner. It may possibly belong to the ferruginous schist deposit. The rock is like the siliceous layers occasionally associated with the porphyritic gneiss.

The Bradford pond area distinctly belongs to this Lake formation. It extends into Warner, where the stone has been quarried, as it splits readily into long slabs suitable for underpinning and pillars. It is believed to dip north-west at its east border by Day pond. It crops out along the west side of Bradford pond. The rock also occurs in enormous boulders over this area, and the dips are obscure. At the outlet of the pond the dip is 50° N. 26° W.

The Hillsborough area may commence two or three miles below the bridge, the land being free from ledges in the valley. The village at the end of the railroad occupies a ridge of glacial drift that has been thrown across the valley in ancient times, producing a lake which by filling up gave rise to the long flat meadow land above. The ledges at the upper dam consist of gneiss and coarse granite, dipping N. 40° W. On the east side of the river a rough gneiss dips 80° N. 80° W.

About two miles into Deering, by H. Preston's, is a small ledge of a hard variety of the Lake gneiss, which constitutes the eastern limit of the formation. On the line of Section III, about three miles from the bridge in Deering, is a gneiss of similar character. The dip is uncertain. It should be westerly if like the same strata farther north, but easterly if it agrees with the schists overlying it. The latter is the probable dip, thus giving us an anticlinal axis in the Contoocook valley. The rock is supposed to extend south-westerly to pass into the known outcrops of similar rock between Antrim centre and Clinton village. Just south of the latter hamlet the rock is a hard, dark-colored, crystalline gneiss, such as is characteristic of the Lake group farther north. This Hillsborough area is very much like the well-defined one already noticed in Bradford, only larger, being nine and a half miles in length instead of three and three quarters.

I think it well to regard the three isolated patches in Francestown, Deering, and North Weare as continuous, constituting a range ten miles long. On the north-east the gneiss has been observed in a precipitous cliff, facing westward, nearly three miles west of North Weare station, and near the union of Dudley brook with a large tributary from the north-west. Half a mile south from the cliff is a gneiss of this age, yellowish from superficial oxidation of iron, having the strike N. 23° E., and a vertical position. Other ledges occur a mile west, and at the town line between Weare and Deering the dip is 85° N. 75° W. The next gneisses crop out at J. Downing's, and in the brook to the east of his house, south-east from Deering centre, and are thought to dip westerly. At D. Gregg's, two miles south of Deering, is the unmistakable gneiss of the Lake group, dipping 85° N. 70° W. This is upon a hill. The rock may not be more than a mile in width. Ledges are rare in this neighborhood, because of the extensive development of the lenticular hills of drift, to be described fully hereafter.

Next we have the larger portion of this area in Crotched mountain, in Francestown. I have not ascended the summit of this peak, but on the north and south sides ledges of Lake gneiss occur, which make it probable that the mountain is composed of the same. The large boulders on the south side of the mountain are also of the same character, as would be the case if our view is correct. About a mile and a half west of Francestown village are the first known ledges of this rock, and they occur through the township on the old turnpike leading to Hillsborough. Near the town line the strata dip 80° N. 60° W. There are no ledges exposed along the road on the south side of Crotched mountain, only enormous boulders. The first rocks seen to the south-west of this mountain are the overlying ferruginous schists, and the range just described is therefore terminated.

The Dunbarton-Peterborough Range. The next line of elevation is less extensive. Nothing is seen of it,—that is, of this rock,—beyond the Dunbarton elevation. It will be noticed that the five hundred feet contour line almost isolates Dunbarton, and that the rock is largely the Lake gneiss at the north-east end of this range. Moraines cover the low neck of land connecting the Dunbarton island with Hopkinton, so that the north-western limits of this rock are not fully known. To the north-east it is easily confounded with the Concord granite. I think it well to say that the latter stop with the south-west end of Great Turkey pond, and hence the similar rock in the very south-west corner of Concord may be regarded as the first ledge of the Lake gneiss. It is near a saw-mill, and dips south-east. The next known ledge is at J. Heath's, in the north-west corner of Dunbarton, the north-west part of Bow being concealed by river deposits. The rock is white and slaty, dipping from 55°–60° N. 55°–80° W., opposite to the other position. There are several of these ledges between Paige's corner, or North Dunbarton, and Dunbarton centre. At H. Jameson's, not far from the west line of the town, opposite East Weare, and on the brow of the hill, the gneiss dips 50° N. 60° W. At a school-house nearly a mile east, on another road, the dip is essentially the same, or ten degrees less. An abundance of drift covers the ledge at the village, and a mile and a half to the south the Montalban rocks succeed. A narrow strip of territory in the east part of Weare is included in this part of the gneiss. The porphyritic gneiss has the shape of a wedge, and makes, as it were, a notch in the edge of the granitic variety, another spur running out from East to North Weare. On the south side of the North Branch, at East Weare, the gneiss dips 20° W. Other ledges occur farther south, and notice has already been taken of the gentle north-west dip of this rock a mile north-east of the village. The western edge of this spur comes within a mile of Clinton Grove. The same rocks occur in several places at the north base of Mt. William, in following the road around to East Weare. Mts. William and Wallingford are composed of mica schist, which take another piece out of this Lake area, only this is by covering the other formation instead of eliminating it, as was the case before. The south part of Weare shows the Lake gneiss as characteristially as its typical locality on Winnipiseogee. Two miles south of Mt. William pond, by H. S. Hoyt's, the gneiss dips 80° N. 20° W. Next the porphyritic range in the south-east corner of the town the dip is 45° N. 50° W. The most western outcrop is about a mile and a half south-east of M. A. Hodgdon's, at the east base of Mt. Misery and Odiorne hill. Other outcrops are near J. G. Dearborn's and at the village of South Weare, by a school-house. West of A. H. Buxton's and a school-house the dip is 80° N.W. Near J. Sargent's the dip is 70° N. 80° W. At A. W. Cilley's, near the south line, is the most western ledge noted, dipping northerly and north-west. At the town farm the dip is 50° N.W. In New Boston there is a fine exposure at G. Cram's. This formation does not occupy quite the whole of the township of New Boston to the north-west of the porphyritic range, as the ferruginous schists appear at the extreme corner. Possibly the gneiss may just enter the eastern limits of Francestown, near Haunted pond.

The gneiss of Peterborough is believed to be an extension of the Dunbarton and New Boston ledges, although isolated, because it lies close to the Greenfield branch of the porphyritic gneiss, which has been regarded as on the same axial line with that in the north part of Weare. The dimensions of this area are correctly given on the map, but little is known of the dips. By Mrs. Chapman's and J. Smith's, near the south town line, the dip is westerly. Gneissic strata appear in Peterborough village, near the mouth of Nubanusit river, standing vertically, and as far as W. French's, a mile and a half north, also a mile to the north-west. East of the Contoocook the gneiss is extensively quarried for underpinning, and is an excellent material for that purpose. The dip is 80° N. 72° E. The same rock extends south-westerly towards Jaffrey. These observations indicate a synclinal structure to this area, but are too meagre to enable us to assert that no other axes exist, as that is of great consequence. The west side of the basin, or that nearest the porphyritic gneiss, is the steepest, as might be expected from its proximity to the older formation. Perhaps the north end of the gneiss area in Royalston, Mass., seen on the map, may be the continuation of this other Antrim range.

The Manchester Range. This is the most important of all the areas of this rock in the state, because it is traversed by two parallel bands of quartz, certainly thirty-three miles in length in this district, and probably over eighty in all between the remotest points of occurrence. The area may be naturally divided into two parts,—first, that enclosed by the two bands of quartz; second, that lying to the south-east of them. With the first may be included an inconsiderable portion to the north-west, lying south-east of the anticlinal line indicated by the long narrow band of porphyritic gneiss in New Boston and Weare. Perhaps, however, it will be best to describe, first, the courses of the two bands of quartz. We may distinguish them by the names of the towns where the bands respectively cross the Merrimack river, or Hooksett and Manchester. Their general course is north-east and south-west, and of course the Hooksett range lies to the north-west of that denominated Manchester. The history of their exploration and certain facts concerning their distinction were first given in our Report of Progress for 1872, and in Vol. I, pages 49–51, of this work. The material of this rock is usually a stratified white quartz, varying somewhat in color according to local circumstances. Wherever it bends, and at other parts of its course, it is penetrated by an immense number of veins of a whiter or more milky quartz, insomuch that these veins often constitute the principal part of the rock. The whole bed may have been deposited from thermal waters ; but we do not yet discover evidence that the original stratified siliceous material occupied a previously existing fissure. The beds we regard as conforming with the stratification, and as guides in the study of the structure of our rocks.

The Hooksett Range of Quartz. Leaving out of view the bed in the south part of Pittsfield, as that may be either Montalban or Rockingham, we find first of all, on the north-east side, ledges of this rock in Allenstown, in the narrow neck of land between the Suncook river and Hooksett. Next, in Hooksett, between Lakin's pond and a road turning south-westerly towards the village, are exposures about forty rods long. I think there is another ledge between this and the river. The railroad bridge of the Concord & Portsmouth Railroad, at Hooksett, rests upon ledges of this rock, the two islands consisting of quartz dipping north-west. Next we find it prominently in the Pinnacle, a conical, isolated peak, perhaps three hundred and fifty feet above the river. There is a pretty pond on the west side of it. A little to the south-west, perhaps a mile from the bridge spoken of, is a vein of metalliferous quartz carrying galena. The stratified quartz dips 50° N. W. From the Pinnacle one can look to Hackett's or Whittemore's hill, in the west corner of the town, in a south-west direction, the next conspicuous hill of quartz on this range. The outcrops are numerous between the lead mine and Whittemore's hill, all having essentially the same position, but not so great a width. There is a high hill of it, covered with trees, back of S. Bachelder's. My impression is that the widest part is not over two hundred and fifty feet in breadth. I did not see any outcrop of this quartz along the line of Section III. It should appear near W. A. Hackett's, near the west town line. The dip of the rocks here is to the north-west, and judging from the position of the strata along the section line, there is a possibility that the quartz may reäppear, dipping south-east, in the east part of Bow. South-west from Hackett's the country rises gradually into a ridge, culminating at Whittemore's, between seven hundred and eight hundred feet above the sea. The dip is high north-west here, and there have been excavations in search of gold. The west border of it is calcareous. To the south-west, and west of J. Cheney's, in the edge of Goffstown, is a high peak that has not been visited, but is surely made of this rock. North of M. W. Woodbury's, upon Black brook, the quartz is fully displayed, dipping north-west usually, but having a strike west of north for a short distance. For more than a mile the country is away from roads, and the condition of the rocks cannot be reported upon, but the quartz comes out on the next road, near E. Jones's, on the west side. Next to the south-west our line crosses the lower land of Harry brook, and the rock crops out just on the east side. On the next northerly running road, near D. Kidder's, are outcrops upon both sides of the road. No other outcrops are reported for three miles, when it is seen along the railroad, a quarter of a mile south-east from Oil Mill station, dipping 70° N. 25° W. A hard schist overlies it, and there is a nondescript sort of gneiss beneath. The band may not be over fifty feet wide. It next appears between the Piscataquog river and south of Mrs. Morse's, in the north-east corner of New Boston. We failed to find it on the two roads next crossing the line, but it appears between a school-house and Miss Beard's, about three miles to the south-west of Oil Mill Village. The line must curve a little more south-westerly, but being somewhat back from roads, and the country covered by lenticular drift hills, no satisfactory outcrop is reached till we arrive at P. Dodge's, a mile and a half north-west of New Boston village. Near J. H. and L. Richards's is a small drift hill chiefly composed of angular fragments of this rock, so that its place cannot be far distant. At Dodge's the dip is 80° N. 80° W., and the band is not more than thirty feet thick. There is a possible exposure of the quartz west of L. Dodge's, two miles south-west of the village. Here we lose sight of this rock. Diligent search has been made all through New Boston and the adjacent towns, but nothing can be discovered short of a hill east of J. Haggett's, in the east part of Lyndeborough, probably with the usual north-west dip of the neighborhood. The distance between these exposures is five miles, and the direction S. 15° W. There is said to be a little quartz by a saw-mill a quarter of a mile north of the natural place for the line of outcrop to cross the stream, but the rock appears near E. N. Patch's. Irregularities in direction are to be expected in Lyndeborough, since the trend of the rock at Patch's if continued, would carry the ledge a mile below its next outcrop, west of J. F. Holt's. It continues south of west, and makes the hill near the glass works at South Lyndeborough. The range runs S. 55° W., near the village, and dips 50° S. 35° E. The first railroad cut west of the station barely touches this bed of quartz dipping 75° S. 40° E. By the eye this range can be followed over the large hill east of Burton pond, on the town line between Lyndeborough and Wilton. I am not certain of the occurrence of this rock in the north-west corner of Wilton, but it may be seen just in the edge of Temple, between A. H. Fry's and J. Kendall's. On the other side of Kendall's is one of the finest developments known anywhere along the range. It is from four hundred to five hundred feet wide. The strike is about N. 30° E. It may be traced continuously from Kendall's to near Temple village. The dip is probably north-westerly. The rocks adjacent dip in that direction, and the only observation I have of the position near Temple is that it is doubtful. About two miles west of Temple village is a small quartz outcrop, west of N. Holt's, dipping N. 50° W. into a hill. There is a valley running west from this point, or rather a notch between Temple and Kidder mountains leading to Sharon. I have searched diligently all through this gorge, the mountains upon both sides, and the whole of the adjacent townships of Sharon and New Ipswich, and am unable to find any further traces of the Hooksett band of quartzite. Whether it is concealed by the material composing Temple or Barrett mountain, seeing that it overlies the gneiss formation, whether some enormous dislocation has put it far to one side, whether the formation has pinched out, or whether some other theory may be devised to explain its absence, is at present unknown.

The Manchester Range of Quartz. The first well-developed outcrop of this range, at its north-east extremity, is in the south-west corner of Allenstown, at J. Hall's. We find a high hill, at the corners of Hooksett, Allenstown, and Candia, the existence of which may be due to its being composed of this refractory material. The ledge is clearly traceable from T. J. Cate's to J. Clark's, or nearly to Moody pond, with the dip north-west. The surface at Cate's has been beautifully smoothed and polished by the passage of the glacial sheet. Two miles from Moody pond is an excellent exposure of this quartz upon Campbell hill, dipping about 65° N. W. The rock here partially resembles buhr-stone, being of a grayish color, and filled with numerous reticulated veins of white quartz. The ledges extend perhaps half a mile, and are then covered up by the sand plains bordering the Merrimack river. The same cause prevents a view of the white bosses on the west side for about two miles. As there is a curvature in the river, causing the water to flow in the same direction with the trend of the strata, more of the rock is concealed than would be the case ordinarily at a valley crossing. The quartz shows itself first at G. Kimball's, in Manchester. A high terrace conceals it back from the house, and it has been noticed next on the hill west, on the road east of Black brook, and close by the west line of the town, dipping north-west. A mile farther to the south-west it may be seen at E. Dow's, in Goffstown, after a long stretch of sand. On the south-west side of the Piscataquog river the place of the quartz is near J. Black's. Another ledge is near a saw-mill, a mile to the south-west; and the same is true of another mill about the same distance beyond in the same direction. Next succeeds a long interval away from roads, which has not been traversed. After reaching the roads in the north part of Bedford the quartz is not seen till we approach the Amherst line, at E. C. French's, and at another place still nearer the boundary. In the very north-east corner of Amherst is a well known locality of hard siliceous limestone, carrying garnets, idocrase, and other interesting minerals, immediately overlying quartz, all dipping N. 50° W. Three other outcrops show themselves in the course of a mile. After that, partly on account of the presence of a great amount of drift, the rock is traceable with difficulty, and it seems to pass more southerly. At the crossing of the south tributary of Baboosic pond, in the middle of the town east and west, is a large pile of quartz blocks, too numerous to have been transported by drift. Less than a mile north of the village is a narrow band of the quartz, twenty-five feet wide, on the west of the two roads leading to Manchester. The strike is N. 20° E., the dip vertical. At W. A. Mack's, just against the most south-eastern corner of Mont Vernon, there is an unusual quantity of quartz boulders.

We find now the same state of things which has been noticed between

New Boston and Lyndeborough on the Hooksett range, in the absence of continuity in the rock, and its recurrence five miles distant on a different line of exposure. It appears next on the south side of the Souhegan river in Milford, back of the school-house situated upon a triangular area produced by the intersection of roads. The course from the last locality of the quartz vein in Amherst to this new exposure is S. 65° W. The quartz dips 75° N. 70° W. It is more gray than usual, almost passing into gneiss, and very abundantly traversed by reticulating veins of milky-white quartz. It occupies a hill, and may be followed as a ridge for about two miles. At B. Gray's, just within the town of Wilton, the quartz dips 80° N. 77° W. Other exposures occur in the south-east corner of Wilton. The last ledge of this range that has been found is situated near I. A. Brown's, in the north-east corner of Mason, with the strike N. 15° E., and dip N. 75° W. The country along the proper place for the continuation of the quartz, and all the adjacent towns, have been carefully explored in search of further exposures; but, like the other range, this seems to come to an abrupt termination, and the proper explanation of its behavior remains to be satisfactorily set forth. It may be stated, however, that two parallel ranges of similar quartz occur in Royalston, Mass., the northern about two miles south of a Baptist church, and the southern close by the village of Pine Dale. One of them comes within the limits of our general map, where it is designated. It is twenty-one miles from the last exposure in Temple, and the direction is S. 62° W., almost in the proper place for the extension of the Hooksett range. Both older and newer formations intervene, and I am disposed to think the Royalston ranges belong to another fold, and consequently a parallel line of exposure.

A few words about the relations of these ranges to each other. At their beginning in Hooksett they are four and one tenth miles apart. They gradually diverge till we reach the breaks in New Boston and Amherst, where they are seven and a half miles apart, directly opposite each other, the extreme ends being eight and two tenths miles distant. The next appearances in Lyndeborough and Wilton are four and three tenths miles apart, and their south-western termini in Temple and Mason are seven and two tenths miles apart. At Royalston the exposures are four and a half miles distant from each other. Before drawing conclusions from these facts, it will be well to describe a few carefully measured sections from one to the other range in Goffstown, New Boston, Wilton, etc.

Sections across the Quartz Ranges. In Fig. 87 is a somewhat generalized section from the Oil Mill station in Weare to the locality on the west line of Manchester. This does not run square across the strike. The quartz dips 70° N. 25° W., and is followed by a nondescript siliceous gneiss with the same position. Between here and Goffstown the ledges are mostly concealed by alluvium. From the study of the rocks not far away it is believed the first rock next the quartz is a gneiss, breaking naturally into long angular pieces. Next is a large amount of fine-grained granite or granitic gneiss, dipping perhaps 65° N. 40° W., as at J. Butterfield's, on the south side of the river. This band passes up the west flank of the Uncanoonucs. There is then a gneiss extending to the east part of West Goffstown village. Next is a broad band of coarse mica schist, cropping out along the road for a mile and a half, nearly to the centre village. This is the range occupying the space between the two Uncanoonucs, farther south. Gneiss succeeds, a narrow band occurring where the road bends to the north-east to enter the village. This is followed by narrower belts of mica schist and gneiss before reaching a broader mica schist strip at the west end of Goffstown centre. It is mostly mica schist, with a north-west dip for a mile's width. The rock is somewhat ferruginous and coarsely grained. There is a coarse granite at E. Sargent's, which may be followed a mile north-easterly on the road to the north-east corner of the town. Beyond the first mile of this north-east road the ledges are concealed by drift. East of Sargent's, on the Manchester road, is a few rods width of mica schist, but the rock is mostly coarse granite to a bend in the road east of E. Whitney's. The same may be seen on the southern slope of the hill towards the river. This is succeeded by a half a mile width of granite, in texture like that quarried in Hooksett. This is somewhat coarser than the Concord variety, but otherwise closely resembling it. Near L. Hunkins's or W. Wortley's gneiss is found, which continues to the east line of the town. A portion of it, by E. Morrill's, is usually white and siliceous. About a quarter of a mile's width adjacent to the quartz, mostly within the limits of Manchester, is composed of a coarse mica

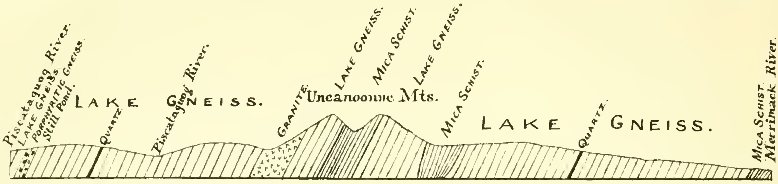


FIG. 88. FROM NEW BOSTON TO BEDFORD OVER UNCANOONUC MTS.

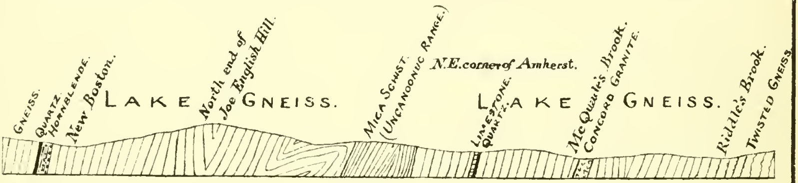


FIG. 89. FROM NEW BOSTON TO THE SOUTH PART OF BEDFORD.

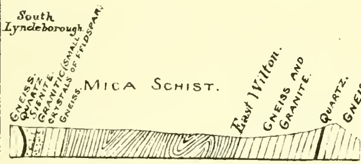


FIG. 90. SOUTH LYNDEBOROUGH TO MILFORD.

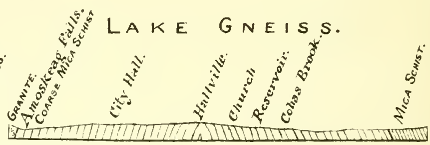


FIG. 92. AMOSKEAG VILLAGE TO S. E. CORNER OF MANCHESTER.

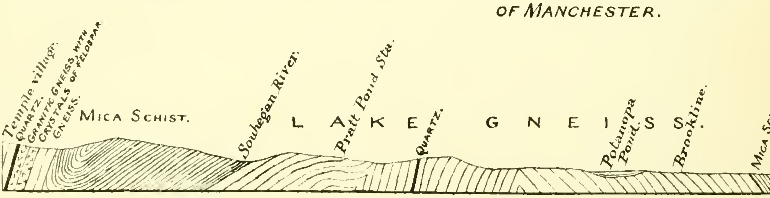


FIG. 91. SECTION FROM TEMPLE TO BROOKLINE.

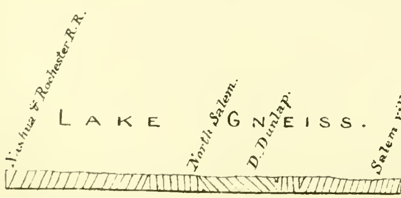


FIG. 93. SECTION IN DERRY AND SALEM.

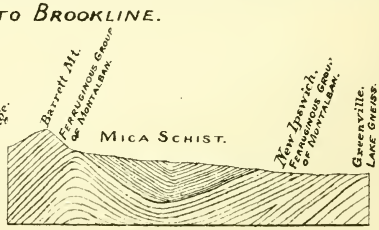


FIG. 94. SECTION THROUGH NEW IPSWICH.

SCALE, HORIZONTALLY, $2\frac{1}{2}$ MILES TO AN INCH; VERTICALLY, 3000 FEET TO AN INCH.

HELIOTYPE.

schist, with a granite to correspond to it in texture. The dip of all these rocks in this section is north-westerly. The western part of the quartz seems to be somewhat calcareous. If the soil were cleared away, beds of limestone might be found.

On the south side of the river through Goffstown, on a line parallel to the section about a mile distant, the correspondence is not perfect. West of Goffstown the conditions do not allow comparison. To the east we find close to the village a large mass of granite that has not been observed in the mica schist across the river. Opposite the centre village the band of gneiss is much broader. The granite on the south side is less abundant, and disappears altogether before coming to the south part of the town. The white gneiss of E. Merrill's is repeated at C. and D. Wyman's. The place of the quartz near J. Black's is underneath the sand. There is an interesting assemblage of igneous boulders by a watering-trough at the second fork in the roads east of the Centre station. It is a sienitic conglomerate, mostly of mica schist fragments, suffering much from weathering, which I have nowhere found *in situ*. The pieces may be four and five inches long, consisting of gneiss, granite, mica schist, and quartzite. A careful search of the adjacent region disclosed very large blocks of it at the bottom of the sand hills towards the river, smaller pieces at E. Moore's, in Bedford, about three miles south from the stream, and none on the north side. Our conclusion is, that the ledge from which they were derived exists underneath the meadow of the Piscataquog river, not far from the station and village. On the road between the quartz at M. W. Woodbury's, at the Dunbarton and Goffstown line, and the Merrimack, all the ledges are inverted, as both ranges dip north-west.

Fig. 88 shows the order and position of the rocks on a sectional line, cutting both quartz bands, through the Uncanoonucs. It is assumed that the quartz has the same position here as the strata on both sides, namely, a dip to the north-west. Near the eleventh mile-post from Manchester, where the section crosses the Piscataquog river in New Boston, gneiss with coarse granite veins dips 60° north of west. Granite is seen at the west base of the Uncanoonucs, just by the west line of Goffstown. Gneiss succeeds, dipping N. W., and is supposed to constitute the bulk of the first of the twin mountains. Mica schist occupies the space between, reaching to the summit of the east and highest Uncanoonuc. There is a large granite vein here also. At the east base of the mountain, back of J. Ferson's, is gneiss, which may connect with that in the edge of Goffstown Centre, upon Fig. 87. Mica schist next occupies the field nearly to E. Dana's, save a narrow band of gneiss at G. Robertson's. Gneiss occupies the rest of the way. The granite and schistose bands found near the east band of quartz on Fig. 87, if present, are concealed, as well as the quartz itself, beneath the drift. All the dips on this section are also to the north-west.

Fig. 89 illustrates the positions on the next line, perhaps the most carefully explored of any, from P. Dodge's in New Boston to the north-east corner of Amherst. The quartz dips 80° N. 80° W. Close to it is a hornblende rock, almost a trap or sienite. Between W. Whittemore's and N. Hall's, beds of mica schist with coarse granites occur. At New Boston village are interstratified gneisses with twisted seams of coarse mica schist. To the south-east thick drift deposits conceal the rocks, supposed to be essentially gneiss, as far as A. Leach's, where it contains ferruginous fragments, and is very much twisted, dipping in a general north-west direction. By J. Fairfield's the gneiss dips 85° N. 60° W. At the north base of Joe English hill the gneiss is much like the Concord granite. The mass of the mountain is composed of similar material, dipping 65° N. 80° W. This is a little south of the section. At S. Moor's are other ledges, and at the school-house by a saw-mill, the gneiss carries coarse granite veins dipping 15° N. 25° W. Following up the stream a short distance, away from the regular road, are similar rocks tending to dip in the opposite direction. Near here is the proper commencement of a range of mica schist, that running between the Uncanoonucs, dipping 60° N. 50° W. Numerous granite veins or beds occur with them. On top of the hill, near the west line of Bedford, these schists dip 75° N. 35° W. They also crop out east of W. A. Hobart's, and along the east road in the north-west part of Bedford, as far as W. D. and J. F. McPherson's. Almost at the south line of Bedford, next Amherst, gneiss dips N. 40° W. Next we find ourselves at the limestone quarry and quartz in the north-east part of Amherst, with the dips of 80° N. 50° W. A short distance northerly, in Bedford, there is a northerly-dipping gneiss.

Fig. 90 illustrates the rocks from South Lyndeborough to the west part of Milford, through East Wilton. The quartz dips 78° S. 40° E., just beyond a railroad cut through a hard sienitic rock. In the south edge of the village, following the carriage road instead of the railroad, the next interesting rock is a granite like the Concord in general appearance, but full of small, distinct crystals of feldspar. This being of peculiar aspect is easily recognizable, and will be mentioned as occurring at the west end of the next section. The sienite rock at the railroad cut also reminds us of the related rock near Dodge's, at the west end of Fig. 89. The gneiss adjoining this porphyritic granite dips 85° N. 80° W. Drift conceals the ledges for more than a mile. Ferruginous mica schist, dipping 70° N. 25° W., crops out shortly after crossing the stream, in the north part of Wilton. At the next crossing of Stony brook the mica schists dip 40°–45° N. 40° W., and are inclined at a smaller angle beyond. Half a mile farther they dip 30° in the same direction, with coarse granite beds. Near a cabinet shop the dip is 65°. Just in the edge of East Wilton is a coarse granite. At the village is mica schist. At the tannery, in the east part of the village, are veins of coarse granite, with a small dip. The dip is 75° N. 75° W. near the new factories, in the west edge of Milford, before crossing the river. The rock next the quartz on the hill in Milford, already alluded to as dipping 75° N. 70° W., is hardly a gneiss. The greater part of this section has been occupied by a low-dipping, coarsely-grained mica schist, the equivalent of those in Figs. 87, 88.

Fig. 91 illustrates the rocks between Temple and the east line of Wilton. The sienitic rock of Figs. 89 and 90 is wanting next the quartz. The gneiss west of the quartz is of the angular-breaking kind, dipping 70° N. 80° W. Between the quartz locality and a north-east road from Temple, the gneiss contains much feldspar, and dips 65° N. 70° W. It is obvious that the quartz must correspond with these dips just recorded of the gneiss upon both sides of it, its own inclination not readily showing itself. The porphyritic granite seen in Lyndeborough is much thicker in Temple, making its appearance next on the south-east road from the village. Next is granitic gneiss, followed by ferruginous mica schist, half a mile distant from the hotel, dipping 85° N. 50° W. on the average. The roads are now inconveniently located for our purpose, and the next ledge seen is at West Wilton, two miles distant from the last ledge, but as it courses with the strike it cannot be far distant from its place on the section. There is a mixture of coarse mica schists and fine-grained granitic beds dipping about 65° N. W. Half way to Wilton the mica schist dips 30° N. 25° W.; also at Wilton. No ledges appear for a mile and a quarter on the section line, when we find a spotted granite by H. F. Frye's, on the north-west slope of a high hill. There is gneiss higher up, and at intervals to B. Gray's. On the hill west of Gray's the rock is micaceous and gneissic, dipping 80° N. 70° W., and that is also the position of the quartz. This is about two miles from the south-east end of Fig. 90. There is a great width of gneiss here at Gray's, though its place seems to be taken by mica schist on Fig. 90. The gneisses, porphyritic granite, and mica schists observe the same order as on Fig. 91, in proceeding from Temple towards Greenville. There is a possibility that the rocks of New Ipswich and Greenville are older than those carrying the quartz, and hence cut it off by rising to the surface. We have taken other observations respecting the rocks between Figs. 87 to 91, which will be presented later. The mica schists of these sections are supposed to belong to the Rockingham series.

Conclusions. These are not altogether satisfactory. 1. We think the quartz bands are stratified, and connect in a synclinal manner with each other, though inverted. Fig. 88 shows repetitions of a basin character, but not in a decisive manner. The comparative recency of the mica schist is apparent. It lies like a blanket upon the older gneiss. All the sections can be explained in the same way, especially Fig. 90, where the quartzes dip towards each other. 2. The southern segment of the Hooksett range has a decided tendency to dip south-east., as shown through Lyndeborough. The Manchester range invariably dips north-westerly. This fact seems to confirm the theory of a synclinal connection between these bands. 3. It would seem as if there had been a great fault in the strata between Amherst and New Boston, so as to explain the absence of the bands over so great a distance. 4. South of the break the bands are much nearer each other than to the north; yet the synclinal structure is seen clearest where the compressions were most powerful, granting that lateral force was the cause of the break and of the crowding together. 5. The Greenfield spur of porphyritic gneiss is parallel with the quartz band, and extends exactly the same distance to the north-east, while beyond there is an expanse of the Lake gneiss directly opposite the break in the quartz. 6. The mica schist seems to have been deposited after the first period of elevation affecting the Lake gneiss. Hence the mountains of it in the Pack Monadnock and Lyndeborough ranges may not have exerted a marked influence in producing the break. It could easily conceal quartz bands by covering them up. 7. An anticlinal ridge composed of quartz would withstand denudation much longer than the enclosing rock alone. Hence certain comparatively isolated ridges of this quartz may represent the tops of underlying formations. Such are the supposed continuation of these quartz bands in Strafford, Wakefield, Effingham, far beyond the limits of the Merrimack district. 8. Quartz bands similar to these occur in the Montalban and Bethlehem gneiss; also in the Lisbon, Merrimack, and Rockingham groups. They occur on both sides of the central ridge of the state, usually much more isolated than the cases recently considered. Care must be exercised not to confound together these bands that were deposited in different ages. 9. The occurrence of fragments of quartz in the drift throughout the state furnishes admirable illustrations of the dispersion of boulders by the ice. Many localities have been discovered through their instrumentality, and we have evidence to suggest the existence of these ledges in localities now obscured by surface accumulations.

Additional Facts. There remain to be stated a few further facts and observations respecting the gneisses between and to the north of these quartz ranges. In Hooksett, three types of rock approach one another, and I do not feel satisfied that their respective limits have been properly assigned. The distinctions were not drawn till after the completion of field work, and therefore perplexing questions arise respecting the proper limits of each. The ferruginous and Rockingham schists contain large granite beds, which often closely resemble the Concord granite. When the adjacent schists are intermediate in texture between the Rockingham and Montalban, it becomes difficult to decide with which formation a particular granite should be placed. There is also a close resemblance between the Concord granite and some of the Lake gneisses, as, for instance, those of Salem. The radical distinctions between all these groups are well founded, and if opportunity were afforded for further examination of their distribution, I do not doubt that entire satisfaction respecting their territorial limits would be attained. As it is, I will draw the lines as well as possible, and beg the indulgence of future observers should any of the boundaries prove to have been incorrectly delineated.

Subject to these modifications, therefore, I shall include the Allenstown quartz with the Lake gneiss, and draw the northern boundary of the formation a little beyond what the mineral character of the rock would seem to warrant, including quite a large portion of Allenstown. This will bring the well-known Hooksett granite into the Lake series, as well as that of Manchester. Either one of these deposits might be said to be a Montalban synclinal outlier, resting upon the Lake gneiss, should the immediately associated layers make such reference desirable. I have not separated the granites of the Lake series from the gneisses on the map, as is the case with the Montalban. Near the east corner of Hooksett, upon Cate's hill, is a hard, jointed, granitic gneiss, just beyond the quartz. Two lines of travel cross the country farther west in Hooksett, between the two quartz beds, nearly at right angles, and may be taken on either side of the Merrimack river. Starting with Campbell's hill, we find the quartz dipping north-west, and then the rocks are concealed by alluvium for more than a mile. Next follow nearly two miles' width of the granite that is so extensively quarried on the hills east of the railroad. The sheets of granite on the hill dip from forty to fifty degrees north-west. The strata are more nearly vertical half a mile north, with large veins of very coarse granite. On both sides of the Pinnacle quartz range are hard granite layers. In the river below the railroad bridge the rock is distinctly gneiss. The dips are north-westerly. On the west side of the river, in Hooksett, all the strata dip in the same general direction. A coarsely crystallized rock crops out by W. Taggart's. The road nearest the west part of Manchester and Goffstown runs over granite similar to that quarried, save a patch of mica schist, at the south corner and on the very west, line dipping 10° N. W. Adjacent to Bow line the soil is entirely ferruginous, and the rocks very much so. The granite is quarried somewhat in the bend of the Merrimack river in the south part of Hooksett.

New Boston is mostly underlaid by the Lake gneiss. The most characteristic lines of outcrop have been discribed in Figs. 88 and 89. Gneiss is the prevailing rock on the high land parallel with the Piscataquog river on the north side. It occurs near the village, two or three miles south, by B. Hopkins's and a saw-mill. The layers resemble mica schist at the looking-glass factory a mile south of the village. Between Joe English hill and the south town line gneiss abounds and is well defined. Its southern limit towards Roby hill is near the south line, and near Joe English pond on the south-east. Between the pond and hill the rock is not so clearly defined. At the base of the hill are possible strata dipping only 30° N. W., containing segregated veins. The south side of Joe English hill is a precipice. Gneiss occurs by J. Cochran's, about three miles south-west from New Boston village; about Colby's pond, in the south-west corner of the town; and about the mills, in a small hamlet adjacent to the east. Nearly opposite North Lyndeborough post-office, by I. Gage's, is the most western exposure of the gneiss in this town. The north-west part of Mont Vernon is made up of the same rock. By E. A. Green's the gneiss dips 30° S. 70° W. The same rock appears at W. Odall's. The south end of Piscataquog mountain, in Lyndeborough, has not been examined. On the west side of Badger pond the rock is like the Concord granite, and is used extensively in the neighborhood for underpinning. The dips about Lyndeborough centre are high to the north-west. It has a similar character two miles to the south-west, near S. Cummings's. A hard granitic gneiss occupies the country in the valley of Stony brook for about two miles west of South Lyndeborough. The range runs through the north-west part of Wilton to Temple. The dip in Wilton is north-west. The New Ipswich rocks present difficulties just like those at Hooksett. It is very likely that this Temple range crosses Barrett mountain near the state line, and also follows the boundary to the east, so as to connect directly with the Manchester range, and perhaps cause the mica schist deposit to terminate near the village of New Ipswich. Our observations are so scanty that it cannot be affirmed that the schists do not converge somewhat at the village, and then extend into Massachusetts. The particular character of the rocks and positions through Greenville and New Ipswich may be best learned by referring to the description of Section I. In the south-west part of the town I have collected gneiss by W. Young's, dipping irregularly S. 60° W. On reaching the ridge of the hill a mile farther north-east, the dip is much the same, greatly crumpled. Near J. Nutting's, on the east side of the ridge, the dip is N. 35° E. There seems to be an anticlinal in this rock on the ridge. At the chair shop the schists have become ferruginous. The next ledge seen near the state line is near W. Frissell's, in the south-east corner of this town, seeming to dip only 5° N. E. This may be a part of the more eastern range.

The strip of gneiss on the east side of the mica schist is very narrow in Bedford, but widens out in Amherst. On the map it seems to make one connected mass with the more eastern range, but the presence of the quartz furnishes us with a fixed stratigraphical boundary. There is little to note of this rock before coming to Amherst, save where it is crossed by the section in Fig. 89. The gneiss in the north part of the town dips north-west. There is a good exposure by S. Austin's, near the Mont Vernon line, and at J. Mark's, close by Williams pond, dipping 50° N. W. About a mile north of Amherst village is a new quarry of granite, or of granitic gneiss, which clearly belongs to the Lake series. The direct road from the village to Mont Vernon is mostly over a plain, and drift, after beginning to climb the hill. At W. Richardson's, a little way into Mont Vernon, the gneiss is well-defined, and dips N. 25° W. To the south, in Amherst, at W. Pratt's, the same rock dips 20° N. W. At L. Elliott's is a limited outlier of coarse mica schist standing vertical, with the strike N. 75° W. This strike also shows itself at T. Patch's, about a mile west of the village. The north part of Milford is supposed to be occupied with the granite that is quarried so extensively farther south. At the south-east corner of Lyndeborough this gneiss appears, and it is near the east line of the mica schist group. Figs. 90 and 91 show the occurrence of this rock in the east part of Wilton. Similar ledges of gneiss occur in the south-east part of Wilton, and the north-east part of Mason as far as the quartz extends. There is a granite at Elliott's mill in Mason, which is the last of the rocks to be described in connection with the quartz. The gneisses and granites farther west properly belong to the next range.

A review of all the positions of the gneiss noted between the mica schist and the Manchester range of quartz shows a uniform pitch towards the north-west, varying to north. The last may possibly belong to the next range, which had been crowded—at Amherst village—to the south-east, and passes nearly due west, directly to join the north end of the western quartz band. More light is required for the satisfactory understanding of the break in the quartz. Perhaps the difficulty may be removed by disregarding the quartz outcrop near Amherst village and thus making the range touch the south-east corner of Mont Vernon.

The Deerfield and Mason Range. We are introduced next to a material somewhat different from the ordinary gneiss of the Lake series. It is thoroughly and coarsely crystalline, being generally much more saccharoidal in appearance than even the typical varieties about Winnipiseogee, and not so fine. It is more like the Laurentian gneiss of typical localities than anything else in the state, except a range of similar type passing through Berlin. In some early publications I have spoken of this formation as the Manchester or Berlin gneiss. Were it not for multiplying distinctions it might be well to separate this from the other ranges; but it approaches the Lake gneiss more nearly than anything else, and therefore may be classed with it. Supposing it to underlie the series associated with the quartzes, it would be repeated in the Weare and Dunbarton range on their north-west side. The latter are very crystalline in their aspect, though readily referred to the Lake series.

Another peculiarity of the Manchester range consists in its ready passage into granite, together with a disposition to a minute twisting of the strata. The readiest method of understanding this peculiarity is to imagine a thorough squeezing of the rock from both sides, and then a melting of the curled layers sufficiently to cause many of them to disappear by conversion into genuine granite. Much of this rock would pass for a true granite, full of miscellaneous patches of twisted strata of mica schist. There are also bands of a coarsely crystalline mica schist connected with this gneiss, which are of the same age, and not to be confounded with the later formation so extensively developed in Rockingham county.

This range extends farther east than Deerfield, but our descriptions must commence with the line separating the Merrimack and Coast districts, which is the height of land between the hydrographic basins of the Merrimack and the Lamprey and Exeter rivers on the east. On reference to the map it will appear that Deerfield is mostly excluded from the Merrimack district; Candia is divided transversely into equal parts; Chester is mostly east of it, and Derry is situated upon both sides of the line.

The following represents the rocks on a line from Campbell's hill, in Hooksett, to the Candia ridge. Campbell's hill is of quartz. Half a mile south are imperfect gneisses with interbedded granites, dipping 30° north-westerly. Near the quartz a more careful measurement indicated a dip of 50° N. 30° W. Traces of similar rocks are to be found all the way to Sawyer's pond, the materials being very crystalline close to the water. At M. Collins's, east of the pond, the layers are micaceous, dipping 50° N. 30° W. Not a great distance beyond are layers of granite, entirely devoid of any marks of stratification, arranged between seams of mica schist. Wherever the schists are bent, the granite layer is also curved in conformity with them. These granite beds are from one to six inches thick. With them are occasional bunches of crystalline feldspar, eighteen inches thick. Rude crystals of quartz occur in some of the feldspar bunches. Before reaching the old Rowe's station on the C. & P. Railroad, a ledge of granite appears. This is the height of land, and, consequently, the eastern boundary of our district.

Near the south line of Hooksett, next to Manchester, feldspathic schists, with narrow granite seams, dip N. 30° to 50° W. Similar rocks occur occasionally all over the north part of Manchester. At the Trotting Park is a ledge of similar character, planed down thoroughly by ice. A little south of the Reform School is a field of granite which has been quarried. This points to the similar material on the west side of the Amoskeag bridge. Opposite to it, near the river, are ledges of micaceous gneiss.

There is a great amount of glacial drift in Manchester, serving to conceal ledges, yet many exposures of rock may be seen. There is an interesting bunch of granite less than a mile north-east from the Amoskeag reservoir, quarried by the Amoskeag Company and by Bodwell. One would judge from the appearances that this granite occupied an elliptic space in the midst of coarse mica schists. It might be said to be a gigantic egg-shaped concretion, containing the good materials segregated from the surrounding uncouth rock. Such an impression is not gained for the first time from the inspection of these quarries. I have thought of the same illustration at Fitzwilliam and Concord. Early in the working of the Bodwell quarry I noticed that a species of cap rock extended over the granite. This required to be blasted away before good stone was found. But the presence of a cap rock was not universal. On the south-east side of the Amoskeag quarry coarse mica schist dips 75° N. 20° W., and also more north-westerly. The granite runs against the edges of the schists at the south end of the quarry, and the two rocks adhere together, though not firmly. In Bodwell's opening there is a plain line of separation between the two, almost a fault. The granite is apt to be of inferior quality when it approaches the walls. The material is related to the Concord, but it is coarser and breaks more readily into angular pieces. It lies in sheets, dipping 10° N. W., while the rock on the east side (Bodwell's) stands vertically, with the strike N. 60° E. On the north sides are very large veins of coarse and graphic granites, standing like chimneys. There are splitting planes in the granite, parallel to the walls. The action of the glacial force in breaking the rock on top of the ground is well shown in these quarries.

The mammoth road passes near these quarries, behind them, and the rock there is the schistose variety. Farther south, on Hanover street crossing, the gneiss runs N. 50° E., the strata vertical. There are several small anticlinal folds, a yard wide, seen here. A few streets to the west, on the crest of the hill, are irregular and coarse granite veins. Many veins in Manchester consist of nearly pure feldspar. I have occasionally seen limestone seams two inches wide in the gneiss. The twisted rocks east of Sawyer's pond, Hooksett, and Candia lie to the east of the schistose ledges holding the granite nodules. They commence at about the crossing of the mammoth road and Hanover street. Ledges occur occasionally between the ridge east of the city proper and Massabesic lake composed of this rock. By the Methodist church south of Hallville, this gneiss dips 85° S. 30° E. Half a mile west of the extreme south end of Massabesic lake is a quarry in this rock, the blocks extracted from which have been largely used in the buildings of the city. The foundation stones and steps of the city hall are of this character. Between the pumping works and Massabesic lake the gneiss dips 80° S. 60° E. The most south-east ledges of this rock observed are about a mile south of the lake, in the south-east part of the town, dipping 65° S. 50° E. The very corner, for half a mile, is occupied by a coarse mica schist. The change is first indicated, in proceeding south-east, by the enormous blocks of the schist by A. D. Corning's. Gneiss dipping north-east occurs on the promontory at the north-west end of Massabesic lake, a short distance within the town of Auburn. The north end of the lake is sandy and swampy, but a large promontory west of the village is composed of gneiss dipping N. 70° E.

The rocks on the south-east side of the lake are of the mica schist division. The whole of Candia is occupied by this twisted gneiss, and most of our observations relate to the ledges on the eastern slope. The dips south of the railroad are generally to the south-east. To the south of Manchester we find a large number of white ledges of this rock below Bakersville, and on the south-west side of Cohass meadows, on the road to Londonderry. Another ledge appears at the fourth mile-post on the same road. It extends into Londonderry as far as R. White's and E. Young's, with the dip south-east. These observations evidence the existence of a main anticlinal axis in this range, and are embodied in Fig. 92.

Passing to the west side of the Merrimack the rocks are found to correspond with those already noticed. The twisted varieties are all on the south-east half of the range. At Amoskeag falls one can examine a large variety of ledges. The basis is a coarse mica schist, dipping north-west, varying to N. 10° W. This contains four or five thick masses of very coarse granite. The very conspicuous bosses of rock seen in the falls consist of this latter variety. Smaller inconsequential veins may cut the strata, like two of somewhat similar character near the west end of the bridge. Some of the schists contain large egg-shaped nodules of a quartzose character. The granite is often graphic, and contains tourmalines. The schistose rocks may also be well seen upon the island, a quarter of a mile to the south. In Amoskeag are extensive ledges of granite similar to that quarried to the north-east of the reservoir. There is mica schist on the north side of Black brook. Near Rock Rimmon is a ledge of coarse granite similar to that in the falls, and with it considerable of the finer grained material, which has been quarried. It is somewhat ferruginous. The dip is northerly and N. 20°–30° E. On climbing the rock itself the material is seen to be distinctly gneissic, some layers being very coarsely crystalline. On the south-east side the dip is S. 85° E.; on the south-west side the dip is N. 85° W.; at the north end 67° N. The strata are often curved along the strike. None of the dips are the prevailing ones, and the peak looks as if it had been subjected to rough pressure. It is isolated by its situation in a sandy plain,—being the rock seen so conspicuously to the west from the streets of the city opposite. South of the Piscataquog river, in the village of the same name, we observe first several ledges of the mica schist variety, dipping 65° north-west. The band shows a width of certainly seventy-five feet. Gneiss appears at the road fork nearly half a mile to the west, and also near the town line on the Bedford road. On the most northern line of roads through Bedford the rock is gneiss as far as J. Witherspoon's, save a single ledge of mica schist at Mrs. Mullett's.

Taking the direct road to Amherst from Piscataquog, all the ledges seen through Bedford are gneiss. It crops out prominently at Bedford village, and a little beyond. Near McQuade's brook, east of G. Fletcher's, is a mass of granite related to that in Manchester. There is more of it half a mile to the north-east. It is probably another ovoid mass at about the same stratigraphical horizon, as well as that in the quarry near Amherst village. At S. P. Campbell's, gneiss dips northerly. On the north and south road, near the north-east corner of Amherst, are ledges approaching mica schist in character, and containing very much coarse granite. South from J. P. Conner's the gneiss dips 85° N. 40° W. Other ledges of this rock occur farther along,—notably, west of W. E. Brown's, in Amherst; west of Williams pond, dipping 50° N. W.; a mile north of the village, vertical, with strike N. 20° E., and elsewhere. South of Williams pond, the country is mostly covered by drift as far as the village. The hill south of the court-house is clearly occupied by this ancient gneiss, as it is also farther west. On the road to Milford, near the height of land, west of A. Hartwell's, it dips 85° N. 30° W. In Milford is a large mass of granite, occurring very nearly on the line of the Manchester quarries. It is extensively quarried about three miles north-west of the village. I noted the two usual sets of joints in this rock at one of the quarries, about 10° W. and 80° E. The gneiss is quite well developed along the banks of the Souhegan, at Milford village.

South from Piscataquog village, along the river road, are ledges of various sorts. At the village is the coarse mica schist previously mentioned. Near the south town line is a red crystalline gneiss, dipping N. 20° W. This belongs to the twisted crystalline variety. Bowman's brook obscures the ledges for the next two or three miles, and we observe the return of the ancient gneiss at the easterly turn of the road near J. Walker's, Bedford. The ledges approach the river here, at the expense of the modified drift. They are also numerous near Goff's falls. Farther south, by C. K. Ball's, this twisted gneiss dips 88° N. 40° W. Layers of dark micaceous gneiss are interstratified here with the common variety. The next ledge seen is at Reed's ferry, in Merrimack; then at the crossing of McQuade's brook, near its mouth, with south-east dip. At the crossing of the Souhegan river, in the village, the coarse mica schists dip 70° S. 40° E. No related rocks appear farther south. It would appear from this line of outcrops that the twisted gneisses possess an anticlinal structure, and are flanked on both sides by a coarsely crystalline mica schist, evidently belonging to the same general series, and not to be confounded with the Rockingham group. It is the same with that at Amoskeag falls.

The next route traversed was from Thornton's ferry, across Merrimack and the south part of Amherst, to Milford. Perhaps a mile and a half back from the ferry is a small ledge of the coarse mica schist with granite, beyond R. H. Pratt & Co.'s, dipping 80° S. 25° E. A coarse granite occurs next, west of the school-house, midway across the township. Just in the edge of Amherst is a coarse granitic gneiss, dipping 50° S. 55° E. This region is covered by wide-spead alluvial deposits, which greatly obscure the ledges. At Danforth's Corner, or South Amherst station, the very twisted gneisses appear in their characteristic development. At the west town line a fine-grained granite, like the Concord, succeeds. It may be seen from the road, also, about a mile and a half south of Milford, by means of the openings that have been made for quarrying. There may be an anticlinal on this route.

South-west from Milford there may be a similar granite as far as Osgood's pond. The gneiss dips north-west by E. B. Tuck's and A. Gutterson's. Taking the south row of towns next, we find the eastern border of the gneiss near the town lines of Brookline and Hollis, a mile north of Massachusetts, and part of this route agrees with that of a section from Temple to Brookline, Fig. 91. West of F. Smith's the gneiss dips south-east. By L. Sawtell's there is a coarse indigenous granite, with the same position. Several varieties of gneissic rocks are found near N. Farrar's, a mile west of the town line, dipping 60° S. E. Next, there is a plain for a mile and a half to Brookline village, where the gneiss contains distinct crystals of feldspar approaching the porphyritic variety, with the same dip as before; here it is 65° S. 70° E. A little west of the village is some mica schist and granite, dipping 50° S. 55° E. South and west of Potanopa pond is a fine-grained granite that has been quarried somewhat. It has a rusty color, so far as seen. At the very west end of the pond, by E. Wheeler's, the granitic gneiss dips 50° S. 35° E. In the east part of Mason, or about the town line, there is an anticlinal. At W. Scripture's, coarse and fine granitic gneisses intermingled, dip 50° N. 70° W.,—the dip being about north-west half a mile to the east. A mile west of Scripture's, the gneiss is coarser, dipping 40° westerly. There is a dark micaceous variety between the Peterborough & Shirley Railroad and Mason centre. The dip is 15° W. at Mason. On the summit of the ridge west, midway between the post-office and the west line of the town, the granitic gneiss dips 20° N. 85° W. Essentially the same dip occurs on all this high land, certainly for two miles to the north. On a parallel line two miles to the south, we find the rocks much like what has been described. Gneiss at R. L. Cumnock's and at C. Blood's, near the railroad, dip 50° N. 30° W. The ledges all over Mason resemble that of Lake Winnipiseogee, both in its granitic aspect, and the presence of segregated veins. Between Mason and Greenville the ledges are abundant upon the high land, dipping at a small angle to the north-west, near the first named village. The dip is north between A. Elliott's and the railroad crossing, and the mica predominates. By Pratt's pond and the edge of Wilton are extensive granite quarries. The texture is fine, somewhat like the Manchester variety. A similar material is abundant by Elliott's mills, and still farther north-east. Mica schists at Pratt's pond dip north-west. On the hill west, small eruptive outbursts of the Manchester granite occur frequently. In one place there is a ledge of porphyritic gneiss. Granite is quarried between L. Joslin's and A. Elliott's, a mile south-east from Greenville village. At the cemetery south of the village, the granitic gneiss dips 25° S. 70° W. In the edge of the village there is another ledge similarly situated. Our observations are meagre for the south-east part of New Ipswich and the south-west of Mason, where this Lake gneiss is supposed to extend. We find in Ashby similar rocks, and in the west part of Townsend a fine-grained granite.

Conclusions. 1. The rocks of this Mason and Manchester gneiss area are arrayed in parallel bands, according to their character. The north-west part consists of micaceous gneisses and schists, holding layers of indigenous coarse granites. The south-east part is made up of the crystalline twisted variety of gneiss. 2. There is a row of ovoid masses of a fine-grained granite from Manchester to Mason, all having a similar character, and contained within the micaceous part of the formation. They are the Amoskeag and Bodwell quarries to the north-east, that near Fletcher's in the west part of Bedford, and those near the villages of Amherst, Milford, and Mason. This line is one along which those needing this material may search for new localities. 3. There is a well marked anticlinal in the south-eastern part of this range, confined to the twisted gneiss. It would seem to commence near the west part of Candia, pass near the north end of Massabesic lake, north of the city reservoir, Manchester, the south-east corner of Bedford, Danforth's corner in Amherst, and the south-east corner of Mason. 4. On both sides of this anticlinal is a very coarse mica schist, different from the Rockingham group. It has not been traced throughout the range, because attention was not directed to it sufficiently early in our explorations. It is not distinguished on the map.

Hampstead and Pelham Range. The east boundary of the Merrimack district being rather indefinite in the south part of the state, I will regard, for convenience, this gneissic area as its south-eastern limit, and not describe the gneiss beyond Hampstead, so as not to encroach upon the maritime district. This is an independent range. In its character it is losing the peculiar features of the Lake gneiss, being intermediate between that and the Concord granite. The range may commence in Epping and terminate in Massachusetts, only a short distance beyond the limits of our map. It terminates because covered or surrounded at the southern end by the Merrimack schists. It begins very narrow in Epping,—if that is to be regarded as the same area,—and at Hampstead it is two and a half miles wide. Its course at first is almost south, but changes to south-west in Windham and Pelham. It is eight miles wide from Nashua to Dracut, across the strike, and ten miles in breadth on the southern border of our map.

The eastern limit of the gneiss in Hampstead seems to be at the Congregational church south of Wash pond, and a section across it to Derry shows a monoclinal dip. At N. Hoyt's, half a mile from the church, the dip is 50° N. 30° W., with beds of granite. Near the west line of the town, on the first road north of Island pond, we find the same materials dipping 85° N. 50° W. On the town line, at A. Ordway's, the dip is 70° N. 40° W., and the beds of granite are noticeable for their large size. For a few rods a south-east dip was noticed. On the west road it is at least three miles before coming to the next observation, at Mrs. Black's, dip 70° N. W. On a road farther south I noticed, near J. C. Drew's, very abundant ledges on high bluffs, facing westward. Other ledges crop out at H. N. Campbell's and R. Taylor's. Perhaps these dips diverge sufficiently to authorize us to believe that there exists here an anticlinal axis. There is more gneiss in the south-east part of Derry, said to be granitic, and to dip N. 50° E. Passing through North Salem we find the same rock standing on edge. At the school-house next D. Dunlap's the dip is 40° S. 60° E. Near Merrill & Bailey's factory the dip is vertical again.

At B. Foster's the direction is to N. 35° W. On reaching the westerly branch of Spicket river we come to a narrow range of sienite, supposed to extend beneath the village of Salem as far as I. T. Foster's, nearly three miles. Fig. 93 embodies these observations through Salem in graphic form. In the west edge of the village the gneiss dips 80° N. 75° W. A coarse feldspar rock is interstratified with it at W. G. Crowell's, two miles north-west. It is a coarse schist east of E. Sanders's, but farther west the same gneiss dips 80° N. 50° W. North-west from Policy pond are several exposures of the best defined Lake gneiss seen in this neighborhood, dipping 85° N. 50° W. It is succeeded by a modern mica schist beyond the school-house. These ledges are traversed by segregated veins, and the series of outcrops just named represent a section across the whole belt. The strata are more distinctly monoclinal here than in Hampstead and Derry. West of the Salem depot are quarries of granite, or rather of this gneiss, the dip being distinctly 50° N. 70° W. It behaves just like the Concord granite in respect to its excavation. It is traversed by the same vertical and nearly horizontal joints. There is a cap of inferior rock over it also. This is at Gage's quarry. At B. A. Cole's, a little to the east, the material is more granitic, and has large masses of mica schists caught in it, in conjunction with large veins of coarse granite. Passing westerly into Windham, on top of the hill a short distance south-west from Policy pond, is a ledge of dark, fine-grained gneiss, dipping north-west. Farther along are mica schists, holding a similar position, at the south end of Corbett's pond. At the centre of

Windham the gneiss dips north-west, and is speedily followed by a similarly inclined mica schist of the newer series.

Upon Section I this formation assumes the anticlinal form. The western edge of the gneiss dips 50° N. 30° W. in the west part of Hudson. Near the east line it is inclined 85° N. 35° W., changing very soon to S. 35° E., and just in the edge of Pelham, 87° S. 50° E. There is a very fine exposure of gneiss, 75° S. 55° E., west of Compass pond. It is followed by ledges of intermingled gneiss and granite, and by porphyritic gneiss a little more than a mile south-west from Pelham village. The granite of this town is like that of Salem, a stratified gneiss, with some porphyritic crystals in it. After passing a wide alluvial tract,—Beaver creek,—we find granites and slaty layers dipping north-west. For two or three miles on the section line the dips are concealed.

In the south-east part of Nashua are various gneisses not fully characteristic of the formation. They are seen on the road nearest the state line, about a mile back of the Merrimack, with a vertical vein of granite one foot thick. They dip about 70° S. 20° E. The strata are much contorted. Near M. F. Sawyer's, a mile farther west, they dip 70° N. 50° W. This is their western limit, save as they may be buried beneath drift. This corner of the town shows us an anticlinal in the gneiss.

We conclude there must be at least one anticlinal in this range, and perhaps other folds. It is so well developed in Hudson and Pelham that it is easy to believe it continues to the monoclinal section in Salem, and the presumed anticlinal in Hampstead. The Merrimack group lies upon both sides of it. Our studies of Massachusetts rocks lead us to call gneisses very similar to this band,—and, in fact, the repetition of this one beneath the Merrimack synclinal,—Laurentian. Should the Lake and Laurentian series prove identical with each other, it would not be strange.

The small area of similar gneisses and granites in Nashua may be the same with this Pelham range. That follows the Nashua river from the city to the state line, and perhaps further. It is quarried extensively a short distance beyond the city cemetery. There is a fine opportunity at the quarry to observe the strata. On the south wall there is a change of color, one shade showing distinctly strata dipping 80° S. 35° E., and the other simulating the granite stone. The latter seems to be the more highly prized by the quarrymen. There appears to be little other change between these masses save in the color. Both sets of joints occur here, as in the regular Concord granite. Of the minor features of interest, I observed a good case of *slickensides*, where one part has slid over another, affording a smoothed plane of contact, and small veins of translucent quartz. Ledges of gneiss are found farther south-west, dipping S. 40° E. There is a porphyritic mica schist with gneiss at the crossing of the Nashua river, in the south-east corner of Hollis. The extreme north-east and south-west limits of this area are unknown, on account of the great profusion of sand and gravel in the Nashua and Merrimack valleys.

3. Montalban Series.

There are three principal areas of the Montalban rocks in the Merrimack district, and certainly three smaller patches. The three larger ones are disposed like basins. The first lies in the Pemigewasset valley, commencing in Lincoln in the White Mountain district, and extending south to Salisbury. It is connected with our second area, extending from Boscawen to Winnipiseogee lake; but that is spoken of separately, on account of its great divergence from the first. The third is the largest of all, extending from the west corner of Barnstead south-westerly to the edge of Goffstown and Weare. It is twenty-five miles long and nine miles wide, oval in shape. There is a small area of this rock in Antrim, and a little known expanse in New Ipswich. There is a third in Warner and Webster.

The Pemigewasset area. This is fifty-five miles long. It starts on the east flank of Mt. Kinsman, increases in width to the north part of Thornton, and then suddenly doubles in size, being divided into two parts by a narrow range of porphyritic gneiss, which keeps close to the Pemigewasset river as far as Campton. The range is eleven miles wide in Campton. It narrows at Ashland to four miles, being covered up by the fibrolite variety of mica schist, possibly a member of the Montalban series, carrying the gigantic veins of granite. The same width is attained that we saw in Campton after passing the fibrolite schist. This is continuous to Hill, where the narrowing, on account of the northward extension of the Kearsarge andalusite group, and the westward hedging of the Sanbornton schists, amounts to three and two tenths miles. From Franklin there is a broad spur, extending to the south-west into

Andover and Salisbury, upon the south-east side of the Kearsarge rocks. This is limited southerly by the Salisbury area of Lake gneiss already described. That part of the area in the Merrimack valley north of Concord may be regarded as belonging either to this or the next basin.

The facts concerning this area above Campton have been set forth upon pages 133–136. It would appear that the eastern portion of the mass has generally the disposition of a synclinal basin, and that the strike does not conform to that of the adjacent porphyritic gneiss. Nothing is said about the exposures west of the river in Woodstock and Campton. A portion of those in Woodstock are with difficulty separable from the Lake gneiss. About half a mile south-east of Elbow pond the dip is 80° S. 30° E. The rock is much contorted. The dip is S. 85° E. by J. Downing's, in the south part of the town. At Hubbard pond the dip is 75° N. 35° W. For about two miles through the middle of the town, next the river, the rock is a wrinkled andalusite schist, like that in Rumney. I have no observations relating to the occurrence of this rock in Thornton, west of the river, but from what has been stated it seems probable that the synclinal from the east passes near Hubbard pond towards Rumney.

The position of the rocks across Campton is portrayed in the delineation of Section VII. The first rocks west of the porphyritic gneiss dip north-west;—as N. 60° W. in the south-east corner of Thornton, and 35° N. 30° W. on the summit of Mt. Weetamoo. At the base of the mountain the dip changes so as to produce a synclinal. This position is continuous through to the river, giving us probably two foldings. Here is an axis of porphyritic gneiss. On the first considerable hill west the dip is southerly. This dip is so nearly like that in the east part of the town that the axis is truly an inverted one. Near the west line the dip is 70° N. 82° E., so that we have a synclinal here resting upon the older gneiss. The character of the rock in the north-west projection of the town may be known by stating the nature of the ledges proceeding south-westerly from Bald hill to Rumney. At M. Cram's and W. Leavitt's is a mixture of fine and coarse granites interstratified with the more micaceous layers, dipping 30° E. At R. Pike's, in the edge of Rumney (or the school-house south), the granite seams dip three degrees southerly. At I. Chapman's, more than a mile east of Rumney village, is the Concord granite variety.

At E. Blodgett's, in the south-east corner of the town, is an east dip. These are all characteristic Montalban outcrops.

It would not be surprising if the andalusite mica schist of the north end of Stinson mountain were identical with the similar rocks in Ellsworth (page 472), and also with related layers in the central parts of Woodstock. The Montalban of Mt. Weetamoo is now represented as connecting directly with that composing the greater part of Sandwich Dome, heretofore marked as an outlier (Plate XII). The granite of the south-west corner of the town is more or less connected with the Rumney and Plymouth area (pages 509, 510). At the high bridge over the Pemigewasset at the south town line, and at the village on Beebe river, there are ferruginous schists with high south-east dips. Mt. Prospect, in the north part of Holderness, is mostly of porphyritic gneiss interstratified with highly ferruginous schists, dipping N. 60° W. There is therefore a synclinal axis between Prospect mountain and Campton. Specimens of Montalban rocks have been obtained along Beebe river, east of Mrs. J. Leavitt's, N. B. Crowell's, and at the fork of the road leading northerly. Close by the east line of the town the dip is 57° N. 24° W. The same is true respecting the south-west slope of Morgan mountain, Perch pond, and at W. Brown's, in the south-east part of Campton, along the higher part of Ryan's brook. Ledges occur at Plymouth village, and to the west and south, one of them dipping 40° S. 60° E. In the west part of Plymouth there is a small area of Lake gneiss, brought to light since the printing of the pages previous to this one. At C. W. Nelson's and S. Morse's this rock appears, with an east dip. At C. Nutting's, south of school-house No. 10, a ferruginous schist dips 65° W. We find chiefly ferruginous mica schist between Plymouth and Squam lake, with westerly dips. At the town-house on the north side of Little Squam lake, a quartzose schist dips 70° N. 64° W. East of school-house No. 2 of the old town of Holderness is a ledge of quartz like that described in Hillsborough county. The line of Section VI, passing through Ashland, Bridgewater, and the south part of Plymouth, represents westerly dips to Bridgewater, and then the reverse, enabling us to state the presence of a synclinal axis on this route. The similarity between the ferruginous schists belonging to the porphyritic and the Montalban groups in Holderness, Ashland, Plymouth, Campton, etc., produces trouble when attempting to assign the several outcrops to their proper places. Near the outlet of Newfound lake is a fine-grained gneiss, dipping 80° S. 68° E., and also vertical. On a hill west an andalusite schist dips 75° S. 65° E. Near E. Woodbury's, in Hebron, near the lake and south of the section line, a Montalban rock dips 70° S. 60° E. In Bridgewater, fibrolite schist crops out at N. Chapman's, a mile and a half east of a bay in the lake. At S. and N. Brown's is a pyritiferous schist. The same rock near S. Fifield's dips 74° N. 50° W. At J. C. Barrett's the dip is 70° S. 85° E.

The following rocks were observed in the road from Danbury to Bristol, down the valley of Smith's river. Porphyritic gneiss extends for a mile east of the station to its junction with a hard micaceous quartzite, dipping with it 80° S. 70° E. The river valley expands greatly in the east part of the town, covering the ledges with low marshes and meadows, the filling up of a former lake basin. There is a mica schist by T. H. Danforth's, on the east side of the river. Near it, on the north side, the dip is 35° N. 40° W., and the rock carries andalusite. At C. W. Buttrick's and H. S. Clifford's, in the south corner of Alexandria, are fine-grained gneisses, clearly Montalban in type. The dips are 60° N. 60° W., and 65° S. 60° E. Near M. Gordon's are siliceous and ferruginous mica schists, dipping irregularly 80° W. At school-house No. 2 is a distinct gneiss, dipping 65° N. 30° E. Very near it, at J. Tilton's, the rock becomes ferruginous, and dips north of west. Between the corner of Alexandria and Bristol village, extensive sand deposits cover the ledges. At Bristol we find mica schists, somewhat rusty. Following up the Pemigewasset river from Bristol village, we see ledges of similar character at G. Ingalls's and H. M. Emmons's, dipping N. 63° W. The position and material are the same at school-house No. 4, and close by the river at P. E. Heath's, and the rock contains andalusite. At the line between Bristol and Bridgewater, a hard siliceous rock dips 80° S. 50° E. There are several other ledges like it in the next three miles up the river, on the west side. At the bridge leading to Ashland there is a gneiss dipping 63° W. This line of travel has revealed a synclinal in the east part of Danbury, an anticlinal in the south part of Alexandria, a synclinal near the east line of the same town, and an anticlinal in Bridgewater. Perhaps the last is the same that occurs near the New Hampton bridge.

We have indicated an anticlinal line from the neighborhood of Plymouth village nearly due south to the Bridgewater boundary, a mile and a half west of the Pemigewasset; then it continues in the same direction along the Bridgewater hills towards Peaked hill in Bristol. It may pass through Bristol to connect with the anticlinal at a school-house in the south-east part of Alexandria. The one along the river in Bridgewater and New Hampton may be parallel. Fig 95 shows the relations of some of these axes to each other.

In Alexandria, at Lamore and Berry's saw-mill, the dip is 50° E.; near Mrs. L. Gale's it is 49° S. 6° E. At the mill and school-house No. 6 above, is the east limit of the porphyritic gneiss. There is a patch of vertical schists in the north-west part of the town, in the great basin above H. J. Welton's, and lying upon the porphyritic gneiss. At Bristol village the rock is largely ferruginous, but at the south end of Newfound lake it is light-colored and compact.

In New Hampton the most northern outcrop of andalusite schist is on the top of the hill south-west from C. Smith's, and over an interesting glacial clay. The dip is 35°–45° W. The same rock, with a similar position, occurs in several other places in this town on the north-west side of the porphyritic gneiss. At the north end of Shingle-Camp hill it is much contorted, nearly vertical, with strike N. 30° E. The ledge near the bridge over the Pemigewasset dips 50° S. 70° E. It is gneissic in character, dipping 45° southerly, just before coming to Spectacle pond, on the town line towards Meredith. At the south end of the pond the schist is ferruginous, and dips more westerly. In the edge of Sanbornton the dip is to the north-west. East from this point is the south-east dipping gneiss of Cawley pond. From New Hampton village to the crest of high land between Burleigh and Hussey mountains, drift prevails; but mica schist and gneiss occur near J. Merrick's, dipping 45° W. Following what was once a road from here to Cawley pond, I found, on the Sanbornton line, mica schist, dipping 50° N. 50° W. At C. Emerson's, the rocks are horizontal or dip 5° N. W., and hold some gneissic layers. Next the gneissic layers prevail altogether, dipping 50° S. 75° W. South of S. J. Dearborn's the schists dip 60° N. 60° W., occurring in high embossed exposures. At S. Brown's the material is mostly siliceous. Parts of it may be feldspathic, and approach the Concord granite in character. This adjoins the supposed gneiss near Cawley pond, dipping north-west. These facts are embodied in Fig. 96. Sanbornton mountain has not been visited, but it is supposed to consist of mica schists. On the north side of White Oak hill, near Bristol village, the same schists dip south-east. Ledges are abundant on the high hills opposite Hill, but they have not been examined. In Hill the rocks are mostly mica schists. Two miles west of the village, at a fall in Flanders's brook, the dip is to the south. At the town-house the schists become ferruginous, and dip south-east. The hills to the north-west seem to possess the same character. No other ledges appear in proceeding south-west from the town-house till we come to the Kearsarge schists in Andover.

In Franklin, a mile and a half south of the Hill line, the schists dip 50° S. 40° E. At J. W. Simonds's is a local anticlinal, the dips being 80° N. 70° W. and 80° S. 50° E. This is at an angle in the valley, the rock crowding the river easterly. This axis is continued at S. G. Pike's, a mile to the south-west. Near the town farm the rock is gneissic, and has been quarried. Beyond H. N. Ingalls's the dip is 60° S. 25° E. At S. Judkins's the rock is garnetiferous, and dips 80° S. 15° E. The dip is the same in a gneissic rock a quarter of a mile to the west, above the sand. There are many embossed ledges of these rocks in the north-east part of Franklin. The structure of the Andover spur of Montalban may be learned from an examination of the positions along Section V. At the village the dip is 80° S. 50° E. At A. and J. E. Colby's it is 80° S. 30° E. At the south end of the Webster lake it is 50° S. 30° E. It is 65° S. 30° W. at P. Garrily's. The ridge west, in Andover, is covered by drift. These ledges might be the northward continuation of the Salisbury gneiss, unless that line is indicated by the Webster lake anticlinal. At the crossing of the railroad by M. M. and P. Durgin's, the dip is 65° S. 40° W. West of Horseshoe pond the dip is 70° W., the rock being ferruginous. Perhaps this may be regarded as the western limit of the Montalban rocks. So nearly alike are the mica schists of the different groups that no satisfactory line of demarcation can be drawn, with our present limited knowledge. Near the south line of the town the high hill east of Bradley pond is a synclinal of ferruginous and other schists. On the north side the dip is S. 17° E., and in the opposite direction, on the south side, the northern dip being much the steepest. The lower part of the hill is composed of gneiss. At the town line the schists are ferruginous. The schists a mile south of Horseshoe pond dip north-west. Near the town line, along the Blackwater river, are micaceous and ferruginous schists, dipping 75° N. 85° W.

We may regard the anticlinal line by Webster lake as produced by the presence underneath of the Salisbury gneiss;—hence, in connection with the development of that older rock in Salisbury to the south, and Sanbornton to the north, we observe a natural boundary between the Pemigewasset basin and the area following the valley of Winnipiseogee river to the lake. It will be noticed that this axial line points to the area of Lake gneiss extending southerly from Squam lake in Center Harbor and Meredith.

Winnipiseogee River Range. This may be regarded as starting in Gilford and terminating in Boscawen. It touches the lake south of Sanborn's point. Near H. Hunt's, back upon the highest land near the point, is ferruginous schist dipping high S. 85° E. There are micaceous schists on a high hill south from L. Gove's, nearly two miles east from Lake Village, dipping 50°–60° S. 80° E. The layers are minutely contorted. Half a mile east of Lily pond, near M. C. Dexter's, a very ferruginous schist dips 45° N. 60° E. A mile back from Laconia village, towards Saltmarsh pond, the rock dips 25° S. 20° W. Just back of Lake Village there are several outcrops of schists, containing a few garnets and staurolites, dipping 75°–80° S. 40° E. At the south end of Lake Village, the white looking rocks are of andalusite gneiss, dipping 10°–30° S. 65° E. On top of the hill behind them the dip is 80° E. At the fork in the road by J. Davis's, a mile south of the village post-office, the dip is south-west; so that there must be a synclinal or a fault here between the two villages, Lake and Laconia. At J. M. Weeks's, at the west foot of the northern Gunstock peak, the gneiss dips 50° S. At J. B. Morrill's there is a north dip, the ledges about here being considerably distorted. There are schists at Gilford village. Between Long bay and Round bay, in Laconia, are ledges of mica and ferruginous schists, dipping 70°–80° N. 50° E., minutely contorted. A little east of the jail, between Round and Great bays, is a gneiss dipping southerly. North of K. Hall's, near the south line of Gilford, are ferruginous schists with the strike N. 60° E. This is thought to be continuous to ledges of quartzite, ferruginous schist, and granites near R. Randlett's and the cemetery in the north part of

Belmont, dipping S. 10° W., also W. and 12° N. 10° E. At the cross roads, nearly to the west, the dip is S. 10° W. There is a white gneiss running easterly at R. Rowe's, just in the edge of Gilford, to the south-east of K. Hall's. The northern part of Belmont is universally covered with ferruginous debris. Between J. Sawyer's and P. Folsom's is an anticlinal with low dips. Near Sawyer's is a large ledge of gneiss. At the north-east corner of Belmont, at the south end of the Belknap mountains ridge, are ledges of ferruginous schist, dipping 10° N. 5° E., overlaid by a hard gneiss, of texture like that of Concord granite. A few rods to the east, in Gilmanton, the dip is 60° S. W., and the hill south seems to be composed of the same material. At the north edge of the schists next the sienite the indurated layers dip 80° N. 35° W. The line of Section V runs through the south part of Belmont, and the rocks there are probably of the newer age of mica schists.

Diligent search has been made in vain for a range of white quartz, similar to that of Hooksett, in Belmont, Gilford, and Laconia. Boulders of large size are scattered over these towns. They seem to be most abundant on the ridge two or three miles back from Laconia village, but extend as far as to the modified drift close by the houses. None are found on the north side of the river. Hence the conclusion is reached that the source of the fragments must be beneath the alluvium of Winnipiseogee river in Laconia and Gilford. That gives us a range of quartz in the Montalban, just as we had a relic of it in the Pemigewasset basin in Holderness.

The data for the delineation of these rocks in Sanbornton, Tilton, Northfield, and East Franklin are unsatisfactory. In the south-west part of Franklin, half a mile back from the river, the dips are to the north-west. Along the line next the Salisbury gneiss there is a hard quartzite, with unsatisfactory dip. In Boscawen, at the north end of the village, are rocks like Concord granite, with a north-west dip. The same occur near Mrs. P. Arcy's, dipping 60° E.

The Concord area. This extends from Barnstead to Dunbarton, and is noted for the presence of the well known granite of our capital. The Concord granite seems to form two contiguous oval bunches, very much like the smaller ones along the Manchester range, mentioned heretofore, and a little more than eight miles in length. The best known portion is upon Rattlesnake hill, where it has been extensively quarried. The south-western limit is placed in the south-west corner of the town of Concord. It is exposed at the cross-roads east of Great Turkey pond, east of the smaller one, and from Millville across to the western limits of the thickly settled district near the Asylum pond. A massive gneiss flanks it on the west, at Millville. It crops out west of the railroad, in the south-east part of the town, with north-westerly dipping seams; and occasionally in the city proper, as seen in the excavations for laying the water-pipes on Tremont street, near the state prison. On the road to Penacook lake the ledges crop out just beyond the sharp southerly turn of the road half a mile west from Horseshoe pond. Near Little pond the same kind of ledges seem to run N. 20° E. The southward continuation of these rocks is quarried near W. M. Fox's, where the most prominent seams dip 80° S. 70° E. In the other direction the rocks continue into the hill, where most of the quarrying is done, and the same ledge continues through to West Concord. West of Penacook lake is a ridge of ferruginous rock with quartz. There seems to be a recurrence of the Concord granite, or something very much like it, on the north-west continuation of Pine hill, near A. C. Carter's; and there are white ledges between L. F. Ferrin's and the bend in the Concord & Claremont Railroad. This mass has not been observed for more than two miles in length, unless the unusual prevalence of boulders of this material indicates outcrops near D. Dimond's. At Contoocookville is still another mass of Concord granite, perhaps a mile long. It does not appear to advantage upon the map, on account of the overlying alluvium.

At A. A. Blanchard's, beyond West Concord, the rock is more gneissic in appearance, dipping south-east, and must constitute the outer edge of the granite. On the east side of the Merrimack, all the ledges seen north of East Concord are of different character, but the granite makes up the mass of some hills in the west edge of Loudon. The immense sand plain of eastern Concord prevents us from knowing whether the granite is continuous beneath it from the city to Loudon village, the presumption being against a connection.

The most extensive quartz range known in the Montalban runs through Concord. It may be known first at the south-east corner of Warner, in the small area noticed there on page 534. More likely there is a synclinal between the two localities, occupied by the later ferruginous group. It is first seen in Concord, at Pine hill, on the west side of Penacook lake. One would expect to see it on Jerry hill, farther south, but we cannot find any trace of it there. It dips north-west, and comes up again by I. Rowell's, at the north end of the lake. At the first railroad cut beyond West Concord it is certainly fifty feet wide. It is then concealed by alluvium, and comes to view magnificently upon Oak hill, on the east side of the Merrimack, extending into Loudon. It is more than two hundred feet wide. Search for the range farther east has not developed any other exposures, but our explorations have not been sufficiently exhaustive to cover all the territory. From miners' reports it would seem as if it cropped out again to the east of Loudon village.

At the railroad bend two miles from West Concord are gneisses and ferruginous layers dipping 65° N. W., and it looks like the still older Lake gneiss with segregated veins a mile south of Horse hill. Near Sewall's falls the gneiss with protrusive granite veins dips north-west. Hence there is an anticlinal between the falls and Blanchard's. On the Mountain Farm hill the dip is north-west. At Snow pond it is the same. At I. and J. Chase's, east of Hothole pond, Loudon, are coarse mica schists, dipping north-west. The dip is south-east at the north end of Pleasant street, and farther south the strike is nearly east and west. At J. C. Eastman's and J. S. Ordway's the schists carry coarse granite beds with north-west dips. At J. C. Sanborn's, on the continuation of Pleasant street, west of Rollins pond, is a white gneiss, very much twisted, dipping west. On the east side of Beauty pond, in the west corner of Barnstead, there is considerable coarse Concord granite, and this is the most north-eastern outcrop known in this Montalban area. The system is developed farther to the north-east, in the coast district, after passing the overlying mica schists of Barnstead and Alton. The ordinary coarse granites and schists of this region crop out abundantly in the north corner of Pembroke and through Chichester, dipping north-west. On the west side of the Merrimack they constitute most of the towns of Bow and Dunbarton, being the natural continuation of the ledges in Pembroke and Chichester.

On a trip from Hooksett to Hopkinton, through the middle of Bow, I found gneiss and coarse granite dipping north-west for some ways past Bow centre. The south-east dip is first prominent in the south-west corner of Concord. The rocks seen on the river road through the town between Concord and Hooksett may be described in the same language. In the south part of Dunbarton and Bow the successive portions will run along the course of Section III. The dips are N. 60° W. south of Dunbarton centre, as far as Kimball pond, where there is a change to the south-east, in a ferruginous rock. The south-east dip ensuing continues through the rest of Dunbarton and Bow to Hooksett, to the edge of the Lake gneiss. The strata dip so high that there is room for one or more inversions, and there seems to be a sharp synclinal fold on the east line of Bow. I have noted a possible N. 80° W. dip near T. Johnson's, in Dunbarton, south-east from Kimball's pond, in a long ridge of bare rock. It is followed a mile south by a similarly inclined quartz.

Small areas of Montalban rocks occur also in Antrim and Warner, together with the ferruginous tracts in New Ipswich and Deering.

4. Ferruginous Schists.

Three of the designations mentioned at the outset are highly ferruginous: first, portions of the porphyritic gneiss; second, of the Montalban; third, the Rockingham mica schist. These rocks may carry six or seven per cent. of red peroxide of iron, and impart a rusty color to all the ledges and the soil for hundreds of square miles. The basis of the rock is twofold: sometimes a nearly pure gray quartzite, full of pyrites, which by decomposition displays to us the rusty colored ledges; and, again, a mica schist, coarsely grained, probably containing the same compound of iron. Iron is not a mineral that would enable us to use the fact of the presence of a small percentage of it as a satisfactory criterion of geological classification. But in exploring, one finds it nearly impossible to separate the several ferruginous areas from one another. The ledges rarely show themselves free from decomposition. The region is not attractive through the great fertility of the soil, and one is inclined to dispose of any question concerning them in the most rapid way possible. The large area in the south-west part of Hillsborough county may be set down as Montalban, and it is represented upon the map by some appropriate modification of that color. It occupies an equally important area in Cheshire county, and is there described as belonging to the Montalban series, page 489. The rocks of the Montalban group in Bridgewater, Bristol, Alexandria, etc., are as fully ferruginous as those in New Ipswich and Sharon, but have not been separated from the others upon the map. Between the ferruginous portions of the Rockingham and Merrimack groups it is still more difficult to draw a satisfactory line of distinction.

The following notes may express the nature of the rocks across the patch of ferruginous Montalban in New Ipswich. At the south edge of Greenville are gneisses of an older period, dipping 25° W. At the crossing of the Souhegan, by a factory, ferruginous schists hold granite beds, dipping 40° N. 80° W. Taking the road to Factory village, coarse, dark mica schists appear. At M. Farrar's, on the north road to New Ipswich, are Montalban schists, dipping 28° N. 50° W. Half a mile south of the hay-scales a mica schist with granite veins dips 35° W. The same rocks occur farther south, at G. Willard's, with the same position. Taking first a line to the south-west corner of the town, we find ferruginous schists at the chair-shop pond. East of the summit of the mountain is a dip of N. 25° E.; and a crumpled gneiss on the ridge, perhaps dipping west, as a similar rock certainly does in the south-west corner of the town, S. 40° W. irregularly. Returning to New Ipswich village we find mica schist with granitic beds, both somewhat ferruginous. It is thick-bedded, dipping 20° N. 85° W. in the outskirts of the village. By S. C. Wheeler's there is a ferruginous schist, dipping 20° E. This is somewhat local, though it may agree with the rock having the same dip on the ridge near J. Nutting's to the south, just mentioned, and to the dip of N. 85° E., at the south end of Kidder mountain, to the north. At W. Shattuck's it is the same. On reaching the ridge of Barrett mountain the dip changes to 40° W. This is continuous for over a mile. Near G. Stratton's, half a mile before reaching the west town line, the dip has changed to 15° E. It is higher in the east part of Rindge, and soon makes an anticlinal axis. It will be interesting to compare this section delineated in Fig. 94 with that about five miles to the north, in Fig. 91. On the line of Sharon, ferruginous rocks dip 80° N. 60° W. Similar rocks occupy the whole of Sharon. It is conceived that Kidder, Temple, Pack Monadnock, Pinnacle, and Lyndeborough mountains may be distinct from this group, and they will be spoken of as Rockingham schists. I judge the ferruginous type of rock extends west of this into Greenfield.

The next ferruginous group of this age is that of Deering, occupying the country west of the Crotched mountain range of Lake gneiss. The rock a mile south of the south-west corner of Deering, in Francestown, dips 80° N. 60° W. On top of a high hill in the south-west part of Deering, near W. Wilson's, the rock is abundant, and dips 65° N. 50° W. At J. O. Dinsmore's is a hard quartzite, dipping 80° S. 30° E. This gives us an anticlinal, and there must be a synclinal to the east, before coming to the westerly dipping Lake gneiss on Gregg's hill. Through central Deering, along the route of Section III, are westerly dips of gneiss from J. Downing's to S. Carr's, more than a mile west of Deering church. They stand nearly vertical here, but dip 50° S. 80° E. half a mile west, at I. McKean's. Hence we have a synclinal here, and this easterly dip is continuous to the Contoocook river. Through the north part of Deering the rocks dip very much, as along the section shown in Fig. 97. West of J. B. Hall's is a hard, flinty rock, dipping 75° S. 80° E. At J. H. Gould's, on top of a hill, the schists dip S. 65° E. On reaching the valley by I. Smith's, the same flinty rock dips 65° N. 50° W. Large garnets sometimes occur with it, and many layers are ferruginous. A mile east the ferruginous element is more abundant, the dip being the same. West of the school-house by B. Gove's, the rock is as red as ferric oxide ever occurs, with a north-east strike. There are some gneissic layers in a similar rock, dipping 85° N. 75° W., on the town line. This brings us nearly to the vertical layers of Lake gneiss in Weare. The hills in the south part of Henniker are composed of mica schists of different aspect and position, and therefore are not included in this area, though the strike would naturally seem to include with it all the rocks west of the gneissic range, as far as the notch made by alluvium along the line of the old New Hampshire Central Railway.

Another ferruginous area, thought to be like these, lies in Hopkinton, Concord, and Boscawen, apparently occupying the region beneath the abundant alluvium of the Contoocook. It lies east of the narrow porphyritic gneiss range in the east part of Hopkinton. They have the strike N. 20° E., at S. Gale's, with easterly dips nearer the village. Nearer I. Proctor's, in Concord, a mile west of Little Turkey pond, the dip is 80° W. The old gneiss near Tyler's station, Hopkinton, joins a ferruginous rock dipping 75° N. 65° E. West of J. Patch's the dip is 20° N. 65° E., and it may be as low as 10° in some exposures. The same style of very rusty rock covers the road east of Ash brook in Concord, and west of Jerry hill. Between Jerry and Pine hills the dip is north-west. At the west base of Horse hill, at Mast Yard station, the dip is 55° N. 65° W. By E. C. Elliott's and Mrs. Eastman's the rocks are gneissic, dipping 75° N. 40° W. By E. Terry's is a single lenticular ledge, eight feet long, of the same material. Gneiss with north-west dip appears also by G. Colby's. Perhaps the ferruginous rocks next, in Boscawen, should be included with a later group, but everything in the village of Fisherville properly belongs to this section. The rocks there are ferruginous gneisses, compact dark schists, and fine- and coarse-bedded granites, all dipping north-west.

5. Fibrolite Group with Coarse Granite Veins.

This band of rock, carrying the best veins suitable for quarrying mica, enters our field of description in Hebron and Plymouth, but I can add nothing beyond what has already been said of them in Chapter V.

6. Rockingham Mica Schist.

This term was first used in the report for 1872 (Vol. I, page 55). It is very convenient to designate a large mass of mica schists, with the mica often in coarse blotches and the predominant mineral, by a geographical reference until its proper geological place is known; and therefore we cannot yet dispense with the term. The closest resemblance is to the micaceous portion of the Montalban series, specimens holding the coarse mica being undistinguishable from many ledges among the White Mountains. When large crystals of andalusite occur in the schists it is not easy to distinguish them from the Kearsarge group. There is no difficulty in discerning the relations of the formation to the Merrimack group, yet the boundary line between them is not satisfactory. It is thought to correspond with the mica schist division of the Coös group along the Connecticut valley. When well filled with ferric oxide, the rock becomes one of the varieties of the ferruginous division. It is better developed in Strafford than in Rockingham county, but the necessity of separating the group from everything else made itself manifest from the study of the formation in the first named district.

Two features further characterize the group. First, bands of quartz pass through it, as in some of the older series, before described; second, beds of granite are innumerable. They are often of sufficient consequence to be specially colored upon the map. These two features show how closely the formation imitates the Montalban. As regards elevation, the strata are commonly inclined at small angles, with numerous local foldings, and they constitute mountain masses when slightly inclined. These characteristics agree with their reference to a comparatively modern period for their deposition. The grinding up of the Montalban strata would furnish the materials for the recomposition of ledges very similar to them, and at their junction the differences might be so slight as to prevent a ready recognition of the discordances in stratigraphical structure. It has been stated heretofore that this group is spread like a blanket unconformably over several of the older gneissic groups. This statement still seems to be correct. In our delineation of it in map No. 5 of the physical history of the state, the color is made to embrace on the north-west side the Kearsarge group and the fibrolite rock with coarse granite, and on the south-east the Merrimack groups. A small area near Umbagog lake is also placed with it, which is reckoned as Huronian on the final map.

In the Merrimack district the following areas of this rock will be noted: (1) in Sanbornton; (2) (3) branches of the enormous Strafford county blanket, prominently occupying Canterbury and Northfield on the north, and Allenstown and Epsom on the south; (4) (5) at least two long narrow bands between the quartzes of Hillsborough county; (6) the Lyndeborough and Temple mountain range; (7) Mt. William in Weare; (8) that associated with the Merrimack group, between the Manchester and Hampstead gneissic areas.

Sanbornton. This area touches the porphyritic gneiss and the Great bay on the north-east, small patches of Lake gneiss on the north and south, and Montalban on the south-west. It does not seem to cross either the Winnipiseogee or Pemigewasset rivers, though reaching to the banks of both streams. On the slope towards Great bay, the ledges are mostly concealed by a sloping mass of drift. The granite of the series appears north of O. Calef's. Going north from Tilton the boundary of this group is reached at the "gulf," the dip changing abruptly to the south-east instead of north-west. It changes back again a mile north of the "Square," near W. Paine's, 60° N. 27° W., also 30° N. 60° W. The dip sometimes descends to 10°. At T. B. French's, beds of granite occur. As far as E. F. Plummer's, ledges dip N. 60° W. The mica schist is red at J. Flanders's, near the Meredith line. About the granitic rock, on the high hill, the dip seems to be north-west, and to belong to this series better than any other, though there is room for difference of opinion. At J. & H. N. Marsh's, a mile west of the gulf, the dip is 80° N. 85° W., and the ledges are common between this point and Tilton village, some of them belonging to an older series. No further observations have been recorded of dips in Tilton. The only points of interest ascertained are the fact of the unconformable relations of the mica schist to the porphyritic gneiss of Meredith, with an axis at the gulf. The strike of the schists points square across the gneiss. In the north-west part of Sanbornton the dips are mostly to the north-west. The relations of the several rocks across this area are shown in Fig. 96. It starts near the Pemigewasset river in Bristol, exhibits the anticlinal in that valley in the Montalban series, then a synclinal hill, and mostly north-west inclinations over the Sanbornton mountain ridge, and two ridges of gneiss,—the last in the valley of the outlet of Cawley pond. After this follow the mica schists with the same dip on the "Square" ridge, and the various gneisses of Tilton and Northfield.

Canterbury, Northfield, etc. This north-western extremity of the blanket occupies also portions of Belmont and Gilmanton, west of the eastern boundary of the district. The relations of the rocks appear in a section (Fig. 99) from Belmont to Lower Gilmanton. At Belmont occurs one of the minor irregularities liable to be seen in any of our formations. The average dip is south-westerly. There is evidence of a synclinal near the town line, and it may be the same undulation with the shallow basin on the north side of Little pond in the south corner of Belmont. South-east from the pond is a large mass of coarse granite, considerable ferruginous and other uncanny rocks. Through Gilmanton the dip is monoclinal, north-westerly. The rock is ferruginous north-west from the centre village, and also at the lower village, but not so between them. We find the dip north-west on top of the hill, between Shell camp and Rocky ponds. The Bean Hill area in Northfield and Canterbury has considerable granite in it. That near Little pond crops out again in the Pinnacle,—possibly it is contiguous,—with the same north-west dip. There is a large

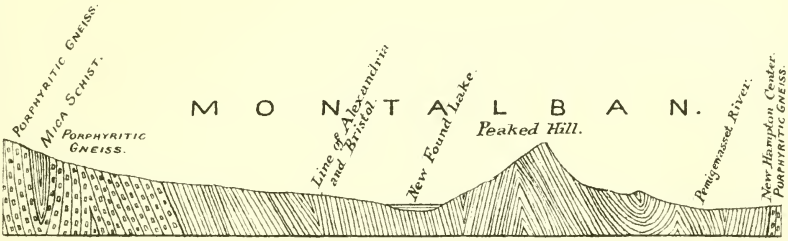


FIG. 95. THROUGH ALEXANDRIA AND BRISTOL TO NEW HAMPTON CENTER.

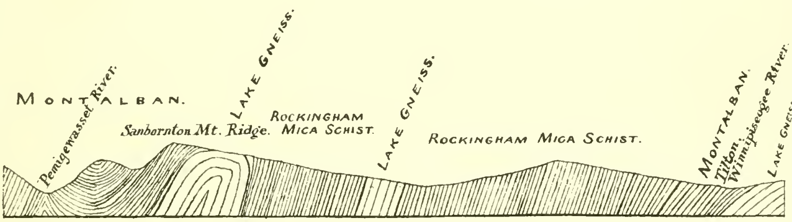


FIG. 96. FROM BRISTOL TO NORTHFIELD.

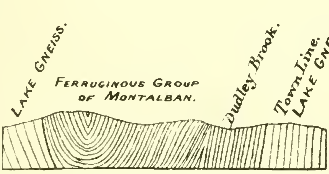


FIG. 97. FROM NORTH DEERING INTO WEARE.

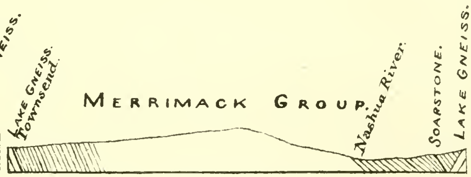


FIG. 98. FROM TOWNSEND TO GROTON, MASS.

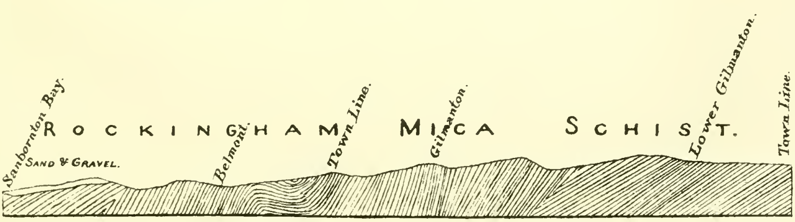


FIG. 99. THROUGH BELMONT AND GILMANTON.

SCALE, HORIZONTALLY, $2\frac{1}{2}$ MILES TO AN INCH; VERTICALLY, 3000 FEET TO AN INCH.

HELIOTYPE.

vein of white quartz near Capt. T. Fellows's. The top of Bean hill is also mostly coarse granite, with only enough ferruginous mica schist to indicate the north-west or west pitch of the mass. The mica schist has the same position at the north base of the hill. The dip is 10° S. 18° W. on the line between Belmont and Northfield, where a tributary of the Tioga river crosses it. The long narrow ridge from Hill's corner to Shaker Village is gneissic schist, with a small dip. Possibly it is an anticlinal. The north part of Canterbury has not been explored.

Pittsfield, etc. In Pittsfield, Epsom, and Allenstown is the other branch of the Strafford county area. At Pittsfield village the mica schist dips south-west. At E. French's, a mile and a half south, we find westerly dips, with small granite beds. On Catamount mountain granite beds occur; the dip is south-east, showing the presence of an anticlinal axis. Near Webster's mills the railroad has cut through a ledge of quartz similar to the bands that have been described above. The dip is N. 75° W. On the east side are two hummocks of coarse granite,—one of them seemingly cutting across mica schist,—dipping N. 30° W. In Epsom the beds of granite are not uncommon, and they often carry tourmaline. The dips along the Little Suncook river, near the east line of the town, are north-westerly. There is an anticlinal in the south-west corner of the town, in connection with some schists in Deerfield. Brush hill, McKoy's, Fort, Nottingham, and Nat's mountains are composed of these schists, and are supposed to dip north-west; but this is an impression from recollection only, not based upon recorded observations. In Allenstown the ledges are not numerous, as deposits of drift are very abundant.

Between the Quartz Bands. The sections in Figs. 87 to 91 cross narrow strips of this mica schist, and have been already described in detail. The rock is closely allied to the Montalban schists. Two bands appear on the map. The first lies chiefly in Goffstown, and runs between the Uncanoonucs, being over six miles long. Possibly it should be extended farther north-east, to include the low-dipping schists on the west line of Hooksett. The other starts from the middle of Goffstown, and extends to New Ipswich, through Bedford, Amherst, Mont Vernon, Lyndeborough, Temple, and Wilton, a distance of twenty-three or twenty-four miles. It is a trifle over a quarter of a mile wide at its north-east end, and gradually increases to nearly four in Temple and Wilton. The dip is invariably north-westerly, and usually at a small angle. It forms a sort of plateau through Mont Vernon. Roby hill, in the north-west part of the town, is composed of mica schist. It crops out with a low, north-westerly dip at A. J. Twiss's and B. Jones's, near a mill; a mile north-east from the village; at the church, with granite; near G. A. Wallace's, on the Francestown road; near J. Hartshorn's, dip 15° N. W.; near A. Upton's, and elsewhere. At Purgatory falls, on the line of Mont Vernon and Lyndeborough, the schists, with coarse granite beds, dip 50° N. 30° W. In the north-east corner of Wilton the dip is small to the north-west. This range is made to terminate in the north part of New Ipswich, but it may possibly continue into Massachusetts. On the north-east it points towards the Allenstown deposit, and may occupy the same depression with that or some portion of it.

Temple Mountain Range. The map shows a line of elevations from Lyndeborough to New Ipswich, whose similar topographical features suggest identity of geological character. The Lyndeborough mountains rise abruptly from the comparatively flat ground of New Boston and Francestown; and the rocks change as quickly as the elevation. Gneiss is exchanged for mica schist. We observed the following facts in crossing from Francestown to the centre post-office: Irregularly curved mica schists, like those holding andalusite, with westerly dip, on the Piscataquog river near the south line of Francestown; at L. Spaulding's, a mile farther, the mica schists dip north-west at a small angle; on the summit of the ridge the dip is 50° N. 20° W.; and the same rock extends nearly to the centre village. Loose blocks of the schist hold excellent specimens of the long, fibrous mineral andalusite or fibrolite, showing that it characterizes the deposit, though not actually found in place. Between the Pinnacle and Pack Monadnock mountains is a deep valley, cut down by Stony brook, and the place where the railroad passes from Wilton to Greenfield. For two miles or more, the mica schists are well exposed along the axis of the mountain ranges. In the saddle between Pack Monadnock and Temple mountain the schists dip 30° N. 50° W. On the west side and summit of Temple mountain the rock is mica schist, with granitic beds, dipping 8°–10° W. At the south end of Kidder mountain in New Ipswich, which is of the same material with the others mentioned, the dip is N. 85° E. A narrow band of rock has been stated to continue southerly from this mountain to J. Nutting's, on the east side of the Barrett Mountain range, a mile north of Massachusetts. It may represent this formation. Barrett mountain, being more gneissic, is thought to be older. Accepting the correctness of the identity of the rocks of these several mountains, it would appear that the strata have been pushed into an anticlinal form, while the dips are very small. This range presents greater resemblances to the Monadnock rock than any of the others described.

Mt. William. In Weare, Mts. William and Wallingford are composed of this mica schist, dipping 70° N. 40° W.

The Derry Range. This is the most important of all, since it stands closely connected with the Merrimack group. It covers a greater area on the Coast than the Merrimack district. Entering our field of description at Derry, it crosses into Nashua and Hollis, and then leaves the state, being identical with the mica schist group crossing through Massachusetts past Lancaster, Sterling, and Worcester nearly to Connecticut. The best idea of it, as it occurs in this district, may be gained from an examination of a section through Derry (Fig. 100). The mica schist adjoins gneiss in the south-east corner of Manchester, having a south-easterly dip. Just in the edge of Londonderry is a feldspathic layer. A band of white quartz, similar to others that have been prominently described, crosses the section midway through the north-east corner of the town, near a school-house. Other ledges of mica schist occur between the school-house and the west line of Derry, dipping to the south-east. Commencing with the Derry line, we find next a rock consisting of crystalline feldspar, extending, by measurement, two hundred and eighty rods along the route of the section, dipping south-east. A few rods of it dip north-west at the Upper Shields pond. Next follows a quartzite containing numerous segregated quartz bands or veins, dipping about 85° N. 30° W. Near W. Palmer's begins a series of regularly-bedded mica slates, dipping 80° S. E. These extend as far as Beaver pond. The face of the country varies according to the nature of the underlying rocks. Over the feldspathic area the soil is barren; but excellent farms cover the slate area.

There is a feldspathic rock at Derry west village, with uncertain dip.

A broad meadow conceals the ledges next, as far as the double road around J. Patten's, where the mica schist changes to dip 45° N. W. The angle of the dip here is much less than by Beaver pond. Next the mica schists dip south-east at three localities,—the valley of West Run brook, at J. Boynton's, and midway between them. This south-east series of outcrops extends for a mile and a half. At J. Low's, north of Ezekiel pond, mica schists dip 80° N. W. Just east of the pond succeed coarse granites. The same occur at E. Hobbs's, on the south side of the pond, dipping 75° N. 50° W. These rocks are chiefly porphyritic feldspars, with hard mica schists, freshly exposed in a railroad cut. Along the Lawrence railroad, west of Mitchell's pond, near the north line of Windham, similar schists and feldspathic rocks occur. Less than a mile south-west from Mitchell's pond is a large amount of feldspathic rock. Farther south, where small bends in the road are conspicuous, the feldspar beds and mica schists alternate. We find granitic rock at D. Kelley's, schist at T. Dinsmore's, and so on to the Lake gneiss, the last half mile of the section being mostly devoid of granite. The last mile of the way shows small bands of quartz, and there are enough large boulders of this material on the surface to suggest the near proximity of a considerable bed of it. The section suggests a general synclinal structure of the whole band, with correspondences on the sides. We find the coarse feldspathic beds on both sides, with the possibility of a quartz bed repeated. The central portion is occupied by a slate, which may perhaps be traced south-westerly to connect with the clay slate of the Worcester county, Mass., range. The mica schists are usually more siliceous than the majority of the Rockingham schists in the other areas, but are not quite the same with the micaceous quartzites of the Merrimack group. There is a mass of Huronian aspect, however, in the north part of Derry, which requires farther exploration before its relations are satisfactorily made out.

Section II crosses the formation transversely, and we glean the following facts from it. From Derry station, on the Rochester railroad, to East Derry, the dips are north-west, and the rocks mica schists. No ledges occur anywhere about the village. Between this village and the eastern town line a few ledges dip 70° N. W., and carry large granitic beds in their eastern outcrops. Between Derry west village and the Lawrence railroad depot are mica schists with north-west dip. West of the railroad is the mica slate range coming across from the north side of Beaver pond, dipping 70° N. 30° W. At the west town line they stand about vertical. The dip of 85° N. W. extends about half a mile into Londonderry. At the cross-roads east of L. Welch's the first south-east dip is found. The rock stands vertical at A. P. Hardy's and at the school-house. The dip is south-east a mile north, at the Pinkerton cemetery. It is vertical at S. Bancroft's. At the forks in the road by P. Crowell's, a few layers of the feldspathic sandstones begin to show themselves in the schists, dipping high south-east. Between Crowell's and N. Chase's, hard blue schists prevail. Along the Mammoth road east, back of J. Royce's, the white ledges are very conspicuous. At D. Goodwin's an ancient appearing mica schist dips 80° N. 60° W., also at N. Boye's. At F. Corning's the rock dips south-east, and at the cemetery near by the schist is somewhat ferruginous. This is the last ledge seen on the line of the section, and is a mile and a half east from the Litchfield line. The river sand now conceals everything to the river. This gives us the main synclinal and two subordinate axes along this route, and the feldspathic beds near the borders as before.

A few other facts in Londonderry are these. On the Mammoth road the feldspathic beds begin just north of the railroad crossing. A little south are the mica schists, which may be followed north-east to cross the railroad again by Wilson's station, and appearing on Fig. 100, south from the quartz band, a distance of four miles. Next is a feldspathic band beginning south-west, to the south of Cyrus Nesmith's, dipping S. 45° E., appearing east of the Mammoth road, north of J. Brickett's, and so on to its place on Fig. 100. The next schist band is seen about a Baptist church, and farther south-west, north of J. Dickey's, and so on towards Scabies pond. There is a still more prominent feldspathic band adjoining this,—from I. Kimball's, in the west part of the town, to the east of the Mammoth road, by J. Royce's, and at Moore & Perkins's. Almost all these outcrops dip south-east. To the south of this last named white band are no feldspathic layers of any account on the north side of the synclinal line. Numerous quartz boulders near A. Smith's, east of I. Kimball's, suggest the near occurrence of the ledge. Drift is more abundant in the middle of the town, but there are north-westerly dipping outcrops at the town-house and a mile west. There are other ledges of similar nature and position elsewhere in the south part of Londonderry and the north part of Hudson. On the route from Windham town hall across to Nashua the following observations may be relied upon. The schist first appears on the south-east edge of the formation, a mile west of the hall, by J. Evans's, dipping north-westerly. There is a gneissic appearing rock at the west town line, by a railroad station, and feldspathic bands at Noah Robinson's and D. Clement's, in Hudson, with mica schists between. Several other ledges occur on the route, all of them with north-west dips. Under the bridge over Merrimack river micaceous grits dip 80° S. 30° E., and there must be a synclinal between the last two observations. The rocks in Nashua are more like the Merrimack group than those in Derry. The reservoir rock, dipping 80° S. E., is an argillaceous quartzite. This may be the southward continuation of the similar rocks with slates at the drug mill, on the north line of Nashua, dipping south-east. At an excavation in North Pine street is one of the feldspathic bands, dipping 80° N. W., and carrying small oval patches of mica. Two miles south of the post-office, at R. Godfrey's, mica schists dip 45° N. 33° W. At the cemetery a mile north of the state line, next the Lowell railroad, the same rock dips 50° N. 20° W. A feldspathic band occurs a mile north. Taking the route between the two gneiss areas to the south-west, we find a hard mica schist with segregated veins at A. and C. Lund's, dipping 75° S. E. Three miles out, on the Acton railroad, a cut shows several varieties of mica and sandy schists, dipping 15° S. At L. White's, near Lowell pond and the state line, is an unclean, coarse, ferruginous mica schist, dipping 65° S. 60° E. Near S. Swallow's, feldspathic mica schist dips S. 40° E. This section of the formation dips altogether south-easterly.

The more argillaceous member occurs east of H. Wood's, near the west line of the town and north of the Nashua river, dipping 85° S. 30° E. At Terrill's, near the town farm of Hollis, it is more slaty, dipping 45° S. 50° E. Near Hollis centre similar ledges, jointed and micaceous, dip 50° S. 40° E. Proctor hill, in the west part of the town, is composed of mica schist—dip, 45° S. 70° E.—and a large protrusion of the granitic layer. On the western slope of the hill the schists dip 55° S. 80° E. This rock is believed to occupy the south-east part of Brookline. In the north-west part of Nashua, at B. F. Colton's, the schist dips south-east, and breaks naturally into prismatic fragments. The same is true of the rocks at South Merrimack, with the addition of fine-grained feldspathic beds. All the rocks in the south part of Merrimack dip to the south-east.

A few statements will show how these rocks appear farther to the south-west in Massachusetts. In the south part of Lunenburg, along the Fitchburg railroad, is an exposure of a white quartz band, similar to the one mentioned in Londonderry, having the strike N. 10° E. A slate near it dips irregularly to the south-east. Crossing from Townsend to Groton, we find, first, gneiss, then mica schist with feldspathic beds dipping 45° E. In Shirley, the west part of Groton, and in Pepperell the rock is argillaceous and slaty, dipping east. A mile north of Groton centre is a bed of soapstone, in a jointed mica schist, dipping 25° S. 20°–30° E. Near the north line of Ayer we find the regularly-jointed, coarse-bedded gneiss, dipping 75° N. 20° W. Hence a section here indicates easterly-dipping monoclinal strata resting in a synclinal of gneiss.

7. Kearsarge Andalusite Group.

The Monadnock area of andalusite rocks has been described in Chapter V. A similar mass of strata occurs upon Mts. Kearsarge and Ragged, constituting a band twelve miles long and from three to four wide, in the towns of Warner, Sutton, Andover, and Salisbury. Starting from the Warner side, the peculiar rocks of the mountain are first seen at Stanley's, a quarter of a mile south of the toll-gate, standing perpendicular, with the strike N. 30° E. The strata display large contortions, while the gneisses below do not seem to have been greatly disturbed. I have often noticed that the newer strata are usually the ones apparently showing the greatest signs of pressure, but not necessarily crystalline. The older ones may have lost the tokens of a greater action by metamorphism, but it is certainly not apparent in the condition of foldings or faults. For this reason I do not consider it a sure guide to antiquity among our formations, to affirm that the most disturbed are the oldest. Clearly these schists are granitic masses, approximately similar to those so common in the Rockingham country, and they continue until replaced by the ferruginous schists at the toll-gate. These occur occasionally in climbing the turnpike. On reaching "Plumbago point" these schists are vertical, with the strike N. 70° E. The road started out to the north-east, but after passing Plumbago point it changes to north-west, passing along the crest of the mountain, receiving the name "Mission ridge." The rock is a hard, brittle, fine-grained granite. At its north end, near the "White house," at the beginning of trees, the hard schists dip N. W. 85°. Large veins of a porphyritic granite, a little like the Albany, appear next. A quarter of a mile higher up this granite has planes dipping 50° W. Others dip 10° S. Half way to the "Garden" quartzites dip 75° S. 62° E. Further on they contain scattered crystals of andalusite, and dip east. Near the Garden the dip is 50° N. 50° W. At the last abrupt turn in the road the dip is N. 40° W. In the depression called the "crater" the dip is 70° N. 52° W., the rock being mostly an andalusitic quartzite, in strata resembling sandstone. On the very summit the dip is N. 35° W. On descending to the Winslow house the dip veers more northerly. At the top of the clearing below the woods, I measured dips S. 35° and 40° E. At the hotel the dip is 80° N. 80° W. A quarter of a mile below this house the dip is 85° E. There is a ledge of mica schist near the east line of Wilmot, below the hotel. Taking another route down the north-east side, in Andover, I found the dip becoming northerly; also an interesting curvature with a quartz vein, which is delineated in Fig. 101. The ledge had been cut by a joint, leaving a nearly vertical smooth surface, fifteen feet high and forty long, showing two curvatures. The axis of the folds runs N. 42° E. The vein occupies a fissure where the rock had been subjected to the most pressure. At the edge of the woods the dip is 30° N. 18° W. Lower down are abundant crystals of andalusite two inches long. Before reaching the lower edge of the forest the strata are vertical, with the strike N. 50° E. At a saw-mill the dip is 85° N. 40° W., much andalusite being present. Nearly down to the road, parallel with the west line of Andover, the dip is 75° S. 30° W., though more usually N. 30° E. In a sort of meadow north of the "pyroligneous acid manufactory" of the county map, the rock resembles the Montalban schists, crowded with foldings and inclined perhaps S. 80° E. Between Cilleyville and Potter Place a dark quartzite dips 70° N. 70° W., and the rock is said to be plumbaginous. On the west side of Mt. Kearsarge in Sutton, on an old road to S. S. Felch's, the mica schist dips 85° N. 80° W. It lies next to porphyritic gneiss. The south-west and east sides of the

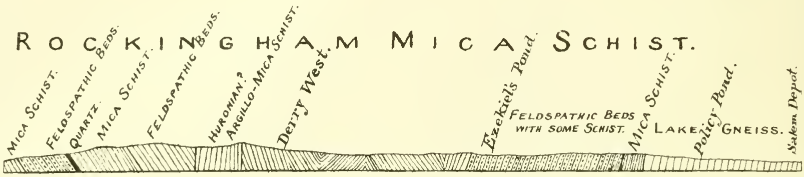


FIG. 100. THROUGH DERRY, &C., TO SALEM DEPOT.—CONTINUATION OF FIG. 92.
SCALE, HORIZONTALLY, $2\frac{1}{2}$ MILES TO AN INCH; VERTICALLY, 3000 FEET TO AN INCH.

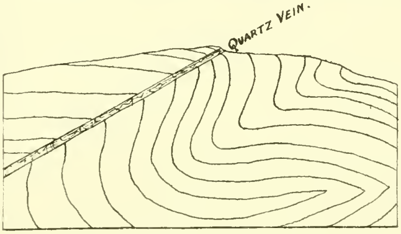


FIG. 101. CURVATURES IN STRATA, MT. KEARSARGE.
15 FEET HIGH; 40 FEET LONG.

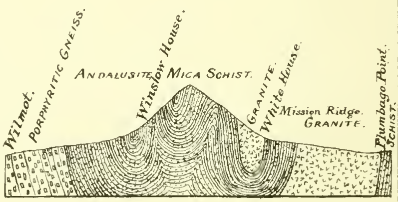
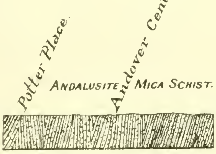


FIG. 102. MT. KEARSARGE.
HORIZONTAL SCALE, $2\frac{1}{2}$ MILES TO AN INCH.
VERTICAL " , 4000 FEET " " " .



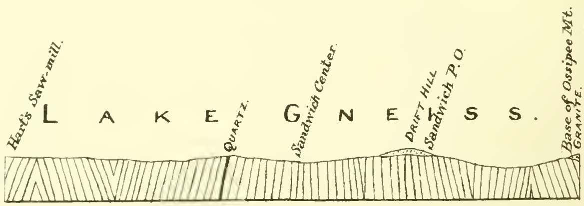


FIG. 103. IN ANDOVER. FIG. 104. FROM HART'S SAW-MILL TO WEST BASE OF OSSIPEE MT.
SCALE, HORIZONTALLY, $2\frac{1}{2}$ MILES TO AN INCH; VERTICALLY, 3000 FEET TO AN INCH.

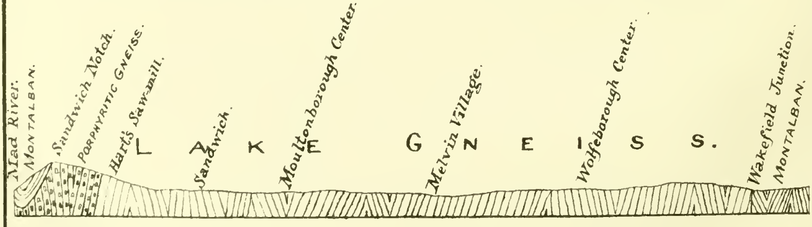


FIG. 105. FROM MAD RIVER TO WAKEFIELD JUNCTION.
SCALE, HORIZONTALLY, $7\frac{1}{2}$ MILES TO AN INCH; VERTICALLY, 5000 FEET TO AN INCH.

HELIOTYPE.

mountain have not been explored. Fig. 102 embodies the observations taken from Plumbago point across the summit to the Winslow house, and so on to Wilmot Flat. The more elevated portion shows the presence of two anticlinals and three synclinals, and the general attitude of the area is synclinal, because it rests upon older rocks everywhere.

Fig. 103 exhibits the stratigraphical structure of the mass in a section through Andover, following the Northern Railroad. It would be possible to recognize the same folds here as in Fig. 102, though they are closely pressed together. The rocks rise again to the north in Ragged mountain, and we ascend from Andover centre. Half a mile before reaching the last house (G. W. Thompson's), andalusite schists dip 70° N. 70° W. The lines of ascent and descent taken may be from a quarter to a half mile apart. On the more western one, six hundred and fifty feet above the house, the rock is vertical, and dips 80° N. 40° W. Eight hundred feet higher than the house the dip is 85° N. 40° W. On the summit the andalusite flags show numerous small convolutions, as on Kearsarge, the average position being 75°–80° N. 40° W. On looking south-westerly, the strike of the ledges points towards Mt. Sunapee instead of Kearsarge. Should this direction prevail, it would indicate the repetition of the Kearsarge strata upon Ragged mountain, separated by an axial line. This mountain is just as much isolated as Kearsarge. The summit is in three parts, the eastern peak being the highest of all, perhaps twenty-five feet above the middle eminence supporting the signal of the Geodetic Connection Survey. The strata on the eastern line of descent agree nearly with those seen in ascending. Near Thompson's the strike is N. 30° E.

The Ragged mountain ridge has been crossed between East Andover and Hill. At the railroad curve, drift conceals the ledges. At L. Brown's, after beginning the ascent, the strata dip high to the north-west. At B. Tucker's are a few ferruginous layers. On top of the ridge the strata dip 80° N. 70° W. On reaching the town line, hard andalusite sandstones and feldspathic beds occur, dipping 10°–20° N. 70° W. On the north slope, east of the road, are numerous embossed ledges, probably of the same character. The first rocks seen in Hill are not adjacent to these andalusite beds, and they are Montalban ferruginous schists, dipping south-east. Our observations on this eastern line indicate the existence of a probable anticlinal, but information sufficient to establish the nature of the other folds in the range is wanting. There is one correspondence between the Kearsarge and Rockingham schists: both contain prominent feldspathic or granitic beds near their borders, perhaps their lower members. The former have not yet shown extensive bands of quartz, but mention should be made of the small lenticular veins of rose quartz, common both on Kearsarge and Ragged mountains. Large portions of the ledges are thoroughly packed with andalusite. The crystals are smaller than on Monadnock, or the east side of Mt. Washington, but are well defined in certain localities,—sufficiently so to render probable the reference of all the elongated prisms to the mineral andalusite rather than fibrolite. The Kearsarge area is more sandy than the Monadnock, or especially the Mt. Washington, which carries a great deal of argillaceous matter. All these areas enumerated are believed to be of the same age, and are so colored on the general map. Possibly the Kearsarge area may reach into Franklin. I have not been able to traverse the road over the continuation of this ridge in the west part of that town.

8. Merrimack Group.

I have not attempted to separate from the Rockingham series a narrow band of Merrimack schists in Nashua and Derry. A few facts in reference to them have been already stated. There remain to be noticed a few areas of rock, easily referred either to the Merrimack or Rockingham series, mostly of a ferruginous character, between Francestown and Canterbury. The range is of importance, because it carries the soapstone beds occurring in these two towns. The distribution of this rock indicates its presence in three separate areas,—Canterbury, Boscawen, and between Henniker and Greenfield. Except for a broad alluvial covering, these three areas would not appear isolated upon the map.

There is not a predominance of quartzite in these rocks. Ferruginous and mica schists, with feldspathic beds, constitute the prevailing strata. The first have lost their original appearance, by the decomposition of the ferruginous mineral, and might perhaps be called pyritiferous quartzites, before disintegration. The soapstone of Canterbury is supposed to lie in this rock. It is about a mile and a half south of the station. There seem to be two beds of the stone, one hundred feet apart, separated by hard hornblendic masses, and each about twenty-five feet wide. On the east side is a broad, white feldspathic band, with the dip of 50° W. This extends south-east to the cross-roads near A. Sargent's. This band must be three fourths of a mile wide. At J. Neil's and G. Barney's, near the south-west corner of Canterbury, is a mica schist, dipping 75° S. 15° W. In the edge of Concord is a very ferruginous schist, dipping 70° N. 50° W. Nothing is known of the extreme north-east extension of this rock in Canterbury. Its limits are marked on the map at random.

In Boscawen the ferruginous schists occur at the village, dipping east. The most western outcrop is near a saw- and turning-mill, next W. B. Burpee's, and it reaches northerly to Salisbury. Back from Fisherville, among the houses, is a slaty, ferruginous rock, dipping 35° N. 30° W. Several ledges occur for a mile. At L. Morrison's the quartzites are interstratified with andalusite bands, dipping 70° N. 20° W. There is a feldspathic ledge here, also. Taking a deserted road towards Horse hill, we pass gneissic rocks just at a brook-crossing, the dip being north-west. In Concord the dip is 78° N. 40° W. At Mast Yard ferruginous slate dips 55° N. 65° W. It occupies most of the west edge of Concord, next Hopkinton, and the whole of Hopkinton south of the Contoocook river.

There are some indications of soapstone at a school-house by Mrs. J. Butterfield's, at four-corners in the west part of the town, dipping north-west. Between D. Tucker's and R. P. Copp's, farther west, is a repetition of the white feldspathic rock seen in Canterbury, which dips to the north-west. The rocks on the north side of the Contoocook are crossed by Section IV, and include the soapstone at Davisville in the south-east corner of Warner. The schists here dip S. 50° E., and they crop out strongly on the east side of Warner river in Webster. The soapstone is certainly twenty feet thick, and has been quarried slightly. About on the south town line of Warner flinty schists dip 65°–70° N. 63° W. This rock crops out at the shingle-mill, and at Annis's and Rand's, with fibrolite. On the hill south of Bear pond in Warner, hard quartzite schists dip 75° S. 70° W. Similar ledges crop out on the hill to the west of J. B. Colby's in the north-east corner of Henniker. Near J. Foster's, a mile west of Gove's pond, the dip is 80° N. 73° W. South of the Contoocook in Henniker are several exposures of mica schist thought to belong to this formation. At the old railroad crossing, a mile north of the Weare line, is a massive rock dipping 10° N. W. South of A. D. L. F. Connor's it is high to the west; farther south it is east of north. The high hills to the south are made of it. This range terminates against the Deering Montalban series.

In Weare the principal range is embraced between two areas of Lake gneiss. Near the north line of the town a large hill contains mica schist dipping N. 60° E., perhaps making an anticlinal with those in Henniker, just named. In the west part of Weare there are numerous outcrops of ferruginous and mica schists dipping north-westerly, as two miles north of Clinton Grove, and a mile west. Mt. Misery and Odiorne hill are composed of this rock, and perhaps a part of Wallingford mountain. The top of Mt. Misery dips north-west. Just over the soapstone fibrolite layers may be seen. The soapstone lies on the south-east slope, and is about sixty feet wide. It has been opened extensively by Hon. M. A. Hodgdon. It is of the same character with that in Francestown, and perhaps on the same line of outcrop. Both are characterized by massiveness, arising from the uniform dissemination of crystalline radiated bunches of talc through the rock. Minute bits of pyrrhotite occur occasionally, but they do not seem to injure the stone for use in the manufacture of stoves. Two horses, or large masses of hard rock, occupy a considerable portion of the breadth of the bed; but they may disappear, as the rock is quarried deeper into the hill. There is arsenopyrite here also, with asbestus and crystals of feldspar. Portions of the wall rock are hornblendic. At the south base of the mountain is a westerly dip, and the rocks on the slope are both ferruginous and fibrolitic. Ferruginous ledges appear with westerly dips at W. H. Hutchins's saw- and grist-mill, north of J. M. Waldo's, and at the school-house by the cross-roads at D. White's, dipping 50° N. 65° W. Between this point and L. Locke's all the ledges are ferruginous. This is a particular band extending into Francestown from Mt. Misery, just north-west of the soapstone. Its place would seem to be near the school-house just named, where a little of the same rock has been found. The fact of three localities of this rock along a line just bordering the ferruginous band should be remembered in further explorations. At the town farm in Weare the ferruginous schists dip 50° N. W., and also in the east part of Deering, interstratified with hard schist. The formation extends to the Lake gneiss.

The Francestown soapstone is one of the most important beds of this substance quarried in New England. It is known to be four hundred feet long and forty feet wide, seems to be free from horses, and is all of good quality. It dips N. W. 60°, and has been excavated to the depth of one hundred feet. Mica schist is found on the south-east side. At Francestown village ferruginous schists dip north-west, and also half a mile north-west of the turn of a road to Deering. The whole of the eastern part of the town is composed of the same material. Near the south-east corner it is compact and twisted. At S. Duland's, near the Greenfield line, the dip is 50° N. 85° W. Ferruginous quartzite crops out at the south-east end of Haunted pond, with the strike N. 57° E., and vertical strata. The same is true of the rocks at S. Langdell's, in the west part of New Boston. Between this point and S. & J. P. Todd's, the white feldspathic rock described in Canterbury and Hopkinton makes its appearance. At times it resembles a conglomerate. With it are gray quartzites, and soft, talcy strata resembling soapstone. The ferruginous rocks of this series make a branch into New Boston from the main range, and are believed to extend as far as the lenticular drift hills on both sides of J. Cochran's. South-west from Francestown the ferruginous band occupies the space between the Rockingham schists of Lyndeborough and Temple mountains, on the east end of the gneissic areas to the west, perhaps extending into the north edge of Peterborough. The mica schist at the south end of Cragin pond, Greenfield, dipping 85° S. 50° E., may belong here. On the north-east side of Pollard pond ferruginous mica schist dips 70° N. 30° W. The short Henniker and Warner range is obviously a repetition of the longer bands, while that is folded in Weare, and probably also in the east part of Francestown, in connection with the spur running into New Boston. The similarity of the rock to the Rockingham series is quite obvious, especially if the feldspathic beds may be the equivalent of those in Londonderry, etc. The presence of the soapstone may be a still better band of union. Boulders of soapstone occur in Pelham, and a short distance over the Massachusetts line, in Dracut. They are of large size. I have also seen specimens of the rock from Island pond in Hampstead. These fragments must have been derived from the Merrimack or Rockingham group, from some ledge north of the localities of the boulders, perhaps the continuation of the Groton range.

CHAPTER VII.

GEOLOGY OF THE LAKE DISTRICT.

THIS is the smallest of all our areas of description. It properly embraces the hydrographic basin of Winnipiseogee lake, the flat country to the north, and the rest of the territory as far as the state line of Maine. There is a large tract in Maine represented upon the map, chiefly of Montalban rocks; and the extremely few facts concerning them in our possession would properly be noted here. For convenience, I will include the whole of the porphyritic gneiss of the Squam Lake region and the Montalban and Moose Mountain granite areas lying partly in the Coast district. I will leave out a very inconsiderable tract of mica schist in Alton. Thus limited, we have only three stratified groups to sketch: 1. Porphyritic gneiss. 2. Lake gneiss. 3. Montalban. The eruptive rocks are more plentiful and varied, consisting of 1. Conway. 2. Albany. 3. Chocorua granites. 4. Porphyry. 5. Pequawket breccia. 6. Labradorite diorite. 7. Sienite. 8. Granite, not allied to any of the foregoing.

1. Porphyritic Gneiss.

The principal area of this rock has the shape of a fish-hook. It comes out of the White Mountain district into Sandwich and Ashland, makes its principal curve in New Hampton and Meredith, and runs to the point just south of Squam lake, while the barb takes a course east of south through the east part of Meredith, and crops out occasionally along the west shore of Lake Winnipiseogee. On the north-west side are two small areas, one of which, Mt. Prospect in Holderness, is the culminating point; and the other extends from the north corner of Sandwich into Waterville, occupying the north flank of Sandwich Dome. A third occurs at J. H. Calder's, in the southern edge of Thornton. There is but a single outcrop, dipping 20° S. 50° E. The Montalban of the Dome is probably an overlying mass in the porphyritic basin. The range in the north-west part of Sandwich exhibits in a section a fan-shaped structure. The dip of these rocks on the south-eastern slope of Squam mountain, in the north-east part of Holderness, is north-west. Taking the road over this range, the hard, ferruginous schists predominate, dipping north-west. Section VI crosses this formation, and also shows the fan-shaped structure. South of Little Squam lake in Holderness is almost a mountain ridge of this rock. We find a north-west dip at J. Weeks's in the north part of New Hampton; a mile south, towards Shaw's hill, the dips are S. 25° W. and N. 50° W. On the ridge between Shaw's and Beech hills the feldspar crystals do not lie in any uniform plane. Schist intervenes before reaching the stream to the south; and at J. H. Harper's the porphyritic rock dips easterly. By H. Harper's, on the north flank of Harper hill, are dips of N. 50° W. and S. 30° W. Westerly dips prevail along the west border of the formation towards New Hampton centre. From this village, for two miles towards Meredith, is the most beautiful display of porphyritic gneiss I have ever seen. The crystals of feldspar are of large size and very beautiful. Other ledges occur in New Hampton near the railroad, but I have not preserved any record of their dips. The western border of the formation assumes a south-east course beyond New Hampton centre, reaching Great bay in the town of Sanbornton. The rocks on the hills overlooking the bay are interesting, on account of the perfection with which the twin crystals of feldspar are displayed, and also for bunches of a mineral like fibrolite disseminated through the ledges. On the west side of Randlett's pond the dip is 75° N. 60° W. Between Meredith centre and the south line of the town is a rich profusion of porphyritic ledges. At the road crossing the outlet of Pickerel pond the rock dips westerly. West of this pond is a crystalline trap dyke, ten feet wide, exposed for one hundred feet, with a north and south course. The feldspar crystals in the north part of Laconia have the direction N. 70° E., and these are supposed to indicate the course of the strata. The rock crops out in several places as far as to the cemetery close by the north end of Round bay. We see it again on the point and hill back of the Wiers station. It is the only rock seen between Wiers and Meredith Village. On Wadleigh's hill are two large veins of quartz,—one, on the summit, a foot wide, with a north and south direction; the other of double width, nearer the lake, and showing decomposed ankerite and dolomitic crystals. Both are vertical, and traceable for half a mile. There are several exposures of this rock between Meredith and Lake villages on the nearest road. The outcrops at the former village dip north-west. At S. M. Lawrence's, west from the Centre, are ledges of hornblende rock—an unusual occurrence in this formation. On the east side of the north-west cove, ledges of porphyritic gneiss are abundant all the way to Spindle point. Rollins hill, the highest land on the Neck, is composed of a hard schistose rock, peculiar to this formation, dipping 80° N. 65° W. The middle ridge of the Neck shows porphyritic gneiss back of W. Mead's. This is the eastern limit of the rock. Stonedam island would naturally belong to this group. This rock occurs on the high land west of Little pond, and near B. G. Young's on the high land to the north. On top of the hill west of the Center Harbor landing this rock appears in not very great amount, perhaps three fourths of a mile wide. There are two important localities in Center Harbor,—one at the extreme south end of Squam lake, by an old saw-mill, the other on Sunset hill. All the ledges here dip northerly.

The barb of the fish-hook is to be found in the country south of Meredith Neck. I have not examined Pitchwood island, but Eagle island, a mile off Wiers landing, is composed of porphyritic gneiss. The same is found at the south end of Governor's or Davis island, dipping S. 85° E. The north end of Gilford is underlaid by the same material, and probably the area of Smith's Neck. Adjacent to the northern end of the Belknap range the porphyritic gneiss dips 75° N. 80° W. Welch and the other islands opposite have not been explored.

About three miles from Alton Bay landing, on the west side of the water, is a mass of porphyritic gneiss, intercalated with the other variety, dipping west. The high land bordering the water may contain considerable of this material. It also occurs on a cross-road at J. P. Gilman's, with sienite. An area known to be longer occurs between Avery hill and

Pine mountain. The line of junction between the gneiss and sienite is a perpendicular seam running east and west. The dip of the gneiss is east. The gneiss occupies the lower ground, the sienite the hills adjacent. There is a possible additional locality of this rock in New Durham.

The most remarkable feature of this range is its singular double curvature. So far as our observations extend, it seems to be a real bending of the strata, rather than an accidental uncovering of an older unconformable formation by the abrasion of the superincumbent groups. The latter have been involved in the bending and overturning, and it is a significant fact that the Lake gneiss within the folds of the hook does not come up again on the west side in Ashland. Were the fan-shaped stratification along Section VI a synclinal, as a slight examination might suggest, then the Lake gneiss should reäppear in the Pemigewasset valley. That it does not, confirms the truth of our theory that the porphyritic gneiss is the oldest.

2. Lake Winnipiseogee Gneiss.

This formation has been so well defined already that it is unnecessary to speak of its particular character in the region where it was first recognized. It has stratification not easily recognized, occupies low ground, occurs in embossed ledges, showing striæ wherever disintegration has not been too rapid, and is traversed by numerous segregated veins. These features are suggestive of Laurentian age. I have in the first chapter called the formation "Atlantic," signifying a period intermediate between the Laurentian and Huronian. I shall not find fault with any who seek to refer it to a still older period. The general course of the area occupied by this gneiss is north-west and south-east, and it corresponds very nearly with the direction of Lake Winnipiseogee. There is a branch on the west, leading southerly to Meredith, and a widening of the territory occupied at the Maine boundary line. The extreme length of the area is thirty miles; average, twenty-two and one half; average width, eleven: total dimensions in square miles, about two hundred and sixty. The following are our principal observations respecting the position of strata:

Sandwich.

At A. F. Irving's, beyond North Sandwich.

Between North and Centre villages, many ledges on both roads, usually vertical, with strike N. 60° E.

At M. Bean's, and all through west part of town, dip north-west, nearly vertical.

Near Hart's saw-mill, north-west part of town, 72° N. 70° W.

One mile south-east of last, dip south-east.

On Israel's mountain, dip northerly.

Near J. D. Cook's, with quartz, strike N. 30° E.

At S. Dinsmore's, next sienite, dip south-east.

Tamworth.

At South Tamworth, 45° N.

At N. Locke's, near west line, 55° W.

Moultonborough.

East side of Round pond, M. Hutchins's, 80° S. E.

At T. S. Adams's, south of sienite, 60° S. 60° E.

South side of Long pond, 60° S. 60° E.

East base of Sunset hill, 80° E.

Half a mile east of landing, Center Harbor, J. Graves's, 85° E.

Near stream at Centre village, dip westerly.

At A. B. Hoyt's, 80° E.

Between P. Brown's and H. Thompson's, 55° N. W.

At H. Smith's mill, 45° N. 85° W.

Center Harbor.

Near M. Wade's, promontory of Squam lake, dip south-east.

East of J. G. Thompson's, dip westerly.

West of Bear pond, 80° S. 50° E.

East side of Long pond, dip north-west.

Abundant between Long pond and Meredith Village, dip north-west.

At J. W. Paine's, south line of town, north-west.

Holderness.

East base of Shepard's hill, anticlinal line, north-east and south-west.

Meredith.

Back of H. Bedee's, north of village, 70° N. 80° W.

Near W. Jenness's, near town line, 70° north-west.

Near Advent church on Neck, 65° N. 50° W.

At chair shop, near J. Quimby's, N. 70° W.

At Meredith centre, dip west.

West side of Lake Wukawan, dip westerly.

Tuftonborough.

At Tuftonborough corner, dip north-west.

Near S. McIntyre's, 70° N. 85° W.

At Tuftonborough Neck village, dip W.

At "Canaan," vertical, strike north-east and south-west.

Islands in Lake Winnipiseogee,

On Sandy island, east end, 85° E.

On Long island, south-east point, N. 85° W.

On Jolly island, east and north sides, 60° S. 80° E.

On Mark island, south-east dip.

On Governor's island, north end, 50° E.

Wolfeborough.

Near N. Brewster's, dip north-westerly.

Same towards Smith's pond.

Near G. W. Nute's, dip east.

At Porcupine ledge, near North Wakefield, 70° N. 80° W.

Quartz at the same, 70° N. 60° W.

Alton.

At West Alton, dip west.

Near H. Hunt's, east of bay, 80° E.

Brookfield.

North corner of town, dip north-west.

Wakefield.

At S. Cook's, dip south-east.

Quartz at L. C. Perry's, dip 80° N. 50° W.

At N. H. Cook's (Peavey place), 15° W. (limestone).

Quartz near foregoing, dip N. 60° W.

Near D. W. C. Wentworth's, dip north-easterly.

Ossipee.

At Samuel S. Fogg's, small southerly dip.

Quartz, at O. Sanders's, strike N. 50° E. 90°.

On Pocket hill, dip north-westerly.

Some of these dips are embodied in a section from Hart's saw-mill in north-west Sandwich to the west base of Ossipee mountain (Fig. 104). The strata generally run north or north-east, so that they do not conform to the direction of the area as it is laid down topographically. The inference from this fact would be that it may continue indefinitely, both to the north-east and south-west, underneath the adjacent Montalban. These observations show the presence of several axes. The Meredith branch gives mostly north-westerly dipping monoclinal strata, as would be expected from the inverted position between walls of porphyritic gneiss. The anticlinal at the east base of Shepard's hill cannot be of much consequence, unless it be proved more extensive. The Sandwich dips are so nearly vertical that folds may be numerous. There seems to be a synclinal west of the quartz; one for the sienite of Red hill; another along the west base of Ossipee mountain; and one strongly marked at Moultonborough centre. Anticlinals appear west of Long island and through Wolfeborough. The long fiörd of Alton bay is situated upon an anticlinal. Between Tuftonborough corner and Canaan it seems like a synclinal. Fig. 105 will show these axes in a section crossing the whole area at right angles from Sandwich to Wakefield.

I will mention a few points of interest in these several towns. At C. F. Hawkins's, Center Harbor, this rock carries a five-foot vein of porphyritic granite. At C. Chase's, on the line between Meredith and New Hampton, small crystals of feldspar are scattered through the rock. At South Tamworth the rock is like the Bethlehem gneiss, including a hard siliceous layer. The strata are highly siliceous and ferruginous in the extreme west part of Sandwich, and this formation extends only a little way into Holderness. At the east end of Sandy island is a vein of very coarse granite, with large crystals of feldspar. At the south-west corner of Long island and on Mark island are numerous beryls. Trap and other dykes occur at the following places: Irregular trap dykes, with very pretty, small granite veins, at S. McIntyre's, Tuftonborough; small trap band on Jolly island; one four feet wide at Canaan; dyke of hornblende and feldspar fourteen feet wide, seen for twenty rods, on the east side of

Lond pond, in Meredith, with course N. 30° E.; trap, west of S. and S. Fogg's, Ossipee; near Wolfeborough village and other places.

The quartz bands of the Manchester gneiss occur here, also, though they have not been traced out so carefully. As they extend but a short distance, they cannot be expected to be so well developed. It is possible that two of the ranges seen in the Lake district are the natural continuation of those in Hillsborough county after their emergence from the mica schist blanket, and beyond the eruptive mass of Moose mountain. An examination of the map will show that the Hooksett and Manchester bands might correspond to these in Strafford brought up with the gneissic island, then, submerged again, turning to run more northerly, and reäppearing in Wakefield and Effingham. In Wakefield the eastern range is one hundred feet wide at L. C. Perry's, midway between Wakefield and East Wakefield stations. There are also signs of the quartz at B. Drew's. At the Peavey place (N. H. Cook's) limestone just like that in Amherst, with similar associated minerals,—epidote and molybdenite,—overlies the quartz, dipping to the north-west, exposed in a ledge twelve feet wide. Inasmuch as the related rocks here agree in mineral contents and position, we have reason for believing this is the Manchester band of quartz prolonged into the Lake district. It may be the same with that on the town line close by Province pond. To the south there is a similar band, to be mentioned under Montalban, on the north side of Lovewell's pond, which occupies very nearly the place of this range, but is a superior formation. The Hooksett range appears on Porcupine ledge, near North Wakefield, in the east corner of Wolfeborough. The quartz is more than a hundred feet wide, lying somewhat to the rear of the precipice. It may be traced for several hundred feet in length, and dips north-westerly; so that both ranges are inclined in the same direction. It is said there is a ledge of quartz at C. Hodgdon's in Ossipee. I have not been there, but it is exactly on the line from the Porcupine ledge to Pocket hill in the east part of the town. At O. Sanders's it runs up hill, being vertical, in the direction N. 50° E., and it is fifty or sixty feet wide. It has been explored by miners in search of the precious metals. There are indications of the continuance of this range at B. H. Emerson's and J. Leavitt's, 2d, in Effingham. The boulders are almost large enough to be called ledges. These two bands have been converging. Those in Wakefield and Wolfeborough are three, and these near Province pond but one mile apart. Those who come after us may find the extension of these bands in Maine, Effingham being the border town of our state.

The limestone of Wakefield deserves a further notice. It is a siliceous rock of peculiar appearance, from the presence of a green mineral, perhaps pyroxene. Its stratigraphical place being known, great interest will be attached to other localities where the associations are somewhat different. In Brookfield, near the "corner," are large quadrangular blocks of this rock, looking as if they had not travelled a hundred feet from their source. There is a siliceous rock resembling this in color, dipping 60° W., at A. Berry's, west of Cook's pond. A related ledge at J. Perkins's, a mile east of the corner, dips 40° N.; a mile south-west from the village of West Newfield, Me., small boulders of this rock are very numerous. There is a limestone bed at the Davis mine, on the east side of Balch pond in this town, which is of this material. In Acton it is quite characteristic, dipping 5° S. W. a mile west of the south end of Manson pond, and is associated with gneiss. Near school-house No. 10 of Milton the blocks are sufficiently numerous to inspire a belief in the existence of a ledge near by. I think the limestone beds described by Jackson in York and Oxford counties, Me., may be of this same variety; and further study may eliminate interesting facts concerning their stratigraphical distribution.

There is a peculiar granitic rock occupying a portion of the east rim of the Winnipiseogee basin. Batson and Trask hills, and Whiteface and Cotton mountains, along the east line of Wolfeborough, are composed of it; and on the continuation of the ridge near J. Jenness's in the same town, at the church on the high land east of Cotton Valley station, and on the hill north of Cook's pond in Brookfield, similar rocks occur. It curves from a south-east course, and runs southerly towards Cropple Crown. I have esteemed the material as gneiss, and have not distinguished it upon the map separately from the Lake group. I have not been able to find marks of stratification in it, though diligent search has not been made for them. The occurrence of this rock along a line of hills suggests a possible connection with the Mt. Bet series of granites in New Durham. The east sides of Whiteface and Cotton mountains are precipitous.

3. Montalban Series.

The Montalban rocks of the Lake district may be grouped in two areas: first, those occupying the north-east portion of the territory; second, those encircling the Moose mountain eruptive rocks, lying partly in the Coast region, but described here for convenience. We may group the dips as follows:

Sandwich.

On Guinea hill, 52° N. 53° W.
At Weed's mills, 50° N. W.
Near L. C. Clark's, east line, 55° S. W.

Tamworth.

At W. Cushing's, N. 30° W.
On Stevenson's hill, near West line, north-west.
At Tamworth centre, westerly, small.
At South Tamworth, 30° southerly.
One mile east of South Tamworth, 50° N.

Madison.

Near John L. Frost's, 60° N. W.
At Lead mine, 60° N. 75° W.
At L. Long's, 60° W. to N. W.
Farther east, S. 65° W.

Effingham.

Near A. W. Drake's, 70° S. 70° E.
At W. Rumney's mill, 80° N. 85° W.
At south-west corner, N. 70° W.

Tuftonborough.

At J. Bean's, east corner, 50° N. W.
At T. Durgin's, near corner, west.

Freedom.

At village, 75° W.
East part, westerly.
At E. Wood's, West Freedom, 50° W.

Ossipee.

At Water village, 60° N. W., contorted.
One mile south-west of court-house, 30° N. 85° W.

It is surprising to find the Montalban rocks over so large an area as is indicated by these figures, possessing monoclinal dips. In rocks at the north base of the Ossipee mountains are evidences of anticlinal structure, but in a gneiss greatly resembling the Bethlehem group. In Effingham, on the south side of a large intrusive mass, are synclinal dispositions, but everywhere else the inclination is uniform. To understand this arrangement we have to resort to the supposition of extensive inversion, as has been already explained (p. 253). The great central anticlinal of Fryeburg, Me., does not, however, make its appearance through Eaton and Madison, as would be the case if the rock in the Lake district conformed to those farther to the north-east. It may pass a little more to the east, and manifest itself in the Green Mountain granite of Effingham.

A few points require special mention. At Weed's mills, Sandwich, the gneiss is a little like the segregated variety, with interstratified ferruginous bands. Across the north part of this town, and the north of Tamworth, no ledges appear, everything being covered by drift. Since the preparation of Plate XII I have thought best to connect this North Sandwich area with the outcrops on the Chocorua range (p. 133), eliminating the intermediate granite, thus located in consequence of a misunderstanding. This gives us an area twelve miles long and from two to three wide, possibly isolated from connection with the principal part of the formation. We can easily understand that this may consist of a folded synclinal, separated from the Tamworth exposure by an inverted anticlinal. At L. C. Clark's, andalusite is present in the ledge, and there are two small trap dykes. On Stevenson's hill, in Tamworth, the rocks are indefinite,—granitic, gneissic, and ferruginous. At T. Perkins's, north of the Iron Works, is a coarse granite vein. Between the two Tamworth villages are gneissic outcrops, whose dips are not recorded. At W. Cushing's, the ledges are mostly of the granitic varieties. The east part of Tamworth and the west part of Madison abound in high, isolated hills, mostly of a granitic variety of the Montalban series, where stratified planes are scarcely recognizable, yet the Montalban character of the material is evident. Chatman hill contains much coarse, indigenous granite. At J. Lyman's, on the south-west side of Hedgehog hill, Madison, is a granitic gneiss. Pine hill is probably composed of the same material. There is a granitic rock at N. Snell's, in Tamworth, nearly two miles west. The same, with ferruginous rock and trap, is repeated at the school-house on the north-east corner of the town. The hill south-west from Whitton pond, in Madison, is composed of Concord granite, with jointed seams dipping 60° N. W. The north-west side of this hill is precipitous. The hill a mile and a half east of this is thought to be composed of similar material.

The east part of Madison is separated by a broad valley from the west, just considered; and the stratified schists take the place of the Concord granites. Very few observations have been made in this region. At L. Long's and farther to the east the strata are variable. Some of the finer-grained mica schists are traversed by segregated veins, and weather like the siliceous limestones of eastern Vermont. The usual dip through the town of Eaton is 50°–60° W. The rock at the old lead mine in Madison, formerly Eaton, is largely composed of silica. On the east side of White's pond, in Tamworth, Dr. Jackson visited an excavation for lead mining in a "solid vein of reticulated and compact jaspery quartz rock." This suggests the possible existence of one of the Hillsborough county bands of quartz. Two miles north of "Atkinson's tavern" Jackson found an interesting assemblage of igneous rocks. They were dykes of a "singular porphyry, having a greenish, compact feldspar base. The porphyry dykes cut through a hill of granite composed of a pure white feldspar, quartz, and bright transparent mica. Porphyritic granite also abounds in the vicinity. These dykes, from ten to sixteen and a half feet wide, traverse this rock, and run in a N. 70° E. direction. One of the dykes contains carbonate of lime in sufficient quantity to produce rapid effervescence with acids. It contains, also, crystals of hornblende, epidote, and feldspar." Iron and copper pyrites in small amount occur in one of these dykes. At Freedom village I found large boulders of a peculiar sienite, which has not yet been seen in place. In the east part of the town are occasional eruptive masses of a porphyritic granite like that composing the bulk of Green mountain in Effingham. Near the Maine line the dip is 15° S. 80° E. At the north end of Ossipee pond the dip is 45° W.

The Southern Area. This seems to be a belt two or three miles wide surrounding the eruptive granites of Moose, Cropple Crown, and other mountains on the borders of Carroll and Strafford counties. In the east part of Wakefield there is an anticlinal, with the ridge near T. Chapman's, where the rock is a micaceous gneiss, with coarse granitic beds, and the dip is 15° S. E. At the outlet of Newichwannock pond the dip is 25° in the same direction. The rock is cut by trap dykes carrying calcite, dipping north-west, also by large granite veins. The opposite dip appears on Brackett's brook, a tributary of Lovewell's pond. Here is a quartz band, also, adjacent to gneiss, inclined 75° N. 70° W.; and another half a mile north. On top of the hill south, near J. Copp's and the town line, ferruginous and mica schists, dipping 25°–30° S., are cut at right angles by granite veins several rods wide. Similar rocks at N. Kimball's, a mile east of the Branch river, have a strike east of north. Between the Junction and "corner" the schists dip 50° N. 10° E., with granitic layers. At Union Village, typical Montalban schists and granite dip 12° N. 40° W. Nearly three miles to the north, by E. P. Gilman's, hard granitic beds dip 80° W.

Tumble-Down-Dick and Mt. Delight, in the west part of Brookfield, show the Montalban schists well, dipping 50° N. 85° W., and 85° W. near R. H. Piper's. The range crops out to the north-east on the Wolfeborough line, dipping 45° N. 80° W.; also at D. F. Stoddard's the mica schists dip 14° N. 85° W. At J. Goodhue's, Brookfield, is an irregular granitoid rock, with trap. On the north side of Cotton Valley station are ferruginous schists, inclined 50° W., about one fourth of a mile wide. At the northern base of the granite mountains, in Brookfield, ledges are scarce; but there are mica schists at G. W. Chamberlain's. These facts show the development of the Montalban rocks between the granite range and the usual Lake gneisses near the Wolfeborough line, and a decided anticlinal in the east part of Wakefield. The variations in the angle of the dips in Wakefield suggest the presence of a synclinal.

Along the line of Section V there seems to be a synclinal in Middleton,—there being a dip of N. 20° W. near J. B. Stevens's and at Mrs. Gibbs's. The easterly dip appears at a "mine" a mile west of the road. The veins there are of coarse granite, containing the minerals mispickel, tourmaline, mica, and feldspar crystals. An anticlinal follows, as there is a south-west dip of mica schist and granite in the east part of New Durham, where the road crosses the Cocheco river. The change to a northerly dip is seen at a mill at New Durham corner and at G. D. Savage's, a little north, 80° N. 5° E. On the north side of March's pond the mica schist is full of granite in its crevices. The dip changes from other easterly observations to N. 30° W., and back to N. 10° E., before coming to Merrymeeting lake. After passing the granite, dips somewhat northerly prevail through Alton to the lake. The rock on this route is therefore full of subordinate undulations. Towards Gilman's pond in Alton the dip is 45° N. E. There are sienitic beds a short distance west of Alton bay.

Eruptive Rocks.

These are finely displayed in the Lake district. Perhaps the southward extension of the Chocorua group into Tamworth has been already sufficiently mentioned in Chapter III. There is also a large ledge of Albany granite in the south-east corner of Thornton. Besides that, there are four important eruptive areas: (1) of the Ossipee mountains; (2) Moose mountain, etc.; (3) Red hill and Gunstock; (4) Green mountain. No two of these areas resemble each other at all, and each one constitutes a mountain mass.

Ossipee group. We find this is an elliptical mass, nearly round, a little more than half composed of porphyry, with a narrow belt of Albany granite on the west side, a considerable tract of Conway granite in the east, and the Pequawket breccia on the north-east. The porphyry is better developed here than anywhere else in the state. It is partly brecciated and partly stratified, like a clay slate without very many cleavage planes. An excellent place to see this rock is near the hamlet east of South Tamworth, half a mile up the mountain's side, where some have fancied there might be coal. The rock is a fine, compact fibrolite, with occasional black seams resembling bony coal, dipping 15° S. 20° W., or into the mountain. Drift conceals most of the ledges at the north base of the mountain, but the slaty band crops out a mile west of the "coal"-opening, at the end of a spur. On following up the valley south from the village of South Tamworth we find slates, felsites, and breccias at Thompson's shingle-mill, mostly dipping west. Epidotic seams and bunches are plentiful. Above N. Johnson's, compact, dark felsites have vertical seams, with a north-east strike. The mountain south has not been visited. At Ossipee falls, on the south side of the mountain, is a fine display of these black and spotted porphyries. The joints at the top of the falls dip south-east, in a reddish rock. The lowest slate seen is black with greenish spots, inclined 25° N. W. The ridge south of Canaan is a coarse gray felsite. North of Dan Hole pond a steep hill is composed of a black, spotted felsite, with joints dipping 60° N. 25° W. We also find felsite a mile south of Bear Camp river, just in the edge of Ossipee, in the valley north of Mt. Whittier. The peak east of Mt. Whittier shows brecciated porphyry, while the principal mass is a spotted granite containing slaty fragments, thus resembling the Pequawket rock. Jointed seams run N. 40° W., dipping N. 50° E. The smaller eminence just against West Ossipee station is composed of breccia, some pieces of slate being two feet long. Some ledges consist of a jumble of masses of the dark porphyry, almost too large to be styled a breccia. Above the "coal mine" is a breccia, where the pieces are of small size, and the cementing material, almost like trap, constitutes the principal portion of the rock. It commences perhaps one hundred and fifty feet above the mine, and is believed to extend to the top of the mountain. It is also seen farther west, on a path used for climbing the mountain.

A strip of Albany granite has been noted upon the west side of the area. From the top of the western spur, next South Tamworth, Prof. Vose brought specimens of this granite. On climbing the mountain from N. B. Hoyt's, on the line between Moultonborough and Sandwich, we find this rock in its relations to others. First is the Lake gneiss, dipping 80° E.; then the porphyritic or spotted granite, about one hundred feet thick. This is covered by a black felsite, perhaps two hundred feet thick, and that in turn is capped by a breccia. The Albany rock is also found farther south, near the Ossipee falls. On the east side we find it north of J. Hobbs's, nearly a mile west of Ossipee lake; and on the road up Lovell's river into the very heart of the mountains, the rock is rather intermediate between the Conway and Albany varieties. There may be some of this rock on the north side of Mt. Whittier.

The Conway granite is also conspicuously present. From the house of S. C. Abbott, a mile south of Moultonville, to the end of the road under the highest Ossipee mountain, this variety predominates in all the ledges. It is well seen on the ridge north of Moultonville. I understand that this variety underlies the Albany, as in the White Mountains. For this reason, and also because large blocks of the latter are common about the lower end of Dan Hole pond and other places on the south-east side of this area, I anticipate the discovery of the Albany rock in place in Ossipee. Near J. Hobbs's are large boulders of a very interesting labradorite porphyry. Nowhere else has anything been found that shows the labradorite crystals so finely. It is probably in place on Mt. Whittier. This area affords an excellent opportunity for the study of these eruptive rocks, since it is comparatively small, easily accessible, and what I have done can hardly be dignified with so full a title as a *reconnoissance.*

The Moose Mountain Area. This lies between the counties of Carroll, Strafford, and Belknap, occupying, in order from the east, Parker, Bald, and Moose mountains, Mt. Major, Cropple Crown, Mt. Molly, Devil's Den mountain, Mt. Bet, Birch hill, and Mt. Eleanor. Moose mountain is largely a felsite, passing into sienite. It is everywhere fine-grained, and reminds one slightly of the Albany granite. The very summit is composed of a fine-grained granite. The ascent was made from the north side. Near the end of the road, at the south base of Parker mountain in Middleton, the same rock occurs. Next, on a trip from Wolfeborough to Middleton, I found a fine-grained granite just to the south of the Lake gneiss, near Rust pond, containing large spots of hornblende. A granite, quarried somewhere in the southern part of Wolfeborough, resembles the Concord very much superficially, but it splits and breaks more like the Moose Mountain rock. Through the north part of New Durham a red granite predominates. At the south end of Cropple Crown it is somewhat like the finer variety of Conway granite found about Mt. Nancy. I think it is rather coarser on the east side, and this mountain may be regarded as a granite. Very pretty banded traps occur in this granite. There is one much coarser from a large hill north of Mt. Bet. From Mt. Bet and the region east comes a similar red, crumbling granite, not unlike that comprising the Profile in Franconia. These hills are sugar-loaf shaped, crumbling down in the usual type of granitic decomposition. Birch hill is sienitic, as indicated by loose blocks at its base; and Mt. Eleanor, for a like reason, may be said to be composed of a fine-grained, reddish, normal granite. It has about the grain of the Concord granite. This whole eruptive mass is therefore quite unique, and well worthy of further study. It is over eight miles in length. Merrymeeting lake is very prettily situated near its southern extremity. The granite seems to prevail at the western, and the hard feldspathic and hornblende varieties at the east.

Gunstock and Red Hill. Two areas are alike in composition,—the Red hill in Moultonborough, and the Belknap mountains. These are all true sienites. The first is only three miles long. It is composed of two summits, the most northern being the highest, and is much visited for views, as it rises conically from quite a plain. The rock is a genuine sienite, abounding in hornblende. Some ledges show the hornblende as conspicuously as the coarse granite veins of Cheshire county carry their tourmalines. Two kinds of feldspar prevail. All these eruptive rocks will be very carefully described by Mr. Hawes, in the mineralogical part of this report; and I will content myself with mentioning their general occurrence and relations to the stratified rocks adjacent. Vertical joints, with a north-eastern strike, cut through Red hill. The junction of the sienite with the gneiss may be well seen at the north end of the mass. To the south of S. Dinsmore's in Sandwich, the gneiss dips 75° S. E.; and the sienite rests upon it at the same angle. Joints dipping 5° N. cut both rocks. Dykes of crystalline compact feldspar, three feet wide, cut the gneiss at a considerable distance from the sienitic mass. Back of S. Smith's, in the north-western part of Moultonborough, the joints in the sienite run north and south, and stand vertical. At M. Hutchins's, on the east side of Round pond, the two rocks seem to meet on the stratified plane of 80° S. 85° E. At the south end of the hill the junction of the two rocks is concealed by drift; and the dip of the gneiss is uncertain. At Moultonborough centre the gneiss is hornblendic, and it is believed to dip westerly. Many of the ledges at the west base of Ossipee dip west also. That would indicate that the Red Hill sienite came up through a fault along a synclinal line. I have a suspicion that the conical mountain just in the edge of Holderness, on the north shore of Squam lake, will prove to be composed of sienite.

The Belknap Area. This lies in Gilford, Gilmanton, and Alton. It is eleven miles long, and six miles in its greatest width, the general direction being parallel to the lake. The most northern exposure is opposite Thompson's island in Gilford. It comes in contact with the porphyritic gneiss, and it is more fine-grained than usual, full of dark hornblendic spots, and brecciated. On the beginning of the mountain range, a mile and a half south-west and back of J. Smith's, the rock is coarser. The northern of the two most conspicuous peaks, directly east from the house of N. Weeks, shows a rock of the texture of the Quincy, Mass., rock. Joints on the summits dip 75° N. 20° W., and also south of east. There is trap dyke there, also, ten feet wide, with the course N. 65° W. Small, reddish feldspathic veins are common. Part way up on the west side is a vein of magnetic pyrites occupying one of the vertical fissures. Green augite occurs on the mountain at some forgotten locality. The gneiss dips 50° S. at the western base of the mountain, with joints, 85° S. E., which may possibly be taken for strata. As the gneiss in West Alton dips westerly, it is likely the Belknap sienite has been exuded through a synclinal fault just like that of Red hill.

The road from Gilford across the mountain to West Alton shows a fine-grained, brecciated variety of the rock at J. J. Morrill's, where the west edge is touched. At M. M. Potter's it has the average coarse texture. At M. Leavitt's, at the crossing of the road by the brook emptying into the lake, is a very coarse and singular breccia, requiring further examination. The coarser sienites occur as nodules in a rock resembling trap, and the jointed planes dip westerly. A climb to the pond on the ridge south of Gunstock mountain shows the fine-grained variety predominating on the way up, and also on the mountain to the east. Between the water-shed in the road to West Alton and M. Leavitt's are several of the brecciated outcrops. A climb of the south end of the mountain shows us ferruginous mica schists and indigenous granite, and next the sienite indurated schists dipping 80° N. 35° W. towards the south-west spur of the former rock. The rock of the mountain is like that on the northern peak, just described, and with similar accessories. The rock has a reddish cast. Joints cut each other vertically, running north-west and north-east. The summit rock is somewhat porphyritic, from the presence of feldspar crystals. The sienite was not reached till we passed up Mt. Straightback in Alton, at some distance beyond the end of the carriage-road. In a large ledge one can see the sienite and porphyritic gneiss joining each other. Avery hill is of sienite. Quite a large piece is taken out of the sienite area here by the presence of porphyritic gneiss and mica schist. The junction of the first with the sienite is well shown between Avery hill and Pine mountain. The line of junction is vertical, running east and west. The latter summit is probably of sienite, but has not been visited. The two Rocky mountains are composed of the ordinary variety of sienite. With them the rock terminates, and the country becomes comparatively flat. The Rocky and Pine mountains, with Avery hill, constitute a semicircular ridge like the half of an amphitheatre. The best part of this sienitic area is away from the travelled roads, in the forest country, so that the facilities for its understanding are not good. Diamond island, in Winnipiseogee lake, is made up of a fine-grained sienite; and it is presumed Rattlesnake island is composed of the same material. Scarcely any of the islands at the south end of the lake have been examined.

The Red Hill and Belknap sienites obviously belong to the same age, as they are so much alike. They are both very free from admixture with granites. The Tripyramid and Jackson sienites are to be allied with them rather than the Exeter or Quincy, and they are unlike the Chocorua series. Opinions as to the comparative antiquity of these several eruptive rocks cannot yet be suggested with any probability. They occur in the midst of Lake and Montalban gneisses, while the granites have disrupted andalusite slates.

Green Mountain Area. This is a little over four miles long and two wide in the north part of Effingham. The prevailing rock is a porphyritic granite, the feldspar crystals usually not exceeding half an inch in length. I have seen this variety of rock for three miles along the southern part of the area. Judging from this circumstance, and from the abundance of large blocks dispersed by drift in the neighboring towns, I have concluded the whole mountain might be composed of the same material. I have found the Mt. Bet granite on the north side, at the ice cave. What the material is upon the very summit can be ascertained only by actual visitation. There are no schists cropping out adjacent to the granite on the northern half of the area. A ferruginous mica schist at A. W. Drake's, upon the south side, dips 70° S. 70° E. This makes an anticlinal axis with the nearest ledges to the west, in Ossipee.

Rocks in Maine.

The geology of quite a wide tract in Maine is presented upon our sheets, opposite the three northern topographical districts. No geologist has ever traversed the north-east portion of the northern sheet. It is from the most meagre data that the delineation represented is based. On the Magalloway river, specimens have been obtained of both the Lyman and Lisbon groups of the Huronian. Mt. Eziscoös and the neighborhood are genuine granites. There is believed to be a considerable area of the Lake gneiss in Andover and westward. To the south the great bulk of the formations consists of the Montalban series in its various forms. There is a greater development of this group in Maine than in New Hampshire.

One of the most interesting areas of igneous materials in Maine is the trachytic rock of Mt. Pleasant, in the towns of Bridgeton and Denmark. This elevation is recognized readily from the mountain summits of New Hampshire, as it is a long mass rising up from an apparent plain. The mass of the mountain is a sienite like that of Tripyramid, with triclinic feldspar. From the south end there extend large dykes crossing Beaver pond, which are entirely composed of trachyte. This same rock has been discovered by Mr. Hawes in Albany, since the printing of Chapter III. It is a very interesting discovery, showing that what has usually been regarded as a volcanic rock of tertiary age has also been erupted in a much older period, and especially in the very ancient region of the White Mountains. The rock will be fully described in Volume III.

I understand, from Mr. Huntington's statements, that the Montalban rocks prevail through Parsonsfield, Cornish, and Limington with a south-east dip. In Newfield, I found the same rocks abundant all through the western part of the town. The granitic beds are the ones most usually showing themselves. At the Davis mine, close by Balch pond, the dip is high to the south-east, and probably elsewhere throughout the town. Dr. Jackson describes sienite from "Thyng's mountain," without naming the town where it belongs. None of the maps give any such name. He speaks of it as the highest summit in the neighborhood; and I have used my judgment in locating it in the northern part of Shapleigh, near some houses marked as owned by men having the same designation. I have extended the area of Lake gneiss into Parsonsfield, because the peculiar minerals of the Amherst and Wakefield limestone occur there in two or three localities. When the exact place of this older gneiss is ascertained beyond Parsonsfield, we may have the data afforded for tracing out the master anticlinal of this region.

I have marked with more care the rocks from Acton across to Biddeford. At first are the Rockingham schists, with north-west dip. There is a small anticlinal by school-house No. 6, and north-west dips beyond. Passing through South Acton village is a band of the Kearsarge andalusite rock, more conspicuous both to the north and south. Half a mile to the east it dips 10° W. The south-east part of the town is believed to belong to the Lake gneiss. Very ferruginous rocks appear in Shapleigh, about Emery's mills and at Spring Vale, in which an anticlinal structure may be perceived. After this, we find compact feldspar and sienite in Sanford and Alfred. All through Lyman is an ordinary granite, succeeded at Goodwin's mills by the Merrimack group. In Biddeford is a very beautiful variety of the Conway granite, eruptive, and extensively used for building purposes.

CHAPTER VIII.

GEOLOGY OF THE COAST DISTRICT.

THE Coast district embraces the south-east corner of the state, principally Strafford and Rockingham, and a little of Belknap counties. It lies altogether east of the Merrimack hydrographic basin, and includes most of the Salmon Falls drainage area, save a little treated of in the preceding chapter for convenience. It is the least elevated part of the state. On a natural scale, where the horizontal and vertical are the same, and the size that of our general map, the highest point in Rockingham county would be elevated one sixteenth, and the most conspicuous hill in the whole district, in Gilmanton, would rise only one eighth of an inch above the base level. The general average would not exceed one twenty-fifth of an inch. The great erosions that have brought the region to this lowly condition have removed the crests of the folds to an unusual extent; and the ice has been instrumental in covering large tracts with sand, gravel, and till, thus preventing the solution of many important stratigraphical problems. The surface deposits, as represented by colors upon the map, cover more area in this district than in any of the others. While this prevents so full a knowledge of the solid rocks, it enables us to carry on successfully the study of surface geology, as will appear in the sequel.

The following formations crop out in the Coast district, including the adjacent portion of York county, Me., and a little of Essex county, Mass., so far as represented upon the south-east part of the map: 1. Porphyritic gneiss. 2. Lake gneiss (including the Laurentian of Massachusetts) 3. Montalban. 4. Rockingham group. 5. Merrimack group. 6. Kearsarge group. 7. Huronian and Cambrian of Massachusetts. The unstratified rocks are the sienites of Exeter and Pawtuckaway, inferior granites, and the well-developed granites and porphyries of York county, besides a great many trap dykes along the coast.

1. Porphyritic Gneiss.

Only a relic of this ancient formation appears in this district, and that is at the extreme south-eastern corner, in Seabrook. It lies at the north-east end of the sienitic range. The crystals are small; and the rock is traversed by segregated veins. Perhaps it had better be ranked with the eruptive mass of Green mountain, or with the Lake gneiss. Its association with the sienite reminds one of the like condition of things to be described presently in Brentwood. The ledges appear in the salt marsh region near the mouth of Little river, and are frequently covered by the tide.

2. Lake Gneiss.

Five principal areas of this formation may be mentioned in this field: (1) in the corners of Barnstead, Alton, New Durham, and Farmington; (2) Strafford and Northwood; (3) Barrington to Candia, connecting with the Deerfield-Mason range; (4) the Hampstead range, with the small patches in Chester, Epping, and Fremont; (5) the north end of an ancient range from Massachusetts, terminating in North Andover and Boxford.

The Barnstead and Northwood Areas. These are isolated patches, almost on the same line of outcrop, each about eight miles long. The first is mainly restricted to the elevation known as New Durham ridge, there being a small village upon the summit. At school-house No. 3 the gneiss dips 5° N. W. By the Free-will Baptist church, at the very highest point, the layers are exceedingly twisted, with micaceous and ferruginous seams, dipping 20° S. E. Coarse granite veins twenty-one feet wide cut the strata. At L. S. Nute's, in Alton, the dip is S. 30° W. For a mile or more the north-west strike predominates. At J. Morrison's the dip is south-east. Drift covers the ledges on the north side of Half-moon pond, and the outcrop is obscure near G. Hill's. Near the west line of the town, west of T. Hill's, the strike is north-east. These observations indicate great irregularities: first, a synclinal east of New Durham church; an anticlinal to the west, before reaching Alton; and a possible synclinal in Alton. The strike conforms with the ridge, north-west, a part of the way, which is an unusual course. In Strafford, the band crops out a mile east of Bow lake, in district No. 16, the gneiss near by dipping 45° N. W. On the eastern side of the lake, farther north, the vertical strata run N. 20° E., and others dip N. 40° W. near by. This rock occupies the north part of Northwood, at the "Narrows," and about Bow and Long ponds is believed to dip westerly. The stone at the Bow lake outlet dam is well-defined gneiss, and comes from a quarry to the west of the village. No ledges except gneiss were met with between the outlet and East Northwood, and also from the same beginning to the west corner of Barrington. North of James Crawford's, in Strafford, the gneiss dips south; a little to the south is a fine, dark colored variety, with the inclination S. 20° E. Close by the small pond in the west corner of Barrington is a knob of coarse, hard granite, seemingly the prevailing rock for a mile into Nottingham.

Barrington and Candia Range. It is probable that most of Barrington is underlaid by gneiss, while observations respecting it are very meagre. It is the north-east end of the Manchester band of the Merrimack district, and does not extend into Rochester. The town consists of hills of coarse granite, not of large size, with schists between in the valleys, the latter having suffered the most from denudation. The specimens collected from Section IV resemble the Montalban series. In the south corner of the town, near E. Randall's, is gneiss; and at school-house No. 9 it dips south-east. At Thompson's, close to the Nottingham line, well-defined gneiss dips S. 60° E. At a saw-mill half a mile west the same rock occurs. The low country to the west reveals similar ledges, as at A. Witham's, dip S. 80° E., and near the Baptist church. There seem to be mica schists in the north part of Nottingham, but most of the west part of the town is believed to be underlaid by this gneiss. There are a few ledges of it between the north outlet from Pawtuckaway pond and the west town line. In Deerfield there are similar ledges on the road from the Square to the Parade, and on the height of land coming very close to sienite. No observations have been taken between this road and Saddle-back mountain, in Northwood. Between the two villages of Deerfield is a coarse mica schist, of the kind associated with the gneiss. The northern boundary of the latter rock is irregular through this town. Granitic gneiss hummocks abound east of the Centre, dip north-west. At the cemetery, south of S. P. Rollins's, the dip is north-west. The same at the brook a mile south. The north-west part of Raymond belongs to the gneiss. The boundary line between it and the mica schists may be drawn from the south end of Pawtuckaway to a little below Jones's pond, and then direct to Massabesic lake. At C. G. Smith's, near the north line of Raymond, the dip is north-west; as also in the south-west part of Nottingham. From Jones's pond to the west line of Candia the rock is the twisted gneiss of Manchester, and there is a synclinal axis in the east part of Candia, followed by a very marked anticlinal in the central part of the town. A short distance north of the depot is the south-east dip; but it is to the north-west at Candia village. The axis has not been traced farther to the north-east. Its course, as mentioned on a previous page (560), would, if continued, proceed to the sienitic eruptive mass of the Pawtuckaway mountains. The south-east part of Candia contains many gneiss ledges, particularly on Patten's hill. Rattlesnake hill, in Raymond, is of this material, and may be an isolated fragment. There is a similar one of unknown extent near D. Ball's, in the south-east part of Auburn.

There is a small area of gneiss in the north part of Chester, constituting a large hill. The strike is N. 55° E. in the south part of it, and the dip N. 30° W. on the summit. It crosses the road near a school-house, more than a mile west of the village. We find the same rock farther north-east, both in Chester and Raymond, but it does not seem to connect with the West Epping exposures. The latter crop out by the mills on the Lamprey river in vertical strata, with the course north-east and south-west. A large number of loose blocks of this gneiss are spread over the plain near the station. Drift covers the natural continuation of the range in the south part of Epping and the north part of Fremont; but it appears near D. Rowe's, west of the village, and in the south-west part of the town dips S. 75° E. These observations indicate the anticlinal structure in this area. The town of Sandown has not been explored yet, so that the representation upon the map is based only upon probabilities. The projection of all the facts at command certainly suggests the direct connection of the Epping and Fremont gneisses with the Hampstead area. In Brentwood a few ledges of this gneiss, dipping 70° S. 60° W., with joints inclined S. 40° E., appear to the east of a Congregational church, more than a mile west of Marshall's corner. It adjoins sienite, and does not extend far along the line of strike.

Massachusetts Area. The map presents to view seven or eight miles' length of the north-east end of a very important gneiss band, called Laurentian by some, and designated as Atlantic upon Plate I. It is noted upon page 23 as forming the outermost of the formations encircling the Boston basin concentrically. The section (Plate II) gives it a monoclinal north-west dip. Concerning this gneiss in Andover and North Andover, I wrote the following in 1867,* including a notice of a very coarse granite:

The gneiss formation includes an ugly looking gneiss,—a very ferruginous variety,—quartzites in limited amount, much fine-grained granite, a bed of steatite, and perhaps other varieties worthy of notice. It occupies most of the area of the two towns, lying north-west of the hornblende rock, and limited by an overlying mica schist on the Merrimack river. South of Aslebe hill is a fine-grained granite, not far from the steatite bed at W. Jenkins's saw-mill. The first ledge observed west of Aslebe hill is quartzite. Patches of the fine-grained granite were noted at J. Cummings's, near Carmel hill; in small amount at the railroad station at South Andover; near J. Adams's, on the south shore of North Andover pond; several localities south-west from the West Andover cemetery; at about three fourths of a mile north from West Andover church, at J. Chandler's, near the almshouse, and in many other places. There may be a synclinal structure in this formation, for at the South Andover station the dip is 80° N. 67° W., and 46° S. E. west of West Andover church. In several other places east of Shawsheen river the north-westerly dip was noticed; and it is my impression that the south-easterly dip prevails in the railroad cut at South Lawrence. Along the north-western boundary of this group there is a belt of peculiar gneiss, whose feldspar has the appearance of small pebbles. I am uncertain whether it belongs to the gneiss below, or to the mica schist above.

The coarse granite appears on the map like a flattened ellipse, with sharp ends cutting the gneiss at an angle of about twenty-five degrees. I have not searched for it south of Foster's pond; but to the north from that point, as far as B. Rogers's in the north-east corner of the Phillips district, the outcrops are very numerous. From the middle of Scotland district to a point west of Moses Abbott's, nearly a mile and a half,

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* *Proc. Essex Institute*, vol. v, p. 157.

this rock forms a high, precipitous ledge, of which the culminating point is Sunset Rock. The buildings of the Theological Seminary appear to be on the boundary between the coarse granite and the gneiss to the west. The most easterly outcrop of the coarse rock is near Simeon's, west of H. Gray's, in the Holt district. The length of this granite is a little more than four miles, and its greatest width 440 rods. The crystals of mica and feldspar are sometimes six inches broad, and are universally very large.

This area carries beds of limestone, in which Eozoön has been found, as at Chelmsford, by L. S. Burbank.* The same fossil occurs at Newbury. The occurrence of the Laurentian and associated rocks in this town will be found further described under the topic of *Economical Geology.*

3. Montalban.

In Farmington is an area of excellent Concord granite, two or three miles long, occupying the valley of a large tributary of the Cochecho river. A hill back of the railroad depot is composed of the same material. The drift is so extensive to the north of it as to make it uncertain whether this area may directly join the Lake gneiss of New Durham, or be separated by a covering of mica schist. This series, without the granite, crops out extensively in Sanford, Alfred, and the adjacent towns farther north in Maine. There is a synclinal axis in it near Springvale.

4. Rockingham Mica Schist.

This may occupy more space in this district than any other group. Two areas may be noted, united to each other in Rochester. The first is the continuation of one previously described, and extends from Allenstown to Alton, and to near Newfield in Maine. The second joins the Nashua deposit, previously noted, and may be followed adjacent to the Nashua & Rochester Railroad to Berwick, Me. The following positions have been noted in the first area:

Gilmanton.

At S. C. Place's, dip 65° N. 20° E.
At J. D. Nelson's, dip 30° N. 20° W.
At J. F. Nelson's, dip 57° N. 5° E.
At D. B. Morrill's, dip N. 30° W.
West of D. B. Morrill's, dip 10° N. 60° W.
At J. L. Page's, dip 45° N. 50° W.
On Grant hill, dip 25° N. 80° W.
At east base of Lamprey hill, dip irregularly 30° N. E.
On Hall's hill, south-east corner, dip N. 60° W.

* *Proc. Boston Society Natural History,* vol. xiv, p. 190.

North of Mrs. J. Gilman's, granite beds, dip N. E.

West of Cogswell hill, dip 25° N. 70° W.

At T. J. Gale's, dip 25° N. 60° W.

At Iron Works village, east edge, dip small N. W.

At tannery south of Butler brook, 45° S. 25° E.

Barnstead.

At T. Edgerly's, dip E. 15°–20°.

At W. Jenkins's, Jr., dip S. W.

At J. Blake's, dip 50 N. 85° W.

At Clarke's corner, dip 30° southerly.

At S. Lougee's, dip 70° S. 30° E.

Alton.

At J. Morrison's, hill west of "Bay," dip 70° N. 50° W.

New Durham.

At brook, east part of town, dip S. W.

At W. H. Tush's, near corner, dip 80° S. 25° E.

At G. D. Savage's, dip S. 75° E.

1 mile north-west from corner, dip N. 20. W.

Northwood.

At north-east corner, dip N. 30° W.

At east border of Jenness pond, dip 60° W.

South-east from Suncook pond, dip S. 40° W.

On Saddleback mountain, dip N. W.

At L. Durgin's, north base of Saddleback mountain, dip 25° W.

Milton.

At mills, dip 12° S.

At W. F. Cutts's, dip 20° S. 5° W.

At school-house No. 8, dip 12° N. 10° E.

At N. H. Roberts's, dip 25° N. 40° W.

At town line, next Wakefield, dip N. 80° W.

At top of Teneriffe mountain, dip 60° W.

At W. W. Ricker's, dip S. 50° W.

On west side of Milton pond, 65° N. W.

At Three Ponds village, dip S. E.

At South Milton, dip 70° N. 30° W.

Farmington.

At J. A. & L. T. Tibbitts's, dip north-easterly, small.

The same at saw-mill in school districts Nos. 11 and 12.

West of O. K. Otis's, dips S. 20° E.

At O. K. Otis's, dip S. 50° W.

North of the above, dip N. 50° E.

At G. F. Nutter's and J. B. Lyman's, dip S. 60° E.

On Chesley mountain, west side, dip S. E.

At Merrill's corners, dip 80° N. 40° W.

Strafford.

At school-house No. 11, dip 15° N. W.

At B. Hayes's, dip 45° N. 60° E.

At C. E. Evans's, dip S. 70° E.

On top of Blue hills and at T. & C. Caswell's, dip S. 80° E.

At D. P. Caswell's, dip S. 80° E.

At "Corner," dip N. 50° W.

At S. Young's, dip N. 40° W.

At A. H. Cater's, dip N. 40° W.

At J. Mills's, top of ridge, dip S. 20° E.

Deerfield.

At north-east corner, dip 85° S. 70° W.

East of E. R. Rowell's, dip N. 70° W.

At W. T. Smith's, dip S. 40° E.

The second area mentioned is hardly to be separated from the Merrimack group, save as certain parts of it closely resemble the typical Huronian. The following positions have been noted:

Auburn.

At P. Preston's, strike N. 70° E.

East of Devil's Den, dip N. 5° E.

Chester.

At C. Chase's, dip 80° S. 30° E.

At I. Forsaith's, dip 75° N. 40° W.

At Chester village, dip vertical.

At Wm. S. True's, dip 50° S. E.

Epping.

At I. F. Norris's, dip 70° S. 75° E.

At A. Randlett's, 80° S. 75° E.

North of J. French's, 80° S. 75° E.

At school-house west of French's, 70° N. 85° E.

Between Gov. Prescott's and the village, dip S. E.

Near J. Bly's, dip 70° S. 80° E.

At J. P. Chase's, dip 70° N. 70° W.

At B. Dow's, near railroad, vertical, strike N. 30° E.

On Red Oak hill, dip N. W.

In north-west part of Epping, dip N. W.

At railroad cut ½ mile south of Junction, dip 75° E.

Danville.

At Wm. Bagley's, dip 45° N. 60° W.

Newmarket.

At E. Hilton's, vertical, north-east strike.

Nottingham.

At North Corner, dip 45° E.

1 mile north of S. Priest's, dip easterly.

At S. Priest's, dip westerly.

At J. C. Tuttle's, dip S. E.

Near Epping line, dip 90°; strike, N. and S.

At J. Gile's, dip S. E.

At Tannery near J. Hill's, dip N. W.

Half mile west of tannery, dip N. 20° W.

At G. Marston's, dip S. 20° E.

West of square, dip north-westerly.

At B. P. Harvey's, near Epping line, dip north-westerly.

Dover.

City, dip north-westerly.

Raymond.

Near pond west of village, dip 70° N. 40° W.

North of village, dip 55° N. 35° W.

At B. Dearborn's and quartz, dip 75° N. W.

At cemetery south of railroad, dip 80° N. 50° W.

Near A. Brown's, south-west part of the town, dip 90°; strike N. 40° E.

Quartz east of village, dip 70° northerly.

East of above, dip 70° N. W.

At S. Blake's and J. Brown's, north-east part of the town, dip N. W.

Near Raymond depot, dip 55° N. 20° W.

Near L. Moulton's, east and west strike.

Fremont.

At J. Morrill's, dip 80° S. 80° E.

Near D. Beede's, dip S. E.

Near O. B. Poor's, dip 80° N. W.

Brentwood.

At north-west corner, dip N. W.

At S. Fuller's, dip 88° N. 10° W.

At nurseries by west line, dip N.

At Ladd's mill, south-west corner, dip 40° N. W.

At Crawley's falls, dip 55° N. W.

Lee.

South of C. H. Tuttle's, dip 80° N. 60° W.

At Wadley's Falls, dip 40° W.

At school-house No. 1, dip 65° N. 40° W.

At M. Thompson's, dip N. 45° W.

At O. Davis's, dip 50° N. 50° W.

At S. W. Bateman's, dip 85° S. E.

At Jas. Gile's, dip 85° N. W.

South of J. P. Haley's, near Epping line, dip 85° N. W.

Somersworth.
Near Smith & Roberts's, dip southerly.
At Great Falls academy, dip 70° N. 30° W.

Rollinsford.
At S. Hale's, dip 65° N. 70° W.

Of the several axes indicated in this list, perhaps the most important is the continuation of the anticlinal from the Hampstead gneiss through Sandown, Fremont, and Epping into Nottingham. This seems to connect the different gneisses together, placing the Nashua and Raymond schists in a separate stratigraphical district from those of Epping, Danville, etc. Through Fremont and Epping we get evidences of a well-marked synclinal, perhaps terminating in Nottingham. Through Fremont and Brentwood this is a natural basin between ridges of gneiss.

Between the Raymond and Epping sides of the anticlinal are marked differences in lithological composition. In the former area is a rock much like the typical Huronian, with its dolomites. They occupy a considerable space in Raymond, characterized by an almost east and west strike. Similar ledges have been noticed in the north part of Derry, north of Beaver pond (pp. 581, 582). There is a related rock more than a mile wide in the south-east part of Auburn, which seems like the natural continuation of the Raymond belt. On the Epping side nearly all the exposures consist of gray micaceous quartzite and mica schist, not different from the common variety of the Merrimack group. The mica schists on the Raymond side are coarser and less siliceous. Perhaps this axial line ought to be employed on the map as the boundary between the Rockingham and Merrimack group.

A few facts of interest respecting the rocks over this area are the following: In Auburn, north of the Devil's Den, at J. Calef's and P. Preston's, the schists are cut at an angle of eighty degrees by a vein of granite. East of the den are many large white beds of granite. The den itself seems to be a knob of mica schist. The south part of Auburn is largely occupied by drift, and the most easterly outcrop of Lake gneiss is by D. Ball's, perhaps an outlier. I do not find mention made of bedded granites in the west part of Chester. The quartz bands have a large development, being nearly continuous from a mile south of Raymond village to Nottingham square. This principal band crosses the railroad east of Raymond village, and there is a smaller one about a mile west of the depot, coming up in connection with a very coarse granite. The principal range rises to Flint hill, in the north part of the town, then falls opposite the Pawtuckaway river, and rises to view with a north-west dip at several places in Nottingham. In Lee, near M. Thompson's, is an unusual display of similar boulders, as if their source could not be far distant. There are ledges of this rock in the other area in Northwood, on the east side of Pleasant pond, with a northerly course. It does not yet show itself to the east of the main anticlinal. The bands observed must belong to a later formation than the typical ranges in Hillsborough county.

The granitic masses are unusually large in Danville, being more than a mile wide east of Wm. Bagley's. In the area lying partly in Danville and partly in Kingston, between Long and Half-moon ponds, the granite constitutes something of a hill. The granites of this group are mostly wanting in Fremont, Brentwood, and Epping. The same is true of the south part of Nottingham, Lee, and Madbury. In Somersworth there is a large granitic area, in the north part of the town, possibly of eruptive character. In Dover, at Sawyer's mills, the schists are well exposed in a railroad excavation, and bear marks of strong pressure, with many small slickensides.

The Rockingham group in Hillsborough county is characterized by orographical features, as exemplified by the presence of a mountain range commencing with Kidder and Temple, continued in Pack Monadnock and the Lyndeborough hills, and preserved farther north-east in the solitary pile of the Uncanoonucs. The Merrimack valley brings up the older gneisses, and as soon as we pass a few miles to the north-east this elevated range reäppears very prominently in the four mountains of Epsom, —Brush hill, McKoy's, Fort, and Nottingham mountains,—Catamount in Pittsfield, and then there is a range just a little farther to the south-east, consisting of the Blue Hills range in Strafford, Blue Job, Nubble, Hussey, and Chesley mountains in Farmington, and Teneriffe in Milton. These disconnected portions of a once continuous range suggest elevations of the underlying formations along what are now valleys of denudation, and the subsequent wearing away of the mountains of mica schist now needed to fill up the gaps in the range.

5. Merrimack Group.

Under this head we may continue the description of the last part of the preceding, or what agrees with it lithologically, but in a different geographical field. This territory embraces all the schists usually referred to the Merrimack series on the south-east side of the principal sienitic range, passing through Exeter, and what lies south-east of the Pelham gneiss. Viewed in its entirety, it may be said to occupy the principal area between the Exeter and Newburyport ranges of sienite, as well as that between the two great gneiss areas of Pelham and Andover. This is the typical area of this group, from which the name was derived. The rock is mostly a micaceous quartzite, varying to argillaceous schist, and frequently reminding one of the rock carrying *Paradoxides* in Massachusetts. We have the following observations of its position:

Massachusetts.

In Andover, along Merrimack river, dip 50° N.

At North Andover, generally, dip 30°–40° north-westerly.

In Dracut, south of Peter's pond, dip 60° N.

At Lawrence post-office, dip 70° N. 80° W.

In Methuen, north part, dip 20° N. W.

In Bradford, on B. & M. R. R., dip 25° N. 50° W.

In Haverhill, dip generally about N. 60° W.

In Boxford, dip 25°–60° N. W.

In Salisbury, dip N. W.

Plaistow.

At J. Noyes's, in east part of town, dip 80° N. 80° W.

At S. Calden's, dip 80° N. 80° W.

Atkinson.

Near school-house in east part of town, dip 50° N. 60° W.

Near D. Noyes's, north corner, dip 50° N. 60° W.

Hampstead.

At S. Harris's, dip S. E.

At J. Bradley's, dip vertical, or 80° S. E.

At E. Morse's, dip S. 80° E.

At S. Dow's, dip S. 80° E.

At the town hall, too variable for measurement.

At J. E. Emerson's, dip 50° N. 30° W.

Newton.

At east part of town, dip 80° N. W.

At N. Gould's, dip 55° N. W.

At M. Bartlett's, dip 50° N. 70° W.

South Kingston.

At E. Hunt's, dip S. 60° E.

South Hampton.

Near west line, dip 85° N. W.

Seabrook.

North of church, dip 80° S. 10° W.

Near school-house east of the railroad, between villages, dip 80° N.

Hampton Falls.

At W. W. Healey's, dip N. W.

At Baptist church, dip N. W.

South of village, dip S. E.

Hampton.

At school-house east of Wolf hill, dip N. W.

At Mrs. C. Leavitt's, dip vertical.

North Hampton.

At S. Brown's, Jr., dip vertical.

Near Little Boar's Head, dip 70° N. 40° W.

At J. S. Hobbs's, dip 55° N. 80° W.

At T. Hobbs's, Jr., dip N. 40° W.

Rye.

At W. Holmes's, dip 65° N. 40° W.

At C. S. Jones's, dip 65° N. 60° W.

At W. W. Seavey's, dip 70° N. W.

At Sagamore house, vertical, N. 40° strike.

At Frost's Point, dip 65° N. W.

On Breakfast hill, dip 75° N. 30° W.

Newcastle.

At north end, dip S. E.

Generally, dip N. W.

At south end, dip 50° N. 50° W.

Stratham.

At G. Lane's, dip N. W.

At north base of Stratham hill, dip N. W.

At J. Thompson's, dip 50° N. 75° W.

At N. Chase's, dip 50° N. 75° W.

Greenland.

At Brackett's crossing, dip 70° N. 40° W.

A mile north of Greenland church, dip 50° N. 40° W.

Newington.

At E. Coleman's, dip 60° N. 50° W.

Rollinsford.

At L. Stackpole's, dip N. W.

At S. Hale's, dip 65° N. 70° W.

Maine.

In Kittery, next Portsmouth, dip 85° N. W.

In York, at Long sands, dips 80° S. 40° E. and N. 50° W; also at a less angle to the north-west.

Near Kennebunk river, north-west strike.

Portsmouth.

Near bridge at south mill-pond, dip 50° north-westerly.

A mile south of post-office, dip 70° N. 20° W.

At bridge over Sagamore creek, dip 70° N. 25° W.

East of railroad intersection, dip 45° N. 35° W. and 55° N. W.

At S. Tacker's, dip S. E.

At A. W. Simpson's, etc., dip N. W.

North of Sagamore creek on road to Breakfast hill, 80° S. 50° E.

At T. Lightfoot's, dip 60° N. W.

At A. Holden's, near S. line, dip N. W.

At Jos. P. Marden's, dip N. W.

On Goat island, dip S. E.

One fourth mile west of Newcastle bridge, vertical, strike N. 55° E.

At school-house north of north mill-pond, dip 85° S. 20° E. and 80° N. 20° W.

Between Eastern Railroad depot and Concord Railroad wharf, dip N. W.

Exeter.

At south edge of village, on branch of the Exeter river, in two places one mile apart, dip 80° W.

At Exeter river, east of village, dip N. W.

In north-east part of the town, dip 80° W.

South Newmarket.

East of Junction, dip 70° N. 70° E.

Much the same through Newmarket.

Durham.

All along the shore of Great bay the dip is usually 80° N. 60° W.

Dover.

At "Point" near T. Couch's, dip 80° W.

At Mrs. Coleman's, dip 70° N. 70° W.

Star Island.

Strike N. 40° E.; dip variable.

In the east corner of Plaistow, quite near the railroad, is a large mass of granite, thought at first to represent the porphyritic gneiss. At J. Noyes's, a prominent set of joints dip 35° N. In the east part of Atkinson coarse granites abound at L. Darling's. Smaller beds are scattered through Hampstead. The schists seen in a trip through the east part of Plaistow and Hampstead were thought to be more like the Rockingham than Merrimack. A fine-grained granite has been observed on the highest land on the west side of Country pond, at South Kingston, which is probably continuous with a similar rock on a north-west ridge in East Hampstead, visible for half a mile. The course of this mass would be about east and west, not agreeing with the strike of the schists. In the very west corner of South Kingston are large beds of coarse granite. Kingston is mostly covered by sand, but there are indications of a schistose ledge in the north-east corner of the town. There are a few outcrops of unclean ferruginous schist near Mrs. Morrill's, in the south-east corner of East Kingston. Almost the only ledge found in South Hampton occurs on a hummock close by the west line of the town. It is a gray quartzite, breaking into innumerable pieces in consequence of exposure to frost. In Seabrook there is more variety. North of the village ferruginous quartz and flinty slates are interstratified, traversed by a peculiar porphyritic diorite. Other trap dykes occur at the village, and at a school-house east of the railroad. Half a mile west of Seabrook village there is a granite mass. At a Baptist church in Hampton Falls the rock is a gray sandstone, easily mistaken for sienite at a little distance. Two miles north the slates are friable and decompose easily. Trap occurs at the school-house east of Wolf hill, and north of Little Boar's Head, in Hampton.

About Portsmouth the ledges are well displayed. There seems to be a synclinal axis from the south end of the town through to the north end of Newcastle. The anticlinal on the north is very near to it. Bands of gneiss or indigenous granite are quite conspicuous in this and the adjoining towns. One of the most prominent is Breakfast hill, perhaps an anticlinal. This band crops out north-easterly at the railroad crossing in the extreme south part of the town, near J. Marston's, T. Lightfoot's, and north of Sagamore creek, on the Telegraph road. It also appears just north of the same creek on the road to Frost's point from Portsmouth, on a parallel band, and near D. D. Whidden's in Ward No. 1. There must be many others. Near the south end of Newcastle the origin of these granitic beds is apparent. They have been formed by the alteration of sandstones *in situ*. There is nothing indicating disturbance in these beds, while there is a freshness about the mica crystals. None of the larger beds are probably over 200 feet in breadth.

Dr. Jackson examined the rocks about Portsmouth. A few sentences are extracted from his report, stating the phenomena in his own language:

The rocks to which I refer are the dark blue flinty slates, possessing an imperfectly stratified structure, a very compact texture, sonorous when struck by the hammer, and often breaking with a more or less distinctly conchoidal fracture. Occasionally they evince a passage into an imperfect micaceous slate, especially where they border on granitic rocks. * * Another change is also observed in the flinty slate rocks near the railroad cutting in the vicinity of Portsmouth. The rock is filled with an infinity of reticulated veins of carbonate of lime. This may have been produced by the fusion [infiltration] of calcareous matter contained in the rock by the action of heat. * * Iron pyrites abound in this locality. * * The strata of flinty slate are much contorted; and this contortion took place, evidently, anterior to the eruption of the trap dykes. The flinty slate contains numerous veins of compact feldspar, which probably were formed at the epoch of the elevation of the granite rocks. * * The joints are generally in directions parallel to those of a rhombic prism. * * The flinty slates are succeeded by granites, which in numerous places have been erupted so as to isolate portions of the slate by intrusion between their masses. Such phenomena would give to a casual observer the idea that the slates and granite alternate with each other. It will be found on further observation that such is not the case, for the primary rocks have merely been forced in between portions of the slate. Near the house of Samuel Langdon, a mile and a half from Portsmouth on the road to Boar's Head, a mass of granite has been intruded through the slate, and occupies a considerable area, beyond which the flinty slate again appears, and then gives way to a regular granite and gneiss formation, which extends through a large portion of Rye. In Portsmouth the intrusion of granite veins and trap dykes into the flinty slate may be seen in Shoar's woods.

The Isles of Shoals have been neglected. I have noted the fact of the presence of gneiss on Star island, without stating which is the predominant dip. The following brief notes about them are taken from Jackson. Star island is said to be composed of a coarse variety of granite, having large crystals of white feldspar, gray quartz, and but little mica, with intercalated beds of mica schist. Along the middle of the island is a trap dyke running north-east. There is very little soil upon the island.

PLATE XXV.

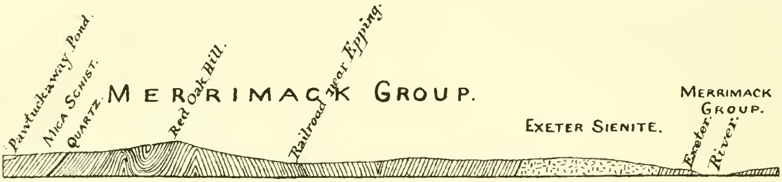


Fig. 106. From Pawtuckaway Pond to Exeter Village.

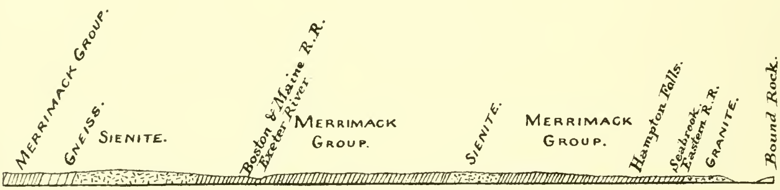


Fig. 107. From Brentwood to Seabrook.

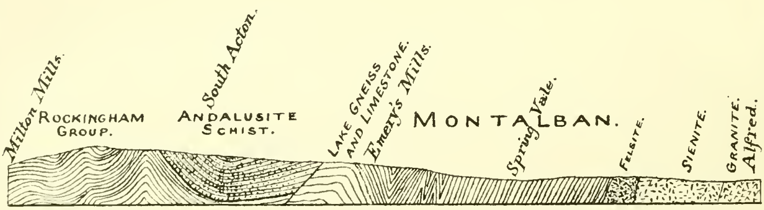


Fig. 108. From Milton Mills to Alfred, Me.

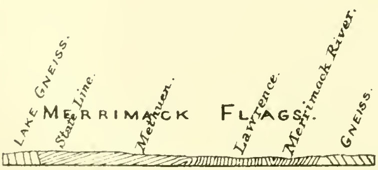


Fig. 109. From Salem to N. Andover, Mass.

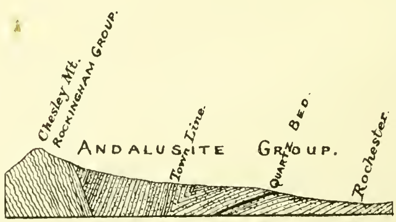


Fig. 110. In Farmington and Rochester.

SCALE, HORIZONTALLY, 2½ MILES TO AN INCH; VERTICALLY, 2000 FEET TO AN INCH.

HELIOTYPE

Hog island is composed mostly of mica schist. Duck island shows granite and gneiss. The other islands are granitic.

The most modern-looking rocks I have seen are situated in a cut by Brackett's station on the Portsmouth railroad. Geologists familiar with Cambrian fossiliferous strata would find many ledges in the east part of Rockingham county very similar to those yielding trilobites, worms, and mollusca elsewhere. Careful search will undoubtedly develop them hereafter.

Kittery, York, and Eliot, Maine, are a continuation of these slaty quartzites of the Merrimack group, and they follow up the Newichwannock river between the two sienite areas to Berwick. Similar strata may be followed along the coast nearly to Portland. On the Kennebunk and Saco rivers are areas more argillaceous, possessing a north-west strike. This fact suggests the existence of later groups resting uncomformably upon the Merrimack series, similar to the Cambrian along Parker river, Massachusetts.

Great bay must be underlaid by these rocks, as they yield to decomposition sooner than the hard sienite. One would naturally expect to find a shallow synclinal beneath the water of Great bay, but the strata dip at large angles, though showing the basin form. From Exeter village to South Berwick the slates occupy only a small space adjacent to the water, being a fringe skirting the sienite. What irregularities of position between these rocks have been perceived, are represented upon the map. These may, perhaps, have arisen from igneous ejections, accompanied with lateral pressure. A like irregular boundary may be seen in York, Wells, and farther along the coast of Maine.

Plate XXV illustrates the relations of the Merrimack group to the adjoining formations. Fig. 106 shows the order of rocks between Pawtuckaway pond and Exeter village. At the west end in Nottingham are the north-westerly dipping mica schists, carrying the quartz band. Then appears the most important anticlinal, dividing the group naturally into two parts, followed by unimportant flexures and the Epping synclinal. The sienite of Exeter occupies an important place at the east end of the section, seemingly supporting the slates; and the high westerly-dipping schists at the east side of the village would seem to indicate an inverted anticlinal, when compared with those on the other side of the sienite.

Fig. 107 gives an insight into the relations of the strata between Brentwood and Seabrook. In the first-named town there is an area of gneiss adjacent to the sienite.

This seems to be a more natural association than between sienite and the schists. The discovery of the gneiss here has raised the question whether it may not be the usual floor of the sienite. Sometimes the latter is traversed by planes like those of stratification, but they have not been carefully traced out in this region. The sienite through Exeter is quite broad. Then we have north-westerly dipping schists of the Merrimack group, followed by a narrower band of sienite in the north part of Hampton Falls. At the Baptist church is the gray feldspathic member, perhaps continuous with one of the granitic beds of Rye or Portsmouth. Seabrook shows more variation in the dip, with a bit of sienite and ancient gneiss at the eastern end.

Fig. 108 illustrates the country between Milton Mills and Alfred, Me., properly connected with the previous chapter, and the continuation easterly of Section V. The first rock is the Rockingham mica schist, with south-westerly and westerly dips. A small anticlinal occurs near school-house No. 6 of Acton, where the dip changes back to north-westerly, and the rock is quite ferruginous. Next occurs the andalusite mica schist of the Kearsarge type, not differing greatly from that already passed over. There is a knob of granite on it at its west edge. East of South Acton post-office the dip is 10° N. W. About a mile before coming to Mousam pond is a siliceous limestone with gneiss, dipping 5° S. W. This is thought to belong to the Lake series. In the neighborhood of Emery's mills in Shapleigh, ferruginous schist of Montalban type dips irregularly 50° S. 80° W. About Spring Vale in Sanford we have similar rocks, with a synclinal axis, the west dips prevailing from the town line. Just in the edge of Alfred the felsite begins; and at a railroad cut the ledge is distinctly of sienite. The same rock occurs several times before reaching the village of Alfred, the last being at the mouth of Middle Branch. At the village there succeeds a fine-grained granite, a little like that about Merrymeeting lake.

Fig. 109 shows the relations of the Merrimack schists to the adjacent gneisses. The Salem gneiss has not been observed south of the railroad station, where the dips are south-westerly (p. 561). Inasmuch as south-east dips prevail along the eastern border of the gneiss in Pelham (Section I), they are supposed to continue to the place of this illustration. Near Messer's railroad station the Merrimack schists appear, and are supposed to agree with those measured in the north part of Methuen, dipping 20° N. W. These rocks are sandy flags, separated by narrow argillaceous seams. At ledges near Lawrence post-office the strata are vertical. On the northern side of the river are other exposures. In the railroad cut, 150 rods south from the junction in South Lawrence, we find the return of the gneiss. It may not certainly be the same with that in Salem. It contains many rounded spots of feldspar, and several small faults are apparent. The dip is thought to be south-east, and within three miles it is reversed; and there is consequently a synclinal attitude to the strata in the west part of the Andover gneiss. An examination along the strike indicates the presence of a synclinal south of Lawrence in the Merrimack group, so that three axes seem to represent its structure in the figure.

6. Kearsarge Group.

The general character of the rocks of the Kearsarge group has been stated previously. In the Coast District the rocks differ from the mica schists of the Rockingham series principally by the addition of the mineral andalusite. Hence what has been called Rockingham may prove to belong to this Kearsarge series after the discovery in it of the mineral andalusite. One such case has come to hand since the printing of the sketch of the Merrimack district. Dr. Jackson says he found fibrolite together with garnets and black tourmaline upon McKoy's and Fort mountains in Epsom. The principal area of this rock near the east line of the state occupies most of Rochester, and may be followed into Maine through Lebanon and Acton into Newfield. In Fig. 110 is a section from Chesley mountain, Farmington, to Rochester village, lying partly in the Rockingham and partly in the andalusite group. This mountain is part of the series of Rockingham elevations from Temple to Teneriffe. The strata are much twisted, with a general south-east dip, and the schists contain beds of granite. Quite near the south base, at M. Thompson's, are the hard rocks accompanying andalusite schists, dipping 80° N. The same direction is continuous through the rest of the section. The dips continue high through Farmington, and in the north part of Rochester become much smaller. At D. Rogers's is a bed of quartz similar to those in Raymond. The section shows a sharp synclinal in the andalusite schists resting unconformably upon the Rockingham. As the dip is greater in the south part of the town, were the section protracted farther we might add an anticlinal to the present delineation. The following observations of dips in this area have been preserved, not repeating those already mentioned:

Rochester.

At school-house No. 17, dip 50° N. 40° W.

At D. G. Ricker's and the brook east, dip 65° N. 10° W.

The same at J. Foss's and H. Evans's.

At F. Gray's, in north-west corner of the town, dip 85° N. 10° W.

At Jas. McDuffie's, dip 15° N. 25° W.

At R. T. Rogers's, dip 15° N. 50° W.

In East Rochester, dip 55°–60° N. 60° W.

In Gonic, dip south-easterly.

At railroad near Mrs. Trickey's, dip 45° N. 10° W.

At Mrs. Pike's, in school district No. 20, dip 10° N. 10° W.

At Hayes's crossing, dip 30° westerly.

Farmington.

At Mrs. B. Willey's, ferruginous, dip N. W.

At Merrill's corner, dip 80° N. 40° W.

Milton.

At south corner, dip 30° westerly.

At South Milton, dip 70° N. 30° W.

Lebanon, Me.

At south corner, dip 50° N. 60° W.

At C. D. Rankin's, dip 45° N. 60° W.

At H. Lord's, dip 45° N. 60° W.

At Lebanon post-office, several places, dip 50° W.

At Baptist church, to the south, an anticlinal.

Acton, Me.

Half a mile east of South Acton, dip 10° N. W.

At Acton corner, dip 85° S. 50° E.

There is not great opportunity afforded in this table for making out many axes, otherwise than by inversion. The observation at Gonic would afford an anticlinal with those farther north. This might agree with the supposed inverted axis south of Rochester Junction. There is another in Acton. The rocks have a fresher look than pertains to the Rockingham schists, and perhaps this fact has led us to esteem the andalusite group the newest, in the absence of the proper stratigraphical evidence. The analogues of this group in other parts of the state are the Monadnock, Kearsarge, Ragged, Mt. Tom, Mt. Washington, and a few other areas. They seem commonly to constitute elevations resting upon older metamorphic formations. This last-described area is an exception to the general rule, as none of it is much elevated. This Rochester area, if continued, might connect with the more argillaceous portions of the Merrimack group in Derry, Nashua, and so on into Massachusetts, to join the celebrated macle rock of Lancaster.

7. Huronian and Cambrian.

The rocks referred to these groups are in the Massachusetts portion of the south-east sheet of the geological map. There are two areas. The first is called "hornblende slate" upon the geological map of Massachusetts, and lies on the west border of the large extent of sienite of the Newburyport district, being about eight miles long by two wide. The second occupies the Parker River basin, and consists of three different kinds of rocks, all of them unlike anything yet recognized in New Hampshire.

The hornblende schist resembles one of the members of the Huronian in the Connecticut valley, seen repeatedly between Bernardston and

Orford. Lying upon the west border of the sienite, one might imagine a gradual passage from the one into the other. The distinction between them is very clear in the south-east part of North Andover, where the sienites exist as limited patches of eruptive materials in the midst of the hornblende rock. This, however, is to the west of the proper field of the sienite, as marked upon the map. I have examined several exposures of this hornblende rock in Georgetown and North Andover, and everywhere see that it is a well-defined stratified rock; and it seems to be like the Connecticut valley deposits, which border the ancient gneiss in the same way with this. If we call it Huronian, it would represent the older part of the system, as it is developed in northern New England. It seems to be cut off by the Merrimack group, which has a north-easterly course, while the hornblende runs north and south.

On my father's map the Parker River area is divided into three parts, the middle called Silurian rocks, the northern porphyry, and the southern metamorphic slates. In 1859 I crossed this basin along the Eastern Railroad, and suggested in the *Proceedings of the American Association for the Advancement of Science* (p. 118), that the two outer bands might be of the same age, being the corresponding parts of a synclinal fold, the northern dipping at the highest angle and considerably altered from the conglomerates of the southern band. The question of the alteration of conglomerates into porphyry has been often discussed in the meetings of the Boston Society of Natural History, and reported in its proceedings. It is claimed by Mr. T. T. Bouvé that the gradual passage of the conglomerate into porphyry can be satisfactorily traced out in Hingham and elsewhere. I do not feel entirely satisfied with the view, because the pebbles of the conglomerate are mostly of porphyry, and it would seem therefore as if that formation had an existence before the sedimentary rock had been manufactured. Elaborate field work will be required to settle the question properly.

The order of the rocks across this basin is the following, from north to south. At the Devil's Den in Newbury is a mass of serpentine and limestone of Laurentian age, furnishing well characterized *Eozoön* from a locality a quarter of a mile to the north. The dip is 30° N. W., and I think there are ledges of gneiss near it. Next are compact porphyries, not very extensive. They are replaced by red and gray argillaceous schists, dipping 75° N. W. Near the crossing of Parker river are compact green schists, somewhat serpentinous, dipping 70° and 60° northerly. The slates dip 52° N. W. On the south side are the coarser conglomerates, with porphyry pebbles, not distorted. The last outcrops on the south side, before coming to the sienite area, consist of compact feldspars and siliceous slates, and a few diorites with dips like the others named. The first sienitic or gneissic rocks are traversed by seams, possible strata, dipping 35° N. E.

Until further exploration, I think the porphyries may be ranked as Huronian, corresponding to the similar rocks of Lynn, Saugus, and elsewhere in the Boston basin, while the slates and conglomerates agree with the related rocks of Braintree containing the characteristic trilobite *Paradoxides*.

Eruptive Rocks.

The most conspicuous of the eruptive rocks of the Coast district is the sienite of Exeter; the quartz is often absent, and it would then be styled diorite. As both types of rock are common in this district, neither name is appropriate for the whole series; but for convenience I will follow the Massachusetts report, and use the name of sienite for the rock generally. My father points out the distinction clearly between these rocks in his report, in the eastern part of the state, in the areas which are the perfect analogues of our New Hampshire ones. The best known of them in Massachusetts is that of Quincy, popularly called granite.

There are six areas of the Exeter sienite upon the south-east sheet. The first extends from Alfred to Berwick, Me. This has been crossed at Alfred, where a compact feldspar occupies the western border. Between Sanford and Lebanon are several exposures; and Bonny Bigg hill in North Berwick is of the same character. The second area, exclusively in Maine, lies in York, South Berwick, and Eliot. Mt. Agamenticus forms a part of it, and it is crossed on the road from York to South Berwick. It extends down to Cape Neddock, also. The shape of this area is like a crescent. The third and most important New Hampshire area is on the line of the continuation of the first one mentioned, and we cannot say with certainty they are not connected together. We have it first in Rollinsford, whence it proceeds directly to Exeter and Brentwood, where it passes beneath the lenticular drift hills that are so numerous there. In Rollinsford the exposures lie to the south of the Portland turnpike, appearing a short distance west of L. Stackpole's and along the boundary road west of Fresh creek. In Dover there are a few outcrops between Fresh creek and the main Cochecho river. The western limit is at Sawyer's mills, and it is the prevailing rock west of Bellamy river south of the Durham road. There is not much of the sienite in Madbury, because of the narrowness of the town. Durham is chiefly underlaid by this rock. It occupies ledges at the village, and at five places on the direct road to Newmarket. West of the railroad it extends to schoolhouse No. 4. Following around the Great bay it is found to alternate repeatedly with the Merrimack slate, as is the case all the way to Exeter village. The slate is wider in the town of Newmarket than at any other point between Dover and Exeter. The west border of the sienite is represented as even, perhaps through ignorance. All through Durham the seams in the sienite dip north-westerly, as if they indicated the place of strata. The more southern portion of this range displays a characteristic feature of the exposures. They are very numerous, not much loose material overspreads the ledges, and the soil is consequently barren. There is also a profusion of boulders scattered upon the surface, whose presence is usually a sure guide to the western limit of the area.

In Brentwood the western limit is reached at Marshall's corner, and it lies next to gneiss. Seeing sienite blocks at Brentwood post-office (Crawley's falls) used for piers of a bridge, I inquired for their source, and was told they came from a quarry about a quarter of a mile to the south. I have put in a small area to represent this statement, not feeling confident that it can connect with the main mass to the east. The unusual amount of surface deposits in Kingston and East Kingston obscure the ledges along the proper line of the continuation of the sienite, yet we have hints of it in Hampstead and Atkinson, and better evidence in Salem. There is reason to believe in its existence also farther south-west in Dracut.

There may be a dioritic ledge on the east side of Exeter river, a mile before coming to the north-east line; but nearly all the east part of Exeter is so covered by drift as to make a knowledge of the ledges impracticable, save after a very thorough examination. The very point of the town touches our fifth area of sienite, from Greenland to the south line of Kensington. There are exposures of sienite along the Winnicut river, on the line between Greenland and Stratham, in the edges of Stratham and North Hampton, and on the confines of North Hampton and Exeter, west of J. L. Philbrook's. The west border of this point is composed of felsite. In the west part of Hampton Falls are exposures by E. C. Sanborn's, and next to a tributary of Taylor's river. At Sanborn's there has been an opening for mining purposes which reveals an intrusive diorite, bunches of ankerite, plates of calcite, chlorite, crystals of smoky quartz, narrow quartz seams, etc. The farthest exposure seen of sienite in this range is near Miss Page's, in the south-east part of Kensington. Its further course is concealed by an abundance of till.

The last of these areas is that of Seabrook, which is the north end of the Massachusetts mass. The western limit of it is where the Eastern Railroad crosses the state line. It extends a mile and a half into the township, and is then covered by drift. In the marshes opposite Bound Rock the natural continuation of the sienite is taken by a granite. I have examined a few ledges of sienite in Salisbury, Newburyport, and Byfield, and have copied the delineation from the Massachusetts map. Our observations develop nothing additional to what has been already published by my father. There may be some further notice of these rocks under the topic of Economic Geology.

The sienite of Mt. Pawtuckaway in Deerfield and Nottingham is represented as like that of the Belknap mountains. As it is midway between the different areas, it is also intermediate in character between them. Situated in the midst of gneiss, it does not afford evidence of age when compared with the various mica schist groups. Like the more northern variety of rock, it is accumulated in a mountain mass, and cannot easily be esteemed a gneiss slightly altered.

The granites of our south-east sheet are of little moment, apart from the numerous beds interstratified with mica schists, which have been mentioned in their proper places. The granite of South Kingston and in Andover, Mass., has been already alluded to. There is a very large granitic area in North Berwick, Sanford, and Alfred, Me., which is more like the Mt. Bet series of New Durham than anything else described in New Hampshire. It may be that some of the sienitic area to the south of Newburyport is to be regarded as granite.

The trap dykes are well represented in this district. Concerning one on Pawtuckaway, Whitney says, in Jackson's report,—"On the lower mountain there occurs a dyke of greenstone trap, which crosses its summit and divides it into two nearly equal parts. This dyke is singularly columnar, and, on the face of a bare ledge, inclined about 45°, it assumes the form of steps, fifteen or sixteen in number, each about nine inches in height. They are known to the inhabitants as the 'Stairs.' It varies from six to twelve inches, and was traced for a quarter of a mile." Final report, page 30. Jackson speaks of other dykes on the sea-coast north of Little Boar's Head, running in a north-east direction, and varying in width from a few inches to ten feet.

One of the most interesting dykes seen near Portsmouth is one of sienite twenty-five feet wide, near the powder magazine, two or three miles out from the post-office. It has the course N. 50° E., and seems to be conformable with the schist adjacent. The phenomena indicate that this diorite, lithologically the same with much of the Exeter group, was erupted after the deposition of the Merrimack group, probably during the epoch of its elevation. I observed it for 200 or 300 feet in length. Such facts suggest the origin of the Exeter rock subsequently to the deposition of the Merrimack series.

There are several trap dykes on Frost's point, Rye. One of them is fifteen feet wide, with many small, irregular branches. Loose specimens near by seem like labradorite diorites. Several have been noted in Seabrook, as in the village and at the school-house to the south-east. A short distance north of the village there is a beautiful porphyritic trap, where the feldspar crystals are like kernels of rye, of light color, scattered through the black base.

Little has been done in the study of the trappean rocks, as we have been waiting to ascertain their proper mineralogical designations, which will be given under the head of Lithology. Meanwhile we may call attention to an interesting case of dykes crossing one another at Bald Head in York. The first eruption was of a large, porphyritic trap dyke, with the course N. 55° E.; the second kind is more compact and fine-grained, running north-east, but irregularly; the third series cuts across both the others, and must therefore have been injected at a later epoch. The material is a brown scoriaceous trap. These three kinds of rock occur in our state, and belong to the same epochs of eruption with those in York.

CHAPTER IX.

DESCRIPTION OF THE GENERAL SECTIONS.

THE conduct of the geological survey of New Hampshire has been based upon the careful measurement and delineation of fourteen sections, crossing the state at regular intervals. These have been drawn several times during the progress of the work, for the museum and for study. Their final representation may be seen upon the geological map in the atlas. Lines are drawn to indicate their positions through the various townships, while the projections appear at the bottom of the several sheets, so placed that the eye can readily connect the profiles and geological coloring. These sections are drawn upon the same horizontal and vertical scale. Our conclusions as to the age and equivalency of the formations are based upon these delineations.

The museums of the New Hampshire College of Agriculture and the Normal School contain the specimens procured for these sections, both for New Hampshire and Vermont, those from the latter state having been obtained at private expense by special trips taken for the purpose. The shelves of the first-named museum show the perfected arrangement, and it is to be hoped the same will be true of the collection at Plymouth. At Culver hall a wall forty feet long is devoted to this set of specimens. Fourteen shelves are arranged in order, one over another, from the floor to the ceiling. Care is taken not to impede the view of the colored profiles between the shelves by braces or railing in the gallery, so that the visitor may take in the whole structure at a single glance. The specimens from each section are placed in front of the drawings, each one directly in front of its place on the profile, and corresponding numbers enable one to identify the place of the 3,000 localities represented. This wall of sections is therefore a truthful representation of nature. Everything is in its proper place, not distorted by theoretical views; and one can study the rocks nearly as well as in the field. The bringing together of the specimens in geographical order will save years of travelling for any who examine the collections.

The College of Agriculture caused to be prepared and exhibited at the centennial exhibition at Philadelphia, in 1876, a delineation of thirteen of these sections across both the states, on the horizontal scale of two miles and a half to the inch. It would be very desirable to have this drawing reproduced, one fourth the size of the original, for the atlas. Much more detail could be given in such a sketch than is possible upon the profiles placed at the base of the map sheets, and it would be possible to illustrate the relations between the formations of the two states. This is done to a small extent upon our sheets, as the profiles are made to extend as far as the coloring, somewhat beyond the state limits. This method of survey and illustration was first proposed by my father for the Vermont survey, and was fully carried out for the report upon the geology of that state. In the museum at Montpelier the specimens were properly placed, but no sections were protracted for the spaces between the shelves. It was supposed that the curator would have attended to this business, as he aided in the collection of the specimens. Our later collections and sections, relating alike to two states, possess more than double the value of the first, since they cover twice as much area, and exhibit the results of ten years of study. Repeated visits to the localities and a comparison of conclusions enable us to locate overturns and faults, very essential to the proper understanding of the positions of the rocks, but which cannot be discovered without great effort. It is not claimed that the representations are yet beyond the possibility of improvement.

Our limited space will prevent us from giving detailed descriptions of all these sections. Those desiring information beyond that of the report will find it at the museum. I will notice the sections in order from south to north.

Section I.

The first section follows the most southern tier of towns in the state, and is made to extend to the Atlantic ocean, in the south part of Ipswich in Massachusetts. Our collection of specimens commenced at Lawrence. The section delineated is about ninety-six miles in length, ten miles distance being in Vermont, beyond Connecticut river.

At the east end next the ocean is a broad stretch of salt marsh. There is a broad band of sienite next, followed by hornblende schist. In Georgetown is the hornblende schist range, possibly of Huronian age. Boxford and North Andover exhibit the gneiss, called Laurentian by some, and much like the Lake group of New Hampshire. After this, in the Merrimack valley through Lawrence, Methuen, and Dracut, we find the Merrimack group dipping usually at a high angle to the north-west. The gneiss east of Lawrence dips easterly; and there may follow, first, a synclinal before reaching Essex street, Lawrence, then an anticlinal, the west end having a smaller dip (see Fig. 109). The junction of this Merrimack quartzite with the Pelham gneiss is not seen; but the dips in Dracut and Pelham indicate that the pressure has been exerted so as to fold the anticlinal beneath the westerly-dipping gneiss at N. Hobbs's. The gneisses in the extreme east and west parts of Pelham dip towards each other, though the presence of a porphyritic gneiss at J. Gage's, west of the village, suggests a double synclinal resting upon an older rock between. There are materials for two axes in Hudson, the western border of the gneiss dipping 50° N. 30° W. at a turning-shop.

Next there is the broad valley of mica schist of the Nashua valley, referred to the Rockingham series, and making a double basin with a narrow range of gneiss in the middle. This extends into the edge of Brookline. Proctor hill furnishes examples in the western part of the micaceous area of the interesting feldspathic or granitic beds, such as have been noticed farther to the north-east. A range of Merrimack slate seems to belong to the middle of the band, in the west part of Nashua. The Lake gneiss following displays a prominent anticlinal along the west line of Brookline, with a probable synclinal to the east of the village. In Mason there is so much divergence between the dips east and west of the railroad as to suggest the presence of a folded westerly inclined anticlinal. On reaching Greenville we are introduced to a considerable breadth of the ferruginous and other mica schists most, likely connected with the Montalban series. The westerly dips prevail entirely through New Ipswich, but we have shown in Fig. 94 a basin of mica schist overlying the older rocks, reaching from the village to the east base of Barrett mountain. It is likely an anticlinal is present in Barrett mountain, which is the mountain ridge between the Merrimack and Connecticut valley depressions. Between the east line of Rindge and Peasley pond are two, perhaps three, axes in the ferruginous group of the Montalban. In Fitzwilliam there rises to the surface a little porphyritic gneiss, with the peculiar granite of the region upon both flanks. There is a difference of opinion whether the latter rock is a true granite or gneiss, whose planes of stratification are usually obliterated. There are also two appearances of the Bethlehem series in Fitzwilliam. In the west part of the town the Montalban rocks dip 75° westerly, making a sharp synclinal with the same strata in the east part of Richmond; and there is another anticlinal before reaching the village. From this village through the rest of the town and the principal part of Winchester the gneiss is thought to belong to the Bethlehem series, with quite variable dips. There would be the basin structure before reaching Muddy brook, perhaps a second synclinal in the valley of that stream, though this is not clear, and a very distinct anticlinal between Muddy brook and the tributaries of Perchog river. This gneiss distinctly and unconformably underlies the Coös quartzites, the point of contact being visible. This comparatively modern group furnishes three ranges of quartzites before coming to Connecticut river, which are supposed to constitute one band repeated, and to underlie the mica schists, the latter assuming the basin shape, and carrying notable quantities of indigenous granite.

The quartzite crops out on the west side of the river at South Vernon. As the next seven miles have been described already with much detail (p. 437, Fig. 71), it will be unnecessary to repeat the observations here. To the west of the Cambrian are easterly-dipping slates, at Fall river. Guilford will be found represented in a basin of the Calciferous mica schist, followed by an anticlinal ridge of hornblende schist, supposed to be Huronian. The sheet ends with the repetition of the calcareous rocks on the west side of the hornblende.

Section II.

The second section commences at Seabrook, at the south-east corner of the state, and passes through the towns of South Hampton, Newton, Kingston, Hampstead, Derry, Londonderry, Litchfield, Merrimack, Amherst, Milford, Wilton, Temple, Peterborough, Jaffrey, Marlborough, Swanzey, and Chesterfield, a distance of ninety miles. About five miles of Vermont are appended, in the town of Brattleboro'.

The very east end of the section consists of the northern termination of the Newburyport range of sienitic rocks, overlaid by thick deposits of sand and marine mud. There are exposures of a granitic rock traversed by segregated veins in the marshes, which may underlie the sienite. There is about a mile width of Merrimack schists to the west of the crystalline masses, extending a short distance beyond Seabrook village, which are much disturbed by miscellaneous trap dykes. They seem to stand very nearly on edge. One of the large feldspathic masses common in this group is found a short distance west of the village. From there no ledges can be found for eight miles, because they are concealed by the enormous development of lenticular drift hills. The rock is thought to be the same with that in Seabrook. Through Newton and Plaistow the dips are north-westerly, and of material suggestive of the Rockingham group, save the first ledge in South Hampton. The dip changes so as to furnish a synclinal in Hampstead, and an inverted anticlinal next the ancient range of gneiss extending from Hampstead village to the Nashua & Rochester Railroad in Derry. In this are some minor undulations, but the general inclination is westerly, to underlie the broad mica schist belt in Derry, Londonderry, and Litchfield. The structure of this last is usually synclinal, the axial line running through the east part of Londonderry. In the west part of Derry are argillaceous schists, the highest part of the series possibly belonging to the Merrimack division. Extensive feldspathic or granitic beds prevail in the outer parts of this basin upon both sides. Litchfield shows no rocks, being covered by sand. The next group is the ancient twisted gneiss of the Manchester range. At Souhegan village are outcrops of a very coarse mica schist, seemingly the upper layer of the formation, and repeated on the other side of the fold. This last axis is a very marked one, the ridge line connecting with the anticlinal noticed on the first section between Brookline and Mason. In Milford is found a large development of granite, one of the ovoid masses occupying the stratigraphical horizon of the rock quarried in the north part of Manchester. There is no change in the position as far west as the formation occurs, into the eastern edge of Wilton. Not far from its western border there occurs one of the famous quartz bands dipping north-westerly, and reäppearing in the eastern part of Temple. Between them the rock is mostly a long, narrow strip of Rockingham mica schist, with several small, subordinate folds, the western part having a less inclination than the eastern. The quartz of Temple lies in a narrow band of Lake gneiss, followed on the west by the mountain mass of mica schist in Pack Monadnock, dipping west. In Peterborough the western edge of the mica schist makes a synclinal trough; and another gneiss area shows itself, with two or more folds in it. In the west part of the town and in Dublin the porphyritic gneiss succeeds. This formation occurs along two different lines in Jaffrey, each believed to extend beneath both the Peterborough gneiss and the ferruginous Montalban rocks of south-eastern Cheshire. Mt. Monadnock follows next. This is believed to belong to the Kearsarge andalusite group, and to overlie unconformably the Montalban rocks. In structure it seems to be a double synclinal, and it rests upon a basin-shaped arrangement of strata. The Montalban strata on the west side in Marlborough dip easterly generally, and contain patches of Concord granite. In Swanzey there is a broad Bethlehem band, with nearly uniform high easterly dips. It overlies the Winchester and Chesterfield anticlinal porphyritic gneiss area. A little Montalban gneiss skirts this on the west, followed by the Coös group, which exhibits the common structure of two basins side by side. In the Connecticut valley it is followed by an older ridge of Cambrian slates. West of the slate the structure is exactly the same with that west of Fall river on Section I, with Calciferous mica schist on both sides of the hornblende schist anticlinal. Denudation has cut through this hornblende in West Brattleboro', and displays the underlying arched gneiss, which may correspond either with the Bethlehem or Lake division of New Hampshire gneiss. I once calculated the amount of erosion from this arch, finding that 950 feet of gneiss and 2,640 of hornblende were required to fill out the gap.

Section III.

Section III extends from Newcastle and Portsmouth to Walpole, as specially measured, a distance of seventy-five miles, but some additional facts are known for a little of Kittery, Me., and Westminster, Vt. From Kittery through to Newmarket Junction the rocks are referred to the Merrimack group, composed of quartzites, siliceous mica schists, argillaceous rocks, with a few feldspathic beds resembling granite, consisting of arenaceous beds metamorphosed in place. From Kittery through to Stratham the predominant dip is westerly, corresponding to the easterly dips on the west side of Great bay in Newmarket. Along this section the water of the Great bay seems to occupy a natural basin. In the eastern section of the basin we find several minor axes, as in the north part of Newcastle, among the houses in Portsmouth, etc. More will be discovered after careful scrutiny. Next to this modern group comes the Exeter sienite, lying in Newmarket and the east part of Epping. It is followed by essentially the same micaceous and quartzitic formation, though described in the report under the designation of Rockingham. There is a well-marked basin just east of Epping village, and an equally distinct anticlinal in the west part of the town. This has been noted as the great line of division between the eastern portion, perhaps belonging to the Merrimack group, and the Rockingham and Huronian beds to the west in Raymond. The anticlinal is made by the presence of the Hampstead gneiss range, choosing for itself a partly subterranean pathway to join the ancient gneiss in Nottingham, but coming to the surface in West Epping. The schists to the west of this gneiss constitute a synclinal, closely pressed in the east part of Raymond, and containing a very marked band of white quartz just east of the depot. On the west side of the village, as far as to Jones's pond, the ledges consist mostly of supposed Huronian hydro-mica schist, with some dolomites, suggestive of the Lisbon group in the Ammonoosuc district. There is next a considerable width of the Manchester range of gneiss, remarkably twisted, very granitic, and showing in the central part of Candia the master anticlinal noticed upon Sections I and II, in Mason and Amherst. East of it is the inverted anticlinal in the west part of Raymond, and a synclinal in the east part of Candia. The Manchester granite is not conspicuous in its proper place on the line of strike, but an additional band shows itself, the continuation of the Hooksett area, in and on the west side of the Merrimack river in the south part of the town. On Campbell's hill is the southern range of quartz, not far from its eastern termination. Through Hooksett the rocks dip westerly to just beyond the western band of quartz, where there is evidence of a short synclinal, which ought to cause a repetition of the quartz if it be a genuine basin. There would seem to be an anticlinal following, between the south end of Bow and Dunbarton. These rocks all belong to the Lake gneiss, but that which follows in Dunbarton is Montalban, and strangely enough it presents the anticlinal structure at Kimball's pond. On Dunbarton hill the Lake gneiss reäppears with west dips. Hence this Montalban development either rests unconformably upon the Lake gneiss, or else there is an inversion equal to that described as characterizing the porphyritic gneiss (p. 529). In the east part of Weare occurs one of these porphyritic gneiss areas, with westerly dips. This has Lake gneiss upon both sides, all three bands similarly inclined, and hence inversion must be invoked to explain the phenomena. In the middle of Weare is the westerly-dipping mass of Mt. William, consisting of Rockingham mica schist, and resting upon the Lake gneiss, which is more characteristically developed in this town than is usual away from its typical region. We have evidence of two foldings in the west part of this area, the last dipping westerly, to come up again in the narrow range to the east of Deering village. The rock between the Merrimack ferruginous slates, partly in Weare and partly in Deering, and so far as seen along the section, dips uniformly to the north-west. West of the Deering gneiss belt the ferruginous slates reäppear, with a very distinct basin shape, resting upon still another gneiss belt along the Contoocook river. The two gneisses are also supposed to dip towards each other beneath the ferruginous formations.

In the Contoocook gneiss, on the west side of the river in Antrim, is an outlier of Montalban dipping with the former, because apparently caught in it and forced to conform to it. On reaching the valley of the northern branch the porphyritic gneiss of the main central range is met with, dipping easterly underneath the Lake gneiss. Very soon the dip is reversed, and in the west part of the town there is a well-marked synclinal in it. The easterly dip is then continuous to Stoddard village, where it is underlaid by inverted gneisses of the Montalban series. In Stoddard this assumes the anticlinal form, followed by a synclinal in the east part of Gilsum. This Montalban area terminates obtusely in the north part of Stoddard. The west part of Gilsum is occupied by easterly-dipping strata of Lake gneiss. In the north part of Surry we cross the narrow range of fibrolite schist carrying the very coarse granite veins. This rock dips westerly at a high angle, and probably rests unconformably upon the Lake gneiss to the east in Gilsum, and upon the Bethlehem group in the west part of Surry, the latter dipping easterly, being almost vertical. Walpole is entirely composed of the Coös rocks. The high hill west of the Ashuelot river exhibits mica schists, carrying granitic beds with small westerly dips, running underneath the quartzites along Fisher brook. Farther to the west the dips are higher, indicating an anticlinal, and hence the quartzite is older than the mica schists, but made to assume the inverted attitude by the terrible crowding from the east by the Gilsum and Surry gneisses. Just east of Walpole village are ledges of argillaceous schists, dipping only 10° N. W. If these belong to the Coös group, as seems probable, they would correspond to the schist in the east part of the town, and are in their normal position.

We have now reached the modified drift of the Connecticut valley, which conceals the ledges for a considerable distance. In Westminster we find the Cambrian clay slates, nearly vertical and inclined towards the Walpole rocks. The few miles west of the river on this line have not been directly traversed. The occurrence first of the calcareous rocks west of the slates, and then of a narrow band of hornblende schist, overlying a large gneiss area, is well established by observations upon both sides of the section line.

Section IV.

Section IV properly commences at Great Falls, passing through Somersworth, Rochester, Barrington, Strafford, Northwood, Epsom, Chichester, the north part of Concord, Hopkinton, edge of Warner, Bradford, Washington, Lempster, Acworth, and Charlestown to Connecticut river, a distance of eighty miles.

The rocks east of it in Maine for ten miles are believed to consist exclusively of the Merrimack mica schist. Their stratigraphical position has not yet been determined. The same group extends through Somersworth and the south part of Rochester, and there is an anticlinal in it. The enormous sand plain of Rochester and Gonic obscures the underlying rock ; but in Barrington is a considerable Rockingham schist, with the uprising of an ancient gneiss in the south part of the town. In the west part of Barrington the Rockingham rock reäppears, followed by the gneiss of the Bow lake and Northwood region, in which there is an anticlinal, and the westerly dips prevail through Northwood, underlying the next Rockingham band through Epsom. This shows us the basin structure, resting upon Lake gneiss in Northwood on the east, and the Montalban in Chichester on the west. In Chichester and Pembroke the dip is north-westerly, so that this White Mountain series is anticlinal in form. Next the broad sand plains of Concord cover most of the ledges. The section passes across the north end of the oval granite area of Concord, and the smaller patch north-west from Pine hill. The same north-west dip prevails through this formation in the north part of Concord, including the interesting band of white quartz at West Concord. This Montalban ridge is not crossed at right angles by the section, as it runs between north-east and east. Before reaching the west line of Concord we discover the later ferruginous slates, with dips at such diverging angles as to suggest the presence of one or more foldings. At Contoocookville another Concord granite area presents itself, following an outcrop of the ancient porphyritic gneiss on the hill south from Tyler's station. The dips of this and the accompanying ferruginous schists are easterly, all overturned. West of the Contoocook granite is another part of the ferruginous group, apparently synclinal in aspect, with soapstone in the edge of Warner. The section nearly crosses the Montalban of the south-east part of Warner, carrying the quartz and limestone, and evidently a repetition of the West Concord exposures. The ferruginous slates to the west of this Montalban upheaval dip westerly, folding over the underlying formation. Next follows a long breadth of porphyritic gneiss from Henniker to Washington. This consists of a series of folds, an anticlinal in Henniker, followed by a synclinal to accommodate the hard schists occurring along Warner or Harriman brook ; a second anticlinal east of Day pond, and the succeeding basin holding the Lake gneiss area about Bradford pond ; another repetition in the same order in the south part of

Bradford, where is another patch of mica schist. Other axes occur just to the north of Murdo hill, East Washington, and perhaps at Washington village, the western border of the gneiss. Part of this section has been given in Fig. 85. The west part of Washington is occupied by the usual Lake gneiss of the country west of the porphyritic dividing ridge. The strata everywhere stand nearly vertical. Near its western border the porphyritic gneiss reäppears in what has been called the Marlow range. West is the Lempster mountain range of mica schist, carrying the very coarse granite veins from which mica is obtained in merchantable quantity. The dips are all easterly.

The greater part of Lempster and the east of Acworth belong to the Lake or common gneiss, as described in Chapter V. Many dips are southerly at small angles, so that one or more folded axes may be made out. The western border of the ancient gneisses is reached near Lynn in Acworth; after which Coös mica schists and quartzites prevail to the Connecticut river through Acworth and Charlestown. These rocks exhibit several foldings; and extensive denudation is indicated by the isolated patches of quartzite on several hills. There is evidence in Acworth and Charlestown of conspicuous faults, insomuch that any present theory of structure must be received with large allowance. Starting from the east border of the mica schist, near the village of Acworth, there is a strongly marked anticlinal. On the hill by J. Grant's (p. 416) the quartzite is said to lie horizontally. The southern extension of the range at Z. Slader's acts like a shallow synclinal. At Prospect hill in Charlestown is a high south-east dip; vertical strata on the high land between Page and Oak hills, so that a synclinal is needed to connect the Prospect with the Acworth schists; four axes before coming to the Oak Hill quartzite range, near Charlestown village; and an inverted synclinal in Calciferous mica schist west of the quartzite range. One can hardly help suspecting the recent age of this quartzite from the descriptions given of them in Chapter IV. They are repeated in Skitchawaug mountain, in Springfield, Vt., making a distinct synclinal axis (p. 412). There is now a new matter of interest on the Vermont side of the river, since a band of Huronian two miles wide has made its appearance in nearly vertical strata. West of it is the continuation of the Calciferous mica schist group, probably in synclinal attitude, and beyond is the ancient gneiss of Chester, whose structure will appear to better advantage farther north, because it has been studied there. The clay slate of the lower sections seems to be wanting on Section IV, unless it be buried beneath the alluvium.

Section V.

We have satisfactory data for the delineation of the whole of this section, from the extreme eastern limits in Alfred, Me., to Reading, Vt., a distance of ninety-five miles. It passes through Alfred, Sanford, Shapleigh, and Acton, Me.; Milton, Middleton, New Durham, Alton, Gilmanton, Belmont, Tilton, Franklin, Andover, Wilmot, Springfield, Grantham, edge of Croydon, and Cornish, N. H.; Windsor, including Mt. Ascutney, West Windsor, and Reading, Vt.

The Maine portion of this section has been illustrated sufficiently well in Fig. 108, Pl. XXV, and the accompanying description. The first rock in our state is the Rockingham group, showing several undulations in the first two towns, usually of little general consequence. The presence of the andalusite schist on the east of a prominent anticlinal in Acton suggests the possibility of finding the same repeated in the east part of Milton. In Middleton may be seen Montalban rocks underlying the mica schists of Milton, imperfectly developed on account of the abundance of drift scattered everywhere as a thin covering over the ledges. The axes through to Lake Winnipiseogee are noted upon page 603. On the west side of Alton bay is a large ledge of sienite; and near the travelled road no other ledge has been noticed, except one of mica schist on the summit, dipping 70° N. W. This is the northern end of a large area of this description, repeated on reaching Gilmanton. Between Pine mountain and Place's pond are areas of porphyritic gneiss, with vertical strata, and sienite. The Rockingham group through Gilmanton and Belmont is characterized by the presence of numerous minor undulations, six or more in number. Among them is a synclinal constituting the ridge of Grant and Lamprey mountains; and the place of an inverted anticlinal west of Belmont village, occasioned by the underlying gneiss. Another well-marked gneiss area appears in Northfield. At Tilton the dip changes abruptly, since the rock is different, most likely Montalban, the beginning of the Merrimack Valley area of this formation. Near the west line of Franklin appears the anticlinal in it, caused by the extension northward of the

Lake gneiss of Salisbury. The Montalban may extend a little beyond Horseshoe pond; after which are the close complicated axes of the Kearsarge group, illustrated in Fig. 103. Past Andover succeeds the great central ridge of porphyritic gneiss in Wilmot, with two closely pressed folds. Across Springfield and Grantham is the widest part of the Lake gneiss development west of the central ridge to be found anywhere in the state. There seems to have been an extensive uprising of the earth-mass in this region, not sufficient to bring up the porphyritic rock, but enough to prevent the deposition of the micaceous group, unless the elevation took place after its accumulation, and its exposure to atmospheric agencies has led to its removal by denudation. Portions of this gneiss are somewhat porphyritic. There must be a synclinal between Col. Sanborn hill and Station pond, both sides dipping easterly, the east one the most. Stocker pond is about the place for the anticlinal. There is a basin for the valley of Croydon branch in Grantham, on the west side of which is a long stretch of white quartz. Farther west we come to an area of Bethlehem gneiss, extending into Croydon, and possibly reaching to the west border of the gneiss, though not so represented upon the map. A synclinal to the east and an anticlinal on the west show us the structure of the area. Protogene gneiss characterizes the centre, and a porphyritic variety the west side of this development. The last dip is quite moderate, only 15° W., and it is covered by the Coös rock of Croydon mountain. The first met with is quartzite, dipping 75° N. W., and soon afterwards the dip is in the opposite direction, so that the first range of quartzite is a closely pressed basin. On the west slope of Croydon mountain the mica schists with staurolite overlie the Calciferous schists, probably by inversion. The attitude of the rocks through Cornish is expressed in Fig. 62, page 397. This is the broadest area of this formation in the state, and is evidently characteristic of the group. The eastern portion is clearly monoclinal, and here is inverted. Two or three faults develop subordinate axes in the west part of the town, the first between two Huronian bunches, the second occurring on the east bank of the Connecticut, a short distance above the bridge. These Huronian bands are the narrow representatives of hornblende and hydro-mica schists developed much more extensively farther north. Crossing into Windsor the section passes over Mt. Ascutney, which is a high mountain composed of igneous material, partly of Eozoic age and partly exuded since the deposition of the Calciferous. The igneous material occupies an east and west chasm in the limestone, and has altered the rock in contact with it. The material is sienitic and felsitic, much like the Chocorua series. On reaching Little Ascutney we find partly the same eruptive rocks, breccias, and gneisses, the latter making an anticlinal with the eastern part of the range found at the west ends of the first five sections. I have traversed this line across the state of Vermont, and find the normal structure of this gneiss range in West Windsor and Reading to be anticlinal. The gneiss is like that of Grantham and Newport in New Hampshire. A depression in it in the west part of Reading carries a small synclinal of the Calciferous mica schist, and the gneiss most likely exists as a synclinal underneath it. This gneiss does not crop out again on the line of strike until we reach Section X.

Section VI.

In proceeding northerly the width of the sections in New Hampshire diminishes, the present one being seventy-one miles long, from Effingham border to the Ledyard bridge at Hanover. The coloring of the map and section extends ten miles farther into Vermont. The eastern portion in Maine has not been explored particularly, though confidently believed to belong to the Montalban series, and so described heretofore. The ridge of Lake gneiss extends into Parsonsfield from Wakefield, thus separating the Montalban into two parts. The dip has been represented as uniformly monoclinal to the east in this section of Maine. Green mountain consists of granite, which has come up through an east and west fissure in the schists, like Ascutney, and accumulated in amount sufficient to build up a considerable eminence. Our observations exhibit an anticlinal to the south of the mountain, the first dips being to the south-east. This has been thought to be naturally connected with the formation of the fissure through which this granite has been erupted. The Montalban schists through Effingham and Ossipee are like those of the typical region, tender, friable, imperfect, and often ferruginous gneisses. In the town of Ossipee there is a closely-pressed synclinal showing this formation to overlie the Lake gneiss of the Winnipiseogee basin. This more ancient gneiss shows itself in vertical exposures about Dan Hole pond, overlaid both to the north and south by eruptive rocks, the Conway granite on the former side, and porphyry on the latter. In passing near Melvin peak the porphyry is found to succeed the gneiss of "Canaan," and to occupy nearly the whole of this eruptive area of Ossipee. At the Ossipee falls, on the west side, the Albany granite is found beneath the porphyry in a thin strip, resting like a blanket upon the upturned edges of the Lake gneiss. To the south of the mountain mass the dividing line between the Montalban and Lake groups runs through Tuftonborough corner. Between Ossipee falls and Center Harbor the section passes through the typical region of Lake gneiss, and exhibits three important flexures. West of the Center Harbor landing we find porphyritic gneiss, with westerly dips. This has been already shown to be doubled like the barb of a fish-hook; and the range repeats itself, with fan-shaped structure, in New Hampton. The Lake gneiss between has been forced into a monoclinal attitude, with a small anticlinal just at its west border north of White Oak pond in Holderness. After passing the porphyritic gneiss, the Montalban succeeds through Bridgewater and Hebron, exhibiting no less than five foldings. The anticlinal of Peaked hill in Bridgewater seems to be quite an important one. Fig. 82 covers nearly the same ground with this section between the Ashland and Groton bands of porphyritic gneiss. Another, on a parallel line to the south, Fig. 95 (p. 567), shows five foldings in the Montalban. North of Hebron village we have the mica-bearing rock in its largest development. Groton, along the section line, mainly consists of porphyritic gneiss, being the northern end of the great central range, and exhibited only because Cockermouth brook has cut down through the superincumbent formations. The western border of the porphyritic gneiss is thought to be overlaid unconformably by the mica schist, the same with that in the north part of Hebron, and is disposed as a double basin. This is underlaid on the west side by the Lake gneiss, in a closely-pressed anticlinal dipping easterly. It is supposed to underlie by inversion the porphyritic gneiss in the axis between the micaceous basins just mentioned.

Two bands of hornblende schist occur in Canaan, on the sides of a synclinal mass of fine-grained Bethlehem gneiss. To the west of this hornblende, cropping out near Goose pond, is an anticlinal mass of the coarser Bethlehem gneiss, occupying all the space between the finer-grained variety and the Moose Mountain Coös development. The western part of it is coarsely porphyritic.

In Hanover we find on Moose mountain a conspicuous and persistent range of quartzite, standing nearly vertical, and not exhibiting, so far as understood, any folding. It is overlaid by staurolite mica schists, dipping westerly, and, it is supposed, beneath clay slates of the later part of the Coös age. These last are disposed in the double basin attitude, supposing that the western part, consisting of purely vertical strata, is a fold closely crowded. They bear some resemblance, however, to the Cambrian slates of the Connecticut valley (p. 394). The segment of micaceous schist following belongs to the upper part of the Bethlehem group; and I have sometimes represented it as separated by a fault from the slates on the east, and the typical Bethlehem area on the west. They have an easterly dip throughout. West of Mill village follows next the Hanover area of Bethlehem gneiss of the typical variety, a coarse protogene gneiss. The structure of this has been studied more than that of some regions, because of its situation near the head-quarters of the survey; and we are well satisfied it is an inverted anticlinal dipping westerly. A band of white quartz traverses it like those so often referred to in other formations. On the west side of it is a repetition of the Moose Mountain quartzite and mica schist, less in their thickness but identical in composition and age. Their dip is westerly, the same as that of their analogues. On the college grounds the hornblende schist, inverted over the Coös slates, makes its appearance, dipping to the west. It is about a mile wide, and may be seen in close contact with the Lisbon group of the Huronian in Norwich. A careful analysis of this formation in Norwich (p. 363) shows the probable existence in it of five flexures. I doubt not similar reduplications can be found in every town of the state, if explored as thoroughly as these conveniently-situated ledges near our head-quarters have been. Next occur the Cambrian clay slates, monoclinal, and in their natural place between the Huronian and Calciferous groups. The latter exhibits through Hartford a synclinal structure, and on the west side succeed micaceous quartzites dipping easterly beneath them. The latter I have referred to the Coös group, believing the calcareous strata usually overlie them. The area occupied by similar non-calcareous schists is quite large in Vermont, and I have not yet been able to satisfy myself thoroughly that they are properly classified. In order to explain their place in West Hartford, one of two alternatives must be taken: either these micaceous quartzites are the equivalent of the clay slates, since the two formations dip towards each other beneath the limestones, or there must be two faults, one on each side of the quartzites, to enable them to lie between two calcareous areas. The larger fault would in this case stretch along the valley of White river, perhaps running up to the neighborhood of Copperas hill. After leaving West Hartford the limestones reäppear, more thoroughly calcareous than before, and dipping at a much smaller angle easterly, or in the same direction. If this rock be followed through to Barnard, we find three well marked folds in it, with a supposed fault before coming to the clay slate group again.

Section VII.

This was not one of the original sections marked out. It was found desirable to represent the rocks along its route, and therefore observations were taken for it from Freedom, just touching the north base of the Ossipee mountains, passing thence north of west to Sandwich notch. Our specimens and observations have been taken along this line. Reflection shows that this is an unfortunate route, because quite crooked and terminating too near Section VI. I have therefore made use of whatever observations could be had along a line farther north, and will draw the profile to fit the new locality, saying what seems to be true of it, hoping to be able to travel over the ground directly along the line before the representation has been finally engraved and colored. Should there be any discrepancy between the description and the protraction, the reader may know the latter to have been obtained from information provided subsequently to the preparation of the text.

As thus altered, Section VII commences near Sebago post-office, in Maine, reaches New Hampshire in Eaton, passing then through Madison, Tamworth, Sandwich, Campton, Ellsworth, Wentworth, and Orford, and in Vermont through the limits of Fairlee, Thetford, and Strafford. The total distance through New Hampshire is fifty-nine miles; from the extreme point in Maine to the end in Vermont, eighty-seven miles. On this line we first touch the outer edge of the White Mountains.

From Sebago across to Chocorua pond the rocks are exclusively Montalban. It is believed the great anticlinal, causing the rocks to dip in opposite directions, while those on each side are mostly inverted, takes its course nearly along the state line, so that all the Maine ledges on this section have the south-east, and those in Eaton, Madison, and Tamworth the north-west, dip of this arrangement. On reaching the north part of Tamworth the Chocorua group of granitic rocks is met with. The section crosses the southern extension of these eruptive masses, protracted southerly from Mt. Chocorua. The view of the latter mountain in our colored heliotype certainly suggests the presence of other groups besides this on the north side of the pond, but I have no positive knowledge respecting their possible occurrence. A range of Montalban succeeds, extending to Weed's Mills, and thought to consist of a folded synclinal. The occurrence of Lake gneiss a little south of the section in Sandwich and converging to a point, suggests its presence across the line of description underground, thus producing an anticlinal division of the Montalban, which may not necessarily show itself at the surface. Farther south the gneiss shows three folds. In order to reach the Notch from Weed's Mills, one may pass north of Guinea hill and over the Black mountain spur of Sandwich Dome. We find here gneiss dipping north-west and north. The west part of the town is occupied by a range of porphyritic gneiss. Next is a synclinal of Montalban holding a large dyke of Albany granite, and showing a slight recurrence of the porphyritic gneiss in the east part of Campton, and quite fully in the Pemigewasset river. Between these two ancient ranges we must conclude the monoclinal Montalban strata to consist of an inverted synclinal. A similar easterly dip prevails west of the Pemigewasset, before coming to the porphyritic gneiss of Ellsworth. The latter consists of two folds, the most western occupying the slope of Carr's mountain. In a basin near Ellsworth pond is a considerable band of andalusite mica schist, either Montalban or later, perhaps connecting related rocks in Rumney with others in Woodstock. On the summit and west side of Carr's mountain the andalusite mica range occurs contiguous to the porphyritic gneiss and dipping towards it. In Wentworth the Lake gneiss has a full development, having a monoclinal east dip before coming to Baker's river, and showing an anticlinal on the west side. An isolated band of quartzite indicates an underlying gneiss basin in the west part of the town. In Orford the prominent quartzite range of Mt.

Cuba rests upon Bethlehem gneiss, the first indicating a basin form, and there being a well marked anticlinal between the two quartzites. Fig. 51 shows facts of stratigraphy in a section from Mt. Cuba to Orford street, a little to the north of our route of examination. The Bethlehem range is well marked west of the Cuba ridge. It contains an important bed of limestone, and exhibits one or two folds, the undulations being less marked here than farther north, because more compressed. West of Bass hill the particular features of this section as far as Connecticut river are shown in Fig. 52. These are, first, two foldings in Coös schists; second, an underlying patch of Huronian with soapstone at Orfordville; third, monoclinal Coös schists containing narrow bands of granite and hornblende schist. Underneath the meadows of Orford and Fairlee there must be a considerable amount of Huronian to connect the known outcrops of that formation in North Thetford and Fairlee. The first rock visible to the west of the modified drift is clay slate, near by the north end of the Hartford and Thetford band. Next is a broad band of the Coös micaceous quartzites, reaching as far west as Podunk pond in Strafford. Next the eastern border of this group, in the extreme north part of Thetford, two folds are obvious, while in Fairlee a synclinal band is indicated by the divergence in the dips, 15° and 60° N. E. There is a new strike in the strata about the Ely copper mine in Vershire, and also at a similar vein east of Strafford. On comparing other copper veins with these, we find a suggestion that the copper is either in or near an older hornblende range, and hence we may be guided in determining the nature of the foldings in the cupriferous region. West of Podunk pond, in Strafford, the change in dip and rock is so abrupt as to suggest the presence of a fault. The hill east of the Centre village appears like an inverted synclinal of the mixed mica schists and limestones lying upon a hornblende band. The characteristic limestones with easterly dips occupy the valley of the Pompanoosuc in the middle of the town, and make an anticlinal in the hill west.

Section VIII.

Section VIII may be said to begin at Bridgeton, Me., reach the New Hampshire boundary at Kimball's pond in Chatham, pass over Mt. Pequawket, and extend through the towns of Bartlett, Hart's Location, Livermore, Woodstock, Benton, and Haverhill to Connecticut river, thence through Newbury and Topsham in Vermont, a total distance of eighty miles.

The Maine portion of this section is believed to consist entirely of Montalban strata, extending to the east base of Pequawket, where it dips westerly at a small angle beneath the mountain. The mountain itself presents interesting peculiarities, whose details are fully given on page 237. We find three kinds of igneous rocks,—a sheet of Conway granite at the base, Albany granite in the middle, and the peculiar breccia of Pequawket constituting the upper half of the mountain. From the Saco valley across to the Pemigewasset nearly all the ledges are of varieties of granite distinctly eruptive. At first is the Conway rock; then the Albany granite over the ridge around which the Saco finds it necessary to flow northerly, or the north-eastern spur of Moat mountain. In Upper Bartlett the Conway granite returns, extending about to the west edge of the town. The section just touches the north edge of the Chocorua group in two places, as piled up in the area of Mt. Tremont and its associated summits. This lies upon a Montalban area in the Saco and Sawyer's rivers valleys, where the strata show monoclinal westerly dips. After crossing a little more Conway granite, the section reaches the very interesting outlier of porphyritic gneiss in Sawyer's River valley, at the south base of Mt. Carrigain, the most northern exposure of this range known. The relations of this rock to the porphyry of Mt. Carrigain are well shown in Fig. 15, Plate X, save that the gneiss should be represented as dipping east instead of west. The porphyritic area is followed by a broad expanse of Conway granite, capped by the Albany in the upper part of the Hancock Branch valley, and about the forks of the east branch of the Pemigewasset. Near Pollard's in Lincoln, and constituting the west border of the eruptive area, is situated the Conway rock, probably the same with some large eruptive dykes. Between Pollard's and the Pemigewasset river the Montalban crops out with high easterly dips, which are evidently normally synclinal. The following broad band of porphyritic gneiss through Woodstock and Benton has not been much studied. It is believed to underlie Moosilauke, so that both the floor and the mica schist of the summit exhibit the basin structure. West of this mountain are the Lake and Bethlehem gneisses, with several folds. In Haverhill the Coös quartzite and schists are well developed, and are fully illustrated upon Plate XIV. Fig. 47 seems to follow very nearly the course of Section VIII. Among its most important features are the numerous flexures in the Huronian; and the presence of the Lyman group for the first time in our sketch of the sections, in following their numerical order. Viewed generally, the Lisbon group is seen clearly to underlie the Lyman. They are followed by the Coös micaceous quartzites, with reversed easterly dips; and these in their turn by the Calciferous mica schists near the western edge of Newbury, dipping in the same easterly direction. The valley of Tabor creek indicates clearly an inverted basin, followed by an anticlinal in the deepest part of the valley. The hill between this and Wait's River village seems to exhibit the double basin character. The great axis of the formation is reached in the east part of Washington, while the rock continues to the east line of Northfield.

Section IX.

Section IX has been measured from the state line between Batchelder Grant and Bean's Purchase, through the last-named tract, Green's Grant, Thompson & Meserve's Purchase, Sargent's Purchase, in which the top of Mt. Washington is situated, Crawford's Purchase, Nash & Sawyer's Location, Carroll, Bethlehem, Littleton, and Monroe to Connecticut river, a distance of fifty miles; thence through Barnet and Peacham in Vermont to the western limits of the map. No attempt has been made to traverse the part lying in Maine east of Bean's Purchase, though that is believed to belong to the same series with those first seen within the state.

In Bean's Purchase the rocks are altogether Montalban. From Mt. Royce to Carter all the strata are said to dip westerly. Between the ridge and the Peabody river there may be two flexures. Concerning the route westward from the Peabody river, or from the Glen house to the summit of Mt. Washington and to the base on the west side, our observations have been numerous, and are fully described upon page 116 and Plate VII. The general conclusion reached is, that the mountain is essentially anticlinal in attitude, with several subordinate flexures upon the east side, including the very important synclinal below the Half-way house carrying the squeezed and somewhat faulted basin of andalusite slates. The pitch of the Mt. Washington anticlinal is westerly. Below the base station of the mountain railway is a broad expanse of a granitic rock, like the Concord, not necessarily stratified. Ledges are wanting for about two miles east of the Lower Ammonoosuc falls, where the Conway granite sheets, dipping slightly north-west, appear, constituting the north end of the Rosebrook range. This is the only ledge seen along the river; but the Sugar-Loaves on the southern side consist of similar material. Shortly before arriving at the Twin Mountain house in Carroll are indications of the presence of the typical area of Bethlehem gneiss. The section, unfortunately for showing structure, follows nearly along the line of strike of this formation. The nature of the axes is somewhat uncertain. It seems clearly enough to be an anticlinal, through the diversity of dips near the east end, but synclinal, with a monoclinal inclination, through Bethlehem. The lower part of the formation is porphyritic, while the upper is nearly a mica schist, with white feldspathic nodules. The best argument for the basin structure is the occurrence of porphyritic gneiss on both sides, with synclinal dips.

At Littleton two formations overlie the Bethlehem series,—first, a strip of ordinary (Lake) gneiss, and, second, the Coös schists, the last the most highly inclined. The last are usually between the two gneisses. On the west occurs a narrow strip of the Lisbon group, and then alternations of this with fossiliferous Helderberg (p. 329). The Lyman group comes up west of the Lisbon; and west of Partridge pond there is a range of clay slate. The section crosses the north end of Gardner's mountain, seen on Plate XIII to consist of several flexures closely crowded together, with an anticlinal in the centre. The clay slate appears in scanty amount west of the Huronian at Barnet. It is inverted beneath the Huronian of Monroe, as is also the Calciferous mica schist farther west. No variation in the dip of the latter is noted; and in the west part of Peacham it comes in contact with the Marshfield area of granite. This eruptive mass is probably of diverse ages, like that of Mt. Ascutney, a part of it being earlier, but most of it later, than the calcareous schists.

This section was first measured for the Vermont geological survey in 1858, and a view of it published in the final report of that state, connecting together the White and Green Mountains. The present sketch is not so lengthy; but the New Hampshire portion has been greatly improved over that early delineation.

Sections X–XIV.

These have been already described on pages 86–97, and figured more in detail upon Plate VI than upon our general map. We have also added something to X and XI from Vermont, besides a great deal to XV in the Canadian portion of the sheet. The west end of Section X in Lancaster is obscure, the dips not being readily understood on account of the nature of the rocks. In Lunenburg, so far as known, the Lyman group is nearly ubiquitous, with a westerly inclination. Miles mountain is of monoclinal westerly-dipping Montalban strata, having Lyman schists upon both sides, so that it may for the present be set down as anticlinal. The Coös group appears at West Concord, then the Lisbon series, probably with easterly dips. The Waterford slate range has the same position still farther west, followed by a broad expanse of the Calciferous mica schist in St. Johnsbury, Danville, Walden, and Hardwick.

Section XI shows the continuation of the Northumberland and Lisbon rocks into Guildhall, dipping westerly, beneath the Lyman synclinal of Burnside mountain. The remnant of the latter is a clay slate, and the Coös mica schists are located between this Lyman rock and the Montalban of Granby. The last series is better developed than upon Section X, and displays unmistakably the anticlinal structure. Inverted Coös schists appear on the west side of this Montalban patch, and are believed to rest upon the latter group, but to dip beneath the Calciferous group of East Burke by an overturn. The synclinal in East Burke is well marked, while an easterly dip is persistent through to the granitic axis in the centre of Sheffield, where they dip in the opposite direction.

Reference has been made already to the west end of Sections XII and XIII. Inasmuch as the north-west sheet could be easily drawn so as to include a part of Canada, I have prolonged the short section XIV, (Pl. VI, Fig. I) to Massawippi lake. It exhibits next to New Hampshire, first, a little clay slate; second, a broad band of the Coös schists; third, the Calciferous mica schist; fourth, a repetition of the clay slate, and perhaps the continuation of the range bordering the Calciferous group on the west side through northern Vermont. Logan connected this slate with the limestone succeeding it on the west, carrying Helderberg fossils, but on account of its situation I have believed it must be the equivalent of that in central Vermont. The Helderberg fossils described in the Canada reports belong to the upper part of the series, or Devonian. The presumption is, therefore, that these limestones upon Massawippi lake are of Devonian age, and therefore different from those of Littleton, Lyman, Lisbon, and Bernardston, which are so plainly Silurian.

I regret very much not to have room enough in this volume to present further details of these sections, and catalogues of the specimens obtained, as has been done with respect to those collected along Sections X–XIV, on pages 92–97. A hundred pages would be required to set forth all these details in a proper manner. An opportunity may be offered for their presentation in the future, after further study. The facts will not be lost, being preserved in the museum at Hanover, where they will be accessible to any one who may desire to become acquainted with them.

CHAPTER X.

CLASSIFICATION OF THE NEW HAMPSHIRE FORMATIONS.

WE have at last reached that epoch in the development of New Hampshire geology when it is proper to state our conclusions in regard to the establishment of the stratigraphical column. The rocks of each topographical district have been taken up in turn, and the most important details of their position and mineral composition presented. As this work has been progressing, many of the formations have quietly found a place for themselves, and there has insensibly arisen a scheme of classification, in some respects peculiar, but mostly similar to the general order of the older American systems. The reference of most of our rocks to systems older than the Silurian early commended itself in preference to the more modern doctrine of alteration from Paleozoic sediments. It has been our business to grapple with one of the most difficult stratigraphical problems ever presented to an American geologist for solution, and it would be presumption in us to claim that entire satisfaction has been obtained. I will first attempt to show how the formations may be classified without reference to their supposed age,—using local names derived from the localities where each one is best exposed for investigation. This course will enable those who may not accept our views of correspondence to establish for themselves any relation to Paleozoic groups which will commend itself. It has been our constant aim so to divorce the facts and theories from each other in the descriptions, that those who hold different general views from our own will not find the observations unwarrantably obscured by individual speculations.

Every one will grant at the outset that our field of labor must abound in inverted flexures and dislocations of the strata. Those who are not familiar with inversions will not be prepared to accept our statements at the first reading of them, because they seem contradictory to nature. It is only because inversions are the opposite of reality that apparently extravagant statements are correct. One who will apply the ordinary rules of superposition to the formations of a country like ours, will not only fail to detect the true structure, but will involve himself in labyrinthine perplexity. If our interpretation fails in any particular it will be in the neglect to invoke all the inversions and faults that are required for truthful elucidation.

Let us take an example for illustration. A section twenty miles long crosses a formation—say a hornblende schist—four times. The strata all dip in the same direction, both the hornblende rock and the intercalated groups. The natural method of interpretation is, to say there are four different horizons of this formation. One who has explored much among the crystallines will find it desirable to say there is but one formation, and that has been repeated three times. That view will simplify the classification, perhaps allowing us to refer the seven separate bands of the section to two. Cases exactly like this can be found, but usually the same bed is not repeated so many times. The principle is one that we are compelled to accept as fundamental, and to apply constantly.

Our older formations show a tendency to assume an ovoidal shape. Those familiar with New England geology will recall the similar representation of Percival's ancient groups in Connecticut, called K 1, K 2, and K 3. Our porphyritic and Bethlehem gneisses show this feature the most markedly. Where no subsequent disturbances have modified the natural order of the later bands, grouped concentrically around the ovoid nucleus, an easy method of determining relative age is afforded, even ifthe whole series is inverted. Then if there is a number of the ovoidal areas, not very far apart, we understand the comparatively recent origin of the rocks between them.

Another important doctrine relates to the identification of formations in our field of labor by means of mineral characters. Allowing for a certain degree of modification, we must believe that the same kind of rock in adjoining counties, or for greater distances, belongs to the same age, unless there is reason of importance to the contrary. For example, we trace one calcareous rock continuously for over 150 miles. There are slight modifications in its appearance from place to place, and still more so when we compare the specimens taken from the most extreme localities. I refer to the case of the Calciferous mica schist. In Canada a considerable portion of the series is purely a limestone, with occasional spangles of mica scattered through it. At the other extreme, in Franklin county, Mass., the limestone is reduced to occasional strata, a few inches thick, of micaceous character, perhaps containing 50 per cent. of calcium carbonate, while 90 per cent. of the formation consists of a mica schist. This modification of character is greater than is usually insisted upon for New Hampshire. The style of similarity, made use of for identification, is better shown in the porphyritic gneisses. There are over thirty areas of porphyritic gneiss, in which the feldspar crystals are very conspicuous for their size, the rock being the *Augen gneiss* of Europe. I assume that all the areas of this rock are identical in age, and, in speculating upon the relative positions of the intervening groups, rely upon the correctness of this starting-point. A thorough study of the specimens from the several porphyritic areas shows there are unimportant but uniform differences between them, so that boulders which have been transported from ten to fifty miles can be referred directly to their particular source, one or another of these areas. The fact of minor differences would seem to confirm our assumption of their identity in age, just as the paleontologist finds, from the presence of the same fossils, proof of contemporaneity in rocks with dissimilar mineral character.

Of still greater consequence is the method in which flexures are disposed. The following are some of their peculiarities in this field: 1. Symmetry of flexure is common, but by no means universal. Our sections are made much more even in the drawings than is natural. The elevating forces have crushed the strata together roughly, and we may not find the same thickness of strata upon both sides of an axis. 2. Hence the tenderest formations, like slates, are the ones most disarranged, the hard bunches of granite or gneiss being incompressible, and forcing the others out of place. 3. The vertical position does not necessarily indicate greater antiquity than an adjacent inclination of a much smaller angle. This appears also from the fact that the less inclined formation may sometimes have been inverted,—that is, moved more than to the perpendicular position. 4. Vertical strata may be resolved into compressed folds,—as many as the necessities of correlation seem to require. 5. Where there is an ascending series of groups, any one of the number may show several flexures. When their whole number is not known, the band may seem to possess an anticlinal structure instead of both the ridge and basin shape, or a fault may have cut away one of them. More than one section is often required to determine the structure of a particular band. 6. We have cases of what the older geologists called *fan-shaped stratification*. Some such are only apparent, and are readily resolvable into separate folds. Others cannot be thus explained, and are regarded as anticlinal, with the arch removed by denudation. 7. We find several examples of anticlinals on a gigantic scale. Should these be regarded as a single fold, thicknesses of 80,000 or 100,000 feet of strata must necessarily exist. A careful study of some of them suggests an origin from a double basin. The rising up of an older rock along the centre induces the anticlinal structure,—the ge-anticlinal of Dana,—and a continuance of the pressure produces on each side of the middle a series of inversions, each set turned outwardly from the central line (see p. 253); or the central line may be occupied by an eruptive rock. This will induce, in connection with subsequent lateral force, the same complicated anticlinal arrangement, while it will allow the belief in the original basin shape of the formation, now appearing so very different. We have, therefore, a basin that has the shape of a ridge for a part of its area; but in such a case there should be a closely compressed synclinal upon each border. 8. A somewhat different structure will result when there has been a sinking instead of a rising along the middle line,—the undulation called geo-synclinal by Dana. 9. The double-basin structure in its simplest form is one that has been very often invoked to explain the position of our formations, particularly in Chapter IX. Its frequency of occurrence, and the ease with which it can be made to explain the fan-shaped and complex anticlinal structure, show it to be the normal condition of flexure in our state. Other important structural features might be specified.

I will endeavor next to ascertain the mutual relations of several of the metamorphic groups, commencing with what seems to be very evident.

Various well ascertained sections will be mentioned, from which our column may be constructed.

In various parts of the Connecticut valley are narrow but persistent bands of hornblende schist, usually skirting the borders of gneiss. Near the west ends of Sections I and II in Vermont this band is seen unequivocally to fold over an arch of gneiss. The same feature is shown even more palpably at Shelburne falls, Mass., where the same four groups appear successively on both sides, viz.,—gneiss at the base, dipping 15 or 20 degrees; hornblende schist, mica schist, and Calciferous mica schist. There is a similar strip along the eastern border of the gneiss between Athens and Hartland, Vt.; and the underlying rock has the anticlinal structure, shown from careful scrutiny upon Section V. The same belt of rock lies above the Hanover gneiss, the Westmoreland area, and others, with the same relative positions. The Vernon-Hinsdale gneissic area is likewise encircled by this rock, but the dip is monoclinal: hence we have here an example of an inversion whose genuineness cannot be called in question. The hornblende layer occurs in a few other localities where our information is scanty; but the facts warrant us in assuming the existence of the same relations in the unknown as well as in the familiar spots.

The position of the porphyritic gneiss may be gathered from two or three classes of facts. The most extensive range, between Groton and Jaffrey, is flanked by the Lake and Montalban groups for a large share of its development. Going east from Warner, the Lake gneiss is well marked in Webster, followed by Montalban schist in Boscawen. Going south-west from the same town, after a long journey to cross the group, the Lake gneiss is first seen, extending all the way from Grafton to middle Stoddard in immediate proximity; and next is the Montalban from Stoddard to the state line south. The topographical distribution of these three formations indicates very clearly a succession. From what has been stated, either the basin or ridge structure is needed to explain the recurrence of identical formations on both sides of the porphyritic gneiss, which, by the way, is located along the height of land between the Connecticut and Merrimack rivers. Now the porphyritic gneiss possesses the fan-shaped disposition of strata; and there is very commonly a dip of the Lake gneisses towards it, both from the east and the west, as if the first-named rock capped the others. To make that view consistent, the Montalban rocks should always dip beneath the Lake series, in localities free from suspicion of inversion. Such are in Gilsum (Section III), the Salisbury gneisses notching into the Montalban (p. 532); the well marked anticlinal of Milan and Berlin, where the latter rock does not press closely upon the gneiss; and other cases. Hence the porphyritic gneiss cannot be the superior rock. Next we have the relations of the porphyritic gneiss to the Montalban, as in the great synclinal in Fig. 95, between Alexandria and New Hampton, the latter being uppermost, and likewise between Ellsworth and Sandwich, where the same truth is apparent. Near Thorndike pond in Jaffrey the porphyritic gneiss is distinctly synclinal beneath the Montalban. Consider, also, the mutual relations of these groups in other particulars. In Warner and Bradford isolated basins of Lake gneiss repose upon the porphyritic gneiss (Fig. 85), which is inconsistent with the notion that the former is underneath the latter. Between the Center Harbor and Ashland ranges (Section VI) the Lake gneisses are forced to conform to the porphyritic series, though at the very western edge of the Lake series is a local anticlinal. This agrees with the curvature of the porphyritic band from Ashland through New Hampton and Meredith. The numerous examples of isolated porphyritic areas can be explained best by their inferior position to the adjacent schists. Some of them are arranged in lines, as from Webster through Hopkinton and Weare to Greenfield.

From these facts it is inferred that the porphyritic gneiss is older than either the Lake or the Montalban gneisses, the last being the newest. Accepting this as a starting-point, we can understand the origin of the usual fan-shaped structure, arising from enormous pressure and subsequent denudation. (Further remarks to the point occur upon p. 529.) Numerous other cases of inversion and complicated structure make themselves clear after accepting these conclusions, which have been stated in the body of the report.

The place of the Bethlehem gneiss areas is not perfectly clear, though probable. They occupy the Connecticut valley to the west of the porphyritic gneisses. In only one place can we find the two ancient gneisses in contact, and that has been represented in Fig. 7, Plate VI. Between Franconia and the Wing road are monoclinal Bethlehem gneisses, while the porphyritic rocks seem to dip beneath them. If the relations between these two sets of rocks are properly represented in this figure, the greater antiquity of the porphyritic series is established. For want of better evidence, we have accepted this as decisive, and must so regard it for the present. The porphyritic gneiss of Winchester is partially encircled by the Bethlehem group, a fact that confirms the conclusion obtained from the Wing Road section. Our order, as now set forth, is the following: After porphyritic gneiss, the Bethlehem, Lake, and Montalban series. It may as well be said now as at any time, that nothing older than the porphyritic gneiss has yet been discovered. This formation constituted the first dry land in the state, as has been set forth in the first volume.

Another set of groups are the argillaceous, talcose or hydro-micaceous and calcareous series. Along the Connecticut river are the Lisbon and Lyman hydro-mica schists or *greenstones*, to use Mr. Hawes's proposed terminology. The same occur more abundantly along central Vermont east of the Green Mountains, characterized by the presence of serpentine, soapstone, and dolomite, which are found likewise in the eastern band. These two bands must be of the same age. Their dips are not constant, so that their relations to each other must be determined by the relations of the rocks between. Adjoining the greenstones, towards each other, are narrow areas of clay slate. Between the two slates the rock is mostly the Calciferous mica schist, with occasional bunches of eruptive granite. A careful analysis of all the dips across this calcareous group shows the structure to be synclinal (p. 402). The very large area of granite in the central part of this group is found showing itself from Section VII to Section XI, ridging up the strata just as might be expected from igneous action in connection with lateral pressure. Now if the central group, twenty miles or more in width, extending more than half through the state with this breadth, is a proper synclinal, and the two groups adjacent on both sides are the same, we have the most positive evidence in favor of the greater antiquity of the outer rock or the two greenstone ranges.

There is no portion of this report more carefully prepared than what relates to these greenstones and associated rocks in the Ammonoosuc field. Our observations may be generalized thus: There is a basin about ten miles wide, with several subordinate flexures, having the Lisbon, Swift Water, and hornblende series for its lower division, the Lyman argillitic schists for the second, and a thin band of conglomerate (auriferous) for its third or upper division. To establish this classification there is no need of resort to inversion, as the strata dip naturally in the basin form. The groups named are covered by several later series,—the clay slate, the Coös schists, and the Helderberg area. The first two are monoclinal, and the Helderberg rocks often stand on edge, owing to the enormous pressure that has been exerted upon them. The slates illustrate finely the change from the basin to the inverted form. In Bath the synclinal shape is perfectly distinct. In passing north the angle of inclination increases. Hills of the Lyman and Lisbon rocks have pushed through the slate very much as a nail punches through the same material in the form of tiling. Patches of the upper rock in Lyman remain as fragments of the original basin, but eventually near the Littleton line all the dips are westerly, and of course inverted. They are in separate parallel bands, divided by the greenstone.

There is another set of rocks, consisting of quartzites and mica schists, called the Coös group, that seems to underlie the Calciferous group, intervening between the limestone and clay slate. They all belong to essentially the same period, and their precise relations to each other are not of great consequence in the present discussion. The latest group of strata have a well-defined horizon in consequence of the discovery of Lower Helderberg fossils in them. They are found resting upon the clay slates and greenstones, while fragments of the Coös group aid in the building up of a supposed Helderberg conglomerate. For these and other reasons set forth in the sketch of the Bernardston deposits (p. 452) it is thought the Helderberg series is distinct from and newer than the Coös or Calciferous group; but if the Helderberg rocks carry with them any of our formations, it would be those named, and no others.

The next important question concerns the relations between the greenstones and the gneisses. This answer can be given quickly, assuming the correctness of the structure of the greenstones and calcareous groups, as already set forth. Gneiss dips westerly beneath the Ammonoosuc rocks, and easterly from the Green Mountain region, thus making a synclinal. There is no great difference between these gneisses, and they are referred to our Lake division in the descriptions. Some of the Bethlehem areas are intimately connected with the eastern band. These two groups, then, are older than the greenstones. In Hanover the apparent ascending order is this: first and lowest, Bethlehem gneiss with the Coös schist on its flank; next, hornblende schists; then the greenstones, followed in Norwich by the clay slates and calcareous rocks. This is apparently the natural order of age, the arrangement of the last three members having been already decided upon, and it shows the hornblende rocks and greenstones to overlie the Bethlehem group. It is more difficult to define between the Montalban and greenstones. A section from Success across to Dummer shows the greenstones bordered on both sides by Montalban, dipping south-easterly. In case the eastern area is anticlinal, as seems probable from the few facts at command, we have a clear case of a Montalban basin supporting greenstones, making the latter the newer rock. Our section in Fig. 5, p. 54, shows a Montalban anticlinal flanked by greenstones upon both sides. In Concord and Granby, Vt., is an anticlinal mass of Montalban rocks crossing Sections X and XI, having the anticlinal structure. Upon the east side are greenstones, and on passing to the next group east we find the Lake gneiss. This section from Concord or Granby to Lancaster would afford another synclinal basin of gneiss supporting the greenstones, but only one of them is Montalban. Essex county, Vt., shows a large amount of ancient rocks, evidently older than the formations of the Connecticut, Passumpsic and Clyde river valleys. Looking to the south-west we find, half way through Vermont, the gneiss range of Hartland and Athens. It seems natural to believe there may be some connection between these gneisses of Essex and Windham counties. This is important only as it carries out the general correspondences of age in different parts of the Connecticut valley. Between the Windham and Cheshire county gneisses is a narrow strip of greenstones, seemingly in a basin. The eastern range is continuous to the more northern section across Lancaster to Granby, where one sees gneisses as before in Windham county, and would naturally consider its relations of comparative antiquity to the greenstones the same. Though the gneissic ridge is not continuous between Essex and Windham, the greenstones may take its place in the gap, certainly so far as it is related to the superior slates and limestones upon both sides.

The Labrador system, if present in New Hampshire, is in very limited amount. Recent investigations make it difficult to say that the labradorite rocks are not of eruptive character. They have the composition of dolerite; and certain exposures of them upon Mt. Washington are surely injected dykes. Hence great doubt arises whether the larger area of Waterville really represents the Labrador system of Canada. At all events, its age is great, for these dykes cut through Montalban strata. This dolerite may be regarded as one of the oldest eruptive rocks in the state, coming to the surface in what was the Labrador age of the world.

Next there is an enormous surface occupied by various types of mica schist. They much resemble one another, and are confined to the region south of Winnipiseogee lake, unless one or more of them should be made the equivalent of the Coös group along Connecticut river. We have the local names of Rockingham, Kearsarge, and Merrimack applied to them. Of these the second is characterized by the abundant presence of andalusite; and the formation lies unconformably upon the Montalban at Mts. Monadnock and Kearsarge. In the sections across the mica schist group at Derry (Fig. 100) its synclinal structure is very obvious, resting upon the Lake group. The Merrimack group holds a similar relation to the gneisses, as in the Massachusetts section (Fig. 98) and between North Andover and Salem (Fig. 109). The Merrimack rocks would seem to rest upon the Rockingham, and probably the Kearsarge series does the same.

The eruptive rocks are not readily assigned to comparative ages, since the epoch of eruption cannot usually be fixed closely. There are three general centres of their distribution within the limits of our map. The largest is in the midst of the White Mountains; the next occupies the northern part of the same mountain group, divided midway by the Grand Trunk Railway; the third is in Essex county, Vt. Perhaps the labradorite diorites, and some of the dolerites cutting the older gneisses, should be ranked as the first rocks that have been injected. The principal eruptive masses seem to have made their appearance in the debatable period, either at the close of the Eozoic or early in the Paleozoic. They are the Conway, Albany, and Chocorua granites, sienites, and other granites. The porphyry has preceded these granites, since fragments of the former occur in the latter rocks. There are dolerites mineralogically like those of Triassic age in Massachusetts, and trachytes. The latter are commonly regarded as of volcanic origin, or later than Cretaceous. The question of the age of these eruptive rocks is now being studied by Mr. Hawes, and he will be able to present more satisfactory conclusions respecting them in his chapter on Lithology.

Equivalency of New Hampshire Formations.

Having stated the probable succession of our formations, it is proper next to correlate them with similar groups in adjacent territory. We find in Canada the systems Laurentian, Labrador, Huronian, and Cambrian. The first two of our groups may be referred to the oldest of these, the Laurentian, without great hesitation. We do not possess exhaustive information about the occurrence of this oldest system in other regions. So far as is understood, there are two sorts of associated rocks in its typical localities, one being largely pyroxenic. That variety is wanting in New Hampshire. A porphyritic or *augen* gneiss is eminently characteristic of the fundamental rocks in every part of the world, and hence ours may readily be called Laurentian. The Bethlehem group, consisting largely of protogene gneisses, is closely related to Laurentian rocks, though not so characteristic of them as the preceding.

Those who are familiar with the crystallines, as Prof. Dana (p. 109) and Dr. Sterry Hunt, after examining some parts of the Bethlehem group in New Hampshire, say that there is a close resemblance between them and the Laurentian. In a geological map of New Hampshire and Vermont, published in 1877 for a topographical atlas of the first named state, I have grouped these rocks, the porphyritic and Bethlehem gneiss, as Laurentian.

The next division, the Lake gneiss, cannot be so readily assigned. Its affinities are strongly with the Laurentian, but it is not pyroxenic nor porphyritic, nor does it abound in any triclinic feldspar. The Manchester range is thoroughly crystalline, and shows intensely twisted stratification, features that do not prevail in the other areas. I sometimes think this particular area, as well as its analogue in Berlin, might be separated from the others and put into an older group. In Massachusetts this group carries the *Eozoön*, but that fossil is not confined to the Laurentian. Limestone is not usually present in this group in New Hampshire.

The Montalban series are certainly not characteristic of the Laurentian. Dr. T. Sterry Hunt has thoroughly discussed this formation in his recent publications, to which repeated reference has been made in the foregoing chapters. In Volume I, page 526, I proposed to have the word *Atlantic* include the Bethlehem, Lake, Montalban, and Franconia groups, signifying a system between the Laurentian and the Labrador, and intending to restore an ancient use of the new word. After consultation with geologists, I find this usage not altogether satisfactory. Hence in the final classification I will drop the word Atlantic as applied to a distinctive system, using Montalban in its place. We retain the term Atlantic, however, in a geographical sense, and understand it as defined upon page 6. The Atlantic area includes geographically all the crystalline terranes that aid in building up the mountains adjacent to the ocean on the eastern border of the continent. There are Laurentian, Montalban, and Huronian rocks within it. The Montalban will certainly embrace the characteristic rocks of the White Mountains, the Concord granite, various ferruginous and fibrolite gneisses carrying the gigantic veins, and the Franconia breccia.

There is a point not yet made clear in the discussions about the relations of the Montalban rocks. Dr. Hunt is satisfied that they *overlie* the Huronian or greenstones. Our own observations lead to the view that the typical Montalban rocks *underlie* the same, as recently stated, though the precise relationship is not beyond controversy. There can be no doubt of the relation between the Berlin range of Lake gneiss and the Huronian, as shown in Fig. 6 and Section XI. These statements indicate the proper place to refer our Lake series. Inasmuch as it has certain affinities with the Laurentian, and clearly underlies the Huronian, we may for the present place it with the former, and leave the question of the relations of the Huronian and Montalban to be settled by other considerations. Our Laurentian column will therefore consist of the porphyritic, Bethlehem, and Lake gneisses.

The word Huronian has just been applied to the greenstones. Much has been said about this formation in the report, particularly a sketch of its distribution in the best known localities in eastern America (pages 457–465). It appeared that there are two well marked divisions of this system, the upper quite chloritic, and the lower quartzose and feldspathic.

The greenstones of our state seem to be closely allied to the upper Huronian, and the porphyries of Lynn, etc., Mass., to the lower division. It is possible that our supposed eruptive porphyries of the White Mountains belong to this lower division. They certainly possess the same lithological features, and in some cases have been protruded through what we consider the upper division. A different view has been taken of these greenstones. Sir W. E. Logan regarded them as the altered Quebec group of the Cambro-Silurian; and we find this view carried to a fatal extreme by Prof. F. H. Bradley, who insists that the original typical locality on Lake Huron is the same Silurian group metamorphosed, so that there is no such thing as Huronian in existence. If logic carries the theory to such an extreme, we need not be troubled to defend the Huronian, since there are few points in American geology better established than the inferiority of the Huronian grits to the Cambro-Silurian. We claim not merely lithological evidence to support the reference of certain New Hampshire rocks to the Huronian system, but also that the study of the stratigraphical relations of the several Canadian sections (Plates II, III, and IV) indicates a similarity in the order of the various groups. The Green Mountain gneisses, being either of the Montalban or Lake series, clearly underlie the Huronian in the East, just as the ancient gneisses do in Ontario and Michigan. We have a different classification of the Huronian in New Hampshire from that in Canada. No one yet understands the system sufficiently thoroughly to institute close comparisons, though only study is required to discover the proper correlation.

There is no reliable evidence yet in our possession to enable us to locate the precise place of the Merrimack, Rockingham, and Kearsarge groups of mica schist. The first is somewhat related to the Huronian, as well as in its argillaceous beds to the Cambrian. They are all referred to the Paleozoic system in our table, with a large interrogation point. The slates of the Connecticut valley are called Cambrian, because they are supposed to be the equivalent of the Paradoxides beds. The various members of the Coös group are ranked as Paleozoic, without direct evidence of their proper place. The same is true of the Calciferous mica schist. Logan referred it to the Niagara limestone. No fossils, except very obscure minute crinoidal fragments, have been found in it. Nothing need be said of the two Helderberg series, as their relations are well known. There are no formations in the state of later date than the Lower Helderberg, save the surface deposits. Full details respecting them may be expected in Part III.

Thickness of the Formations.

Making all suitable allowances for repetition of strata by flexures, I venture to add a column indicative of the thickness of our New Hampshire formations. For future reference, I will briefly state the localities relied upon for these estimates.

The figures for the surface deposits are taken from a general impression of the *maxima*. The thickness of the North Lisbon Helderberg has been roughly estimated at 500 feet (p. 338). In the Vermont report (vol. i, p. 449) the thickness of the Coventry Upper Helderberg deposit is estimated at more than 200 feet. The Calciferous mica schist, at its minimum, perhaps, is given in the same report (vol. ii, p. 617) as 4,800 feet. I have used the thickness of 3,000 for staurolite slate and 3,300 for the mica schist of the Coös group, from the measurements taken from the section in Fig. 28. On the Orford section the same are respectively 2,700 and 2,700 feet.

On the Lyme section they are 2,250 feet (reduced one half from the old measurement in the annual report, to allow the further folding indicated in Fig 54) and 1,500. The green schists following, 3,791 feet, may possibly be the equivalents of the Calciferous mica schist. In Hanover the slates amount to 2,400 feet and the schists to 2,100. These various measurements indicate that the thickness is not constant. The quartzite in Hanover is 800 feet, and in Orford 1,000 feet thick. I will use double the thickness stated in conection with Fig. 28 for the clay slates (Cambrian), because the inversion supposed to be present is doubtful, and 3,000 feet will better express our notion of the usual thickness of this formation.

In Andover the thickness of the Kearsarge group (Fig. 103), allowing five foldings, would be 1,300 feet. The Rockingham group cannot be measured satisfactorily. The average of two attempts (Figs. 99, 100) gives us 6,000 feet. For the Merrimack group, the thickness of one side of the Epping synclinal (Fig. 106) is taken for the standard.

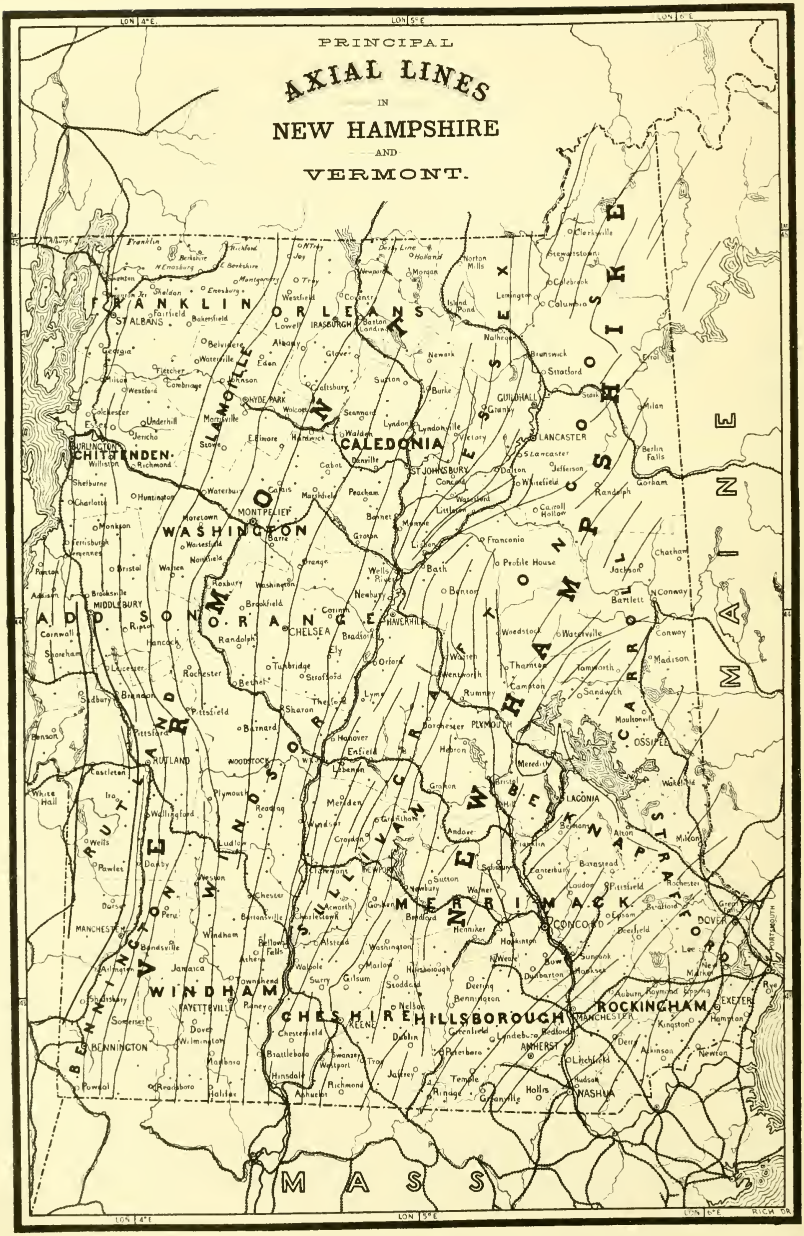
The thickness of the Huronian members is taken from Fig. 28, except the hornblende group. We assume fifteen sixteenths of a mile as its breadth, and 40° as the average dip of this band in Hanover. Dividing the result by two, the quotient is 1,580.

For the Montalban series, I will figure only upon the fibrolite and the ordinary series. The first, three tenths of a mile wide, at an angle of 60°, will show 1,370 feet thickness. Perhaps a fair average of the Montalban series may be obtained from a section between Glen Ellis falls and the north base of Mt. Pequawket, allowing for two folds and an average dip of 50°. This is not satisfactory, but the result of the calculation, approximately 10,000 feet, expresses fairly our idea of the thickness of the series.

For the thickness of the Lake series I have calculated the breadth of one half the Manchester range, or from Hallsville to near the south-east corner of the township, three and three fourths miles, at an average dip of 70°, making 18,600 feet. The breadth of the Bethlehem series in Hanover is calculated to be about 6,300 feet. The upper division may be estimated as 5,000 feet. Taking the broadest part of the porphyritic gneiss from Washington to Warner (Fig. 85), and allowing for seven flexures, we shall get 5,000 feet thickness for it.

Geological Map.

Constant allusion has been made to the general geological map of the state in the descriptions of the rocks. This has been drawn upon the scale of two and a half miles to the inch, and contours for every one hundred feet of altitude. It embraces portions of Maine, Vermont, and Quebec, and is engraved upon six sheets. The facts embodied upon it, both topographical and geological, have been derived from our survey. The formations represented are essentially those of the stratigraphical column given on a subsequent page, with such variations as the state of the case or the degree of knowledge allows. Many persons will recognize in it the features of a topographical atlas of the state recently published by Comstock & Kline. These gentlemen were allowed to use our delineation for their map. Quite a number of improvements in detail over this subscription map will be found upon it by those who examine the topography critically, and it covers a larger area. Many geological facts are added, besides the difference in paper and the elegant coloring. In case the distribution of the formations differs from the description of


PRINCIPAL
AXIAL LINES
IN
NEW HAMPSHIRE
AND
VERMONT.
FRANKLIN
ORLEANS
LAMOILLE
CALEDONIA
CHITTENDEN
WASHINGTON
ADDISON
ORANGE
RUTLAND
WINDSOR
WINDHAM
BENNINGTON
VERMONT
ESSEX
COOS
GRAFTON
CARROLL
BELKNAP
STRAFFORD
SULLIVAN
MERRIMACK
CHESHIRE
HILLSBOROUGH
ROCKINGHAM
NEW HAMPSHIRE
MAINE
MASS
RICH DR

HELIOTYPE

them in Part II, it should be remembered that there has been an opportunity for adding improvements since the printing of the text. Any points of great importance may be noticed hereafter in an appendix to Vol. III.

Axial Lines.

It has not been possible, till the last sheet has been printed, to prepare a diagram illustrating some of the principal anticlinal and synclinal lines of elevation or depression throughout the state. The general map is intended to show all the important dip-observations that have been taken and mentioned in the text, with a few additions. It may not be practicable to draw these lines upon the general map, so I have prepared a small sketch to show the principal ones, both in New Hampshire and Vermont, in Plate XXVI. This is the final summing up of all the multitudinous observations of this report. Very much might be said to good purpose respecting them, but our limits will not permit. This map and the statements of the last few pages are the key to Part II. They are the generalizations derived from our entire work, both in the New Hampshire and Vermont surveys.

The Atlantic Area.

Since the printing of Chapter I, more knowledge has been acquired respecting the distribution and equivalency of several of the groups in the territory adjacent to us. For example, the upper division of the Nova Scotia Carboniferous (p. 21) has been referred to the American representative of the Permian. The Mascarene series (p. 16) is now definitely known to belong to the Upper Silurian. The Canada reports claim the occurrence of the Medina group in the St. Lawrence valley, while no fossils of the period have yet been discovered in the red slates believed to be of that age. I have brought together upon page 675 a list of the larger stratified groups known to occur in the middle section of the Atlantic area. A comparison of the two columns will show that the later systems are absent from our state, while nearly every one of them is represented in the middle section of the Atlantic area.

FORMATIONS IN NEW HAMPSHIRE.

I. Stratified Groups.

Era	Group	Formation	Thickness in feet.
CENOZOIC.		Modified drift, including kames, gravel, and sand deposits, Champlain clays,	250
		Glacial drift,	200
		Total Cenozoic,	450
PALEOZOIC.		Upper Helderberg (Vermont), 200, Lower Helderberg, 500,	700
		Calciferous mica schist,	4,800
	COÖS GROUP.	Staurolite slate,	3,000
		Mica schist, often stauroliferous,	3,300
		Quartzite,	1,000
		Cambrian slates (Connecticut valley),	3,000
		Total Paleozoic,	15,800
PALEOZOIC?		Kearsarge andalusite group,	1,300
		Rockingham mica schist,	6,000
		Merrimack group,	4,300
		Ferruginous slates, with steatite (probably repetition of preceding),	
		Total Paleozoic?	11,600
EOZOIC.	UPPER HURONIAN.	Auriferous conglomerate,	50 to 300
		Lyman group,	2,330
		Lisbon group, containing steatite and serpentine,	3,539
		Swift Water series,	4,400
		Hornblende schist,	1,580
		Total Upper Huronian,	12,129
		Lower Huronian, porphyries of Massachusetts,	
		Labrador system,	
	MONTALBAN.	Franconia breccia,	
		Fibrolite schists, with gigantic granite veins,	1,370
		Ferruginous schists,	
		Concord granite,	
		Gneisses and feldspathic mica schists,	10,000
		Total Montalban,	11,370
	LAURENTIAN.	Lake Winnipiseogee gneiss,	18,600
		Bethlehem gneiss—fine-grained,	5,000
		Bethlehem gneiss—ordinary,	6,300
		Porphyritic gneiss,	5,000
		Total Laurentian,	34,900

Total, ... 86,249

II. Eruptive Masses.

GRANITIC.	Conway granite, Albany granite, Chocorua series, Granite cutting Coös group, Granite not otherwise assigned, Sienite of Mt. Gunstock, etc., Exeter sienite and diorite (Quincy),	FELDSPATHIC.	Labradorite diorite, Porphyry, Pequawket breccia, Trachyte.	AUGITIC.	Diorite, Dolerite.

FORMATIONS REPRESENTED IN THE MIDDLE SECTION OF THE ATLANTIC AREA.

CENOZOIC.	Quarternary, Tertiary.	MEZOZOIC.	Cretaceous, Triassic.
PALEOZOIC.	Permo-Carboniferous, Carboniferous, Devonian, Silurian, Cambro-Silurian, Cambrian.	EOZOIC.	Huronian, Labrador, Montalban, Laurentian.

INDEX TO VOLUME II.

ERRATA.

On page 12 the first entire sentence should be corrected to read thus: The two united extend only as far as Quebec, as shown upon Plate I, while there is an outlier upon the peninsula of Gaspé.

On page 20, lines 18, 20, and 22. omit the commas after First, Second, and Third.

On page 32, line 7, for "Upper," read *Lower*.

On page 126, line 13, for "branch," read *bank*.

On page 134, line 20, for "P. Q.," read *P. O.*

On page 176, line 28, insert *commencing* before 700.

On page 200, line 21. for "notch," read *station*.

On page 204, line 3, for "Waternoo," read *Weetamoo*.

On page 265, omit the sentence commencing "The Atlantic," in line 16.

On page 287, line 19, for "Fig. 32," read *Fig. 31*.

On page 302, line 26, for "Mt.," read *West*.

On page 352, line 8, for "Post," read *Pout*.

On page 408, line 3, for "EAST," read *WEST*.

On page 426, line 7, for "Fig. 80," read *Fig. 81*.

On page 444, line 2, for "Fig. 71," read *Fig. 72*.

On page 507, line 2, for "Grantham," read *Grafton*.

On page 514. line 8, for "east," read *west*.