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A CONTRIBUTION TO THE GEOLOGY OF SOUTHERN MAINE.

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INTRODUCTION.

The aim of this paper is to set forth the salient features of the geology of a small area in southern Maine from the points of view of physiography, chemico-mineralogical petrology and metamorphism, respectively. On the petrological side, the igneous rocks are those especially considered, and all questions of structure or stratigraphy among the sedimentary schists are omitted.

The area discussed comprises that part of the Boothbay quadrangle which lies between the Sheepscot and the Damariscotta river. The region is one of the typical examples of a fiord coast, while its rocks are a metamorphic complex of schists and gneisses, together with dike and plutonic igneous rocks ranging in composition from aplite to dunite. The purpose of the map is to illustrate the rock types described. It is not intended as a complete geological map of the region.

The field work was done during the summer of 1905, the writer being assisted by K. I. Cook and M. W. Adams. Microscopical and chemical work has been carried on during the past two winters in the laboratories of Columbia University. Prof. A. W. Grabau of Columbia University had previously visited the region with a summer field class from the Teachers' School of Science of the Boston Society of Natural History, and he kindly placed his specimens and notes at the writer's disposal. The map of Cabbage Island (Fig. 1.) was worked out by this class, and the diabase dikes on Linekin's Bay were found by him. Most of the rock types of the region were included in Dr.

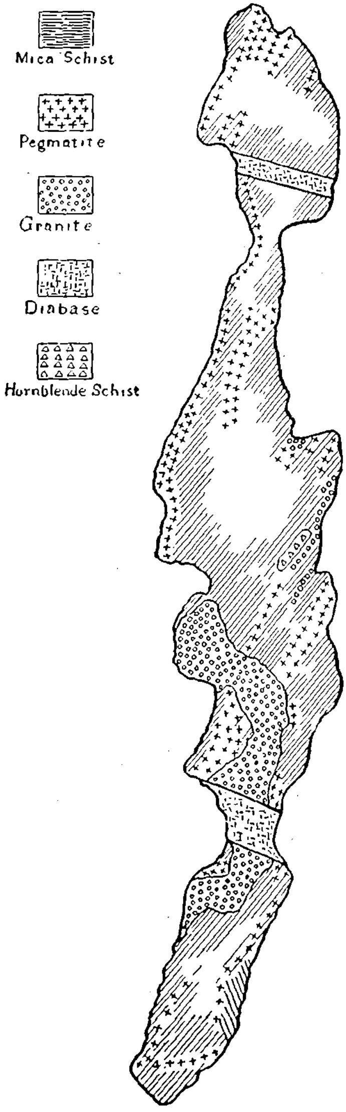
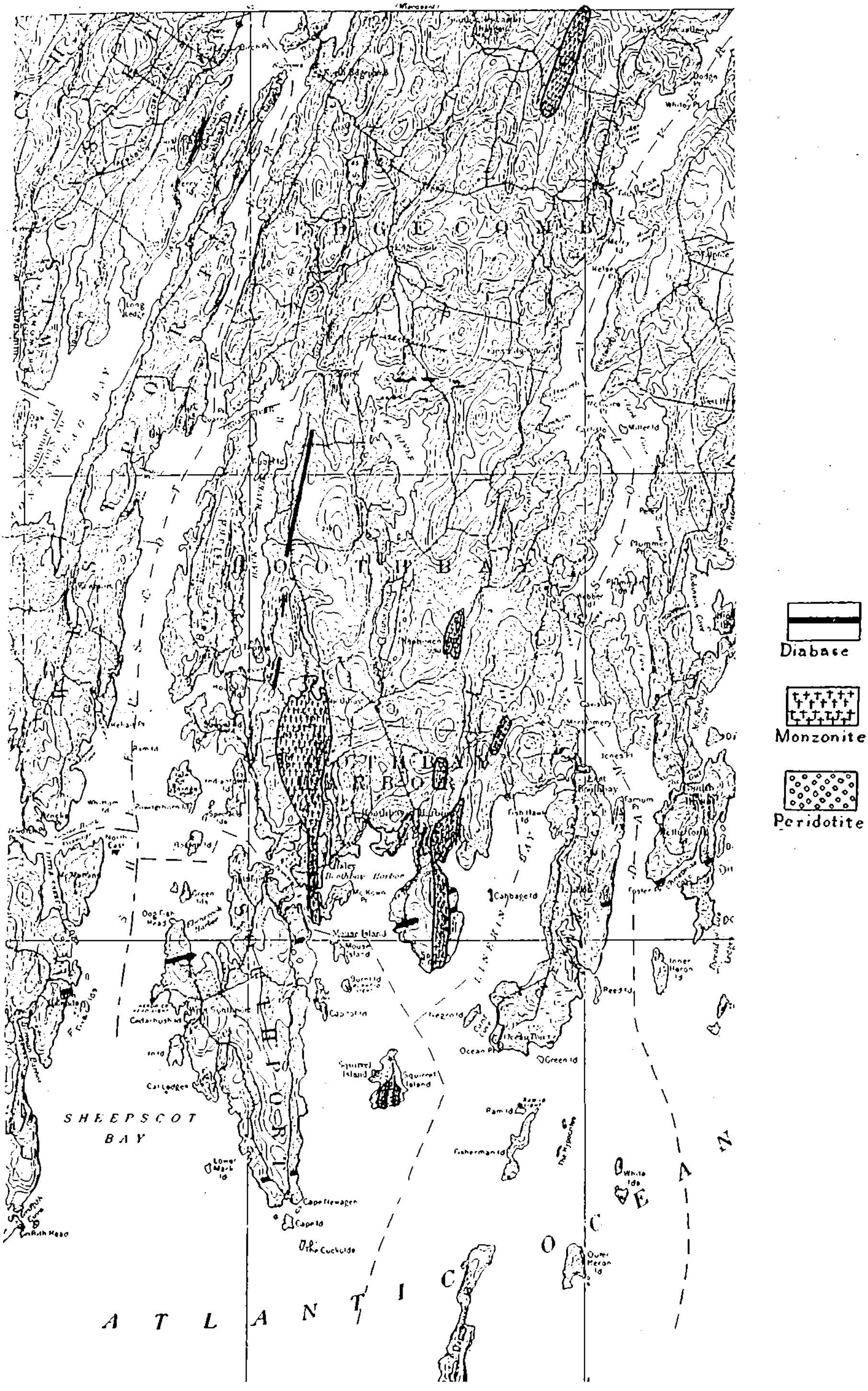


FIG. 1.
Geological map of Cabbage Island, Maine.

Grabau's collection, and especial thanks are due to him for this material.

The chemical analyses were done by M. W. Adams, to whom the writer is greatly indebted. The methods followed were those recommended by Washington in his book *The Chemical Analysis of Rocks.* The most important oxides were determined in each case, including both oxides of iron, titanium and phosphorus. The Lawrence Smith method was used for the alkalies; the colorimetric method for titanium, and ammonia for the precipitation of alumina, manganese being neglected. The bluish-green cake after the first fusion indicated that manganese was present in nearly every case. In the one rock (a diabase) in which it appeared to be greatest in amount, it was determined on a separate portion and found to be 0.35%. The aim of the analyst was to produce analyses that should be "superior" in the sense of being accurate, but which should be inclusive of the rarer oxides only in so far as the interest and importance of the region seemed to warrant.

There is no recent literature dealing with the area here described. Diabase dikes from the eastern part of the Boothbay



Diabase
Monzonite
Peridotite
EDGECOMB
BOOTHBAY
SHEEPSCOT BAY
ATLANTIC OCEAN
Squirrel Island
Mouse Island
Cape Newagen
Cape Id
The Cuckolds
Outer Heron Id
Inner Heron Id
White Ids
Fisherman Id
Ram Id
Ocean Pt
Green Id
Cabbage Id
Fish Hawk Id
Long Ledge
Miller Id
Pemaquid Pt

quadrangle were described by F. Bascom,[1] and these are inserted on the map (Fig. 2). Only the westernmost exposure of these dikes was examined by us. It was at first thought that Dr. Bascom's big dike might be the same rock-body as one of the dikes of Cabbage Island and the neighboring mainland, but repeated surveys across Linekin's Neck showed that, unless there is displacement by faulting, there are without doubt three parallel dikes.

The only other literature dealing with the area is comprised in the reports of C. H. Hitchcock. Of neighboring localities Monhegan Island about twelve miles to the southeast has been described,[2] and in Knox County, about fifty miles to the northeast some interesting rock types have recently been studied.[3]

PHYSIOGRAPHY.

The topography of the Boothbay quadrangle is characterized by an alignment of ridges and depressions in a direction which changes from due north and south in the southern portion to N. 20° E. in the northern. That is to say, each ridge and valley describes a curve. Tide-water enters all of the larger valleys and extends beyond the northern boundary of the quadrangle. The tides rush up and down these narrow inlets with great force and undoubtedly have great erosive power. Many tributaries enter the main valleys at abnormal angles, and the branches of the tributaries sometimes enter at abnormal angles, also, so that it is not uncommon for a single stream course to describe three sides of a square.

It is found that the major features which have produced the adjustment are the strike and the joints of the rock. The principal valleys are outlined by the strike, which has a general north and south trend; the tributaries are adjusted to the joints,

[1] "Dikes in the Vicinity of John's Bay, Maine," *Amer. Geol.*, XXIII, 1899, pp. 275–280.

[2] "Notes on the Geology and Petrology of Monhegan Island, Maine," by E. C. E. Lord, *Amer. Geol.*, XXVI, 1900, p. 329.

[3] "Some Unusual Rocks from Maine," by Edson S. Bastin, *Jour. Geol.*, XIV, 1906 p. 173.

of which the major ones have a N. 85° E. direction. Dikes follow some of the joints.

The oldest rocks of the region are mica schists, which are soft and easily eroded. Intruded into these are granitic rocks of various types, which are hard. The metamorphism which occasioned the schistosity followed the intrusion of the igneous rocks, and the present adjustment of streams is in part to the direction of the strike of the bands of soft rock, in part to the direction of the fissility. There has probably been some folding also.

Faulting on a small scale is frequent. Plate XXXI, Fig. 1 shows a small example of "Graben" on Negro Island. There are many such, the faults being usually of the gravity type. Whether there has been faulting on a larger scale, it is impossible to say; but the fact that the eastern shore of the promontories is invariably steep, while the western has a gentle slope is suggestive.

The drainage is well adjusted, and the only notable pre-glacial interruptions to the erosion cycle have been movements of elevation and depression. Evidence of elevation is to be seen in wave-cut cliffs and gorges, but these are at no great height above the present level of the sea. If any such great subsidence took place as has been described by Shaler in Mount Desert[1] it was of too rapid a nature for shore features to be developed. A single marine beach is to be seen on the north side of a hill east of Boothbay Harbor at an altitude of about 100 feet.

The diabase dikes produce notable topographic features. The dikes are harder than the surrounding schists, and in the interior of the country away from the sea, they stand up as conspicuous ridges. The dikes have a columnar parting which is either horizontal or slightly inclined. When within reach of the waves this columnar structure affords opportunity for wave action, and the dike thus attacked is worn away more rapidly than the surrounding rock, thus producing a chasm. These two contrasting topographic effects are illustrated in Plate XXXI, Fig. 2, and Plate XXXII, Figs. 1 and 2.

The altitude of the highest hills is of moderate uniformity; it varies from 200 to 290 feet above sea. This level apparently

[1] *Annual Rept., U. S. G. S.*, VIII, Pt. II.

does not represent a pene-plain, but is occasioned solely by the attitude and resistance of the hardest rocks—the granites. The softest rocks are the schists. These determine the course of the rivers, and are near sea level, while the more basic igneous rocks usually outcrop at intermediate altitudes. The elevations of intermediate hardness form knolls about 130 feet high.

There are no conspicuous glacial features. The drift is thin and consists mainly of scattered bowlders. If any physiographic work was done by the ice it was of the nature of excavation. There are no deposits of sufficient extent to cause any changes in drainage. Such lakes as exist are wholly or in part artificial. Striæ were found at the following localities and in the following directions. The direction of ice motion was evidently nearly southward.

TABLE I.

Glacial Striæ.

Locality.	Direction.	Rock.	Position on Map[1]
North end Adams Pond	N.–S.	Schist	30.4.3.
West side Linekin's Bay on northern dike	N. 10° W.	Diabase	54.3.3.
Beside road 3½ miles south of North Edgecomb	N. 10° E.	Gneiss	13.3.4.
Beside road 1 mile south of Edgecomb	N. 5° E.	Gneiss	14.7.3.
Same road 1 mile farther south	N. 5° E.	Gneiss	24.1.5.

The fiord character of the coast of Maine is usually ascribed to combined drowning and excavation by ice. The Boothbay quadrangle offers no new evidence on these points. It is clearly drowned, and ice excavation seems very probable; but there is one feature that this history does not explain, and that is the remarkable courses of the streams. As already mentioned it is by no means uncommon for a stream to begin by flowing north, to turn at right angles, and then after a short east or west course to enter one of the southward draining estuaries. The most conspicuous example is afforded by Adams Pond, Back River, Oven Mouth and the lower Back River. Adams Pond is

[1] The figures in this column indicate the position on the map in the manner described by Kemp, *Bull. Geol. Soc. Am.* XVI, p. 411.

artificial. It was thought that possibly there might have been a reversal of drainage brought about by glacial agencies, the Back River and Adams Pond valley having formerly drained southward. This seems clearly not to have been the case. There is more or less sand about the southern end and sides of Adams Pond, but nothing resembling a moraine and nothing in the way of drift that could possibly have blocked a stream. The valley widens northward and has every appearance of being a normal erosion valley developed with the drainage in its present direction. That it is pre-Glacial is evidenced by the presence of both material and striæ. The east-and-west Oven Mouth on the other hand is a very narrow cut with precipitous sides. Three tributaries enter it, two from the south and one from the north, and the tributaries have a much older topographic expression than the Oven Mouth itself. This is clearly due to the fact that the tributaries are developed along the strike and have advantageous courses, while the Oven Mouth is on a joint and cuts across hard layers. There seems no reason to doubt that these tributaries originated after the Oven Mouth, the latter being for practical physiographic purposes, the ocean, and the streams developing as similar streams might arise on an island. But the relation of the larger Back River valley to the Oven Mouth is not so clear. It might have been developed like the tributaries as a normal river valley subsequently drowned, but since the Back River is pre-Glacial, on this supposition the Oven Mouth would of necessity be pre-Glacial too, and the latter is a very steep-sided gorge. It would seem that this and the many similar streams in Maine must date their origin from a time when the slope of the land was somewhat different from what it is at present. The entire surface must actually have been higher than at present, but with relative depression towards the north. The recent drowning has led to the connection of these various valleys by way of much younger tributaries along the joints.

Sea cliffs are notable features of the present erosion cycle. These present interesting variations with respect to the kind of rock involved and the direction of the structure. The granite and the schist each has its particular topographic expression, and the direction of the cliff with respect to the strike has its effect upon the form of the resulting headland.

PETROLOGY.

It was the aim of the present investigation to deal only with those rocks which are of igneous origin, whether metamorphic or not. A considerable complex of schists and gneisses which appear to be of sedimentary origin was therefore left untouched. Some of the types are distinctly doubtful in origin, and it is quite possible that future research may add to the number of igneous members. The probable sediments are clearly the oldest components of the complex. By far the commonest of these older and doubtful rocks is a sandy mica schist, of decidedly sedimentary aspect. Realizing the uncertainty of the evidence of its sedimentary origin, and because of its very wide-spread occurrence throughout the coast region of Maine, it was thought that an analysis would be of interest. The analysis (Table II) bears out the sedimentary hypothesis. The silica is higher than in any of the igneous rocks of the region, though not excessive for a granite. Lime, iron and magnesia are nearly equal in amount, all being about 4%; the magnesia is relatively too high for an ordinary granite; the sum of the alkalis is too low. Though by no means conclusive the balance of chemical evidence points towards a sedimentary origin; the same is true of microscopic, and of field details.

TABLE II.

Duplicate Analyses of Mica Schist (Probably of Sedimentary Origin) from Spruce Point, Boothbay, Maine, by M. W. Adams.

SiO_2	71.28%	71.60%
Al_2O_3	12.17	12.38
Fe_2O_3	.62	.53
FeO	3.64	3.64
MgO	3.27	3.31
CaO	4.07	3.95
Na_2O	2.79	2.46
K_2O	1.86	1.89
H_2O+	.31	.31
H_2O-	.09	.09
CO_2	none	none
TiO_2	1.15	1.08
P_2O_5	.20	.20
Total	101.77	101.12

It is thought to be in the interest of accuracy to publish these duplicate analyses precisely as they were made. A better summation would have been obtained by making a composite of the two.

Microscopically the rock is characterized by shreds of biotite with parallel orientation, giving a typical schistose structure. Quartz, orthoclase, a plagioclase near the albite end of the series, brown hornblende and a very little augite make up the rest of the rock, with a little accessory magnetite and apatite. The pyroxene is of the common augite variety, slightly violet tinted from titanium; it is usually twinned, but with no crystal boundaries. The whole is much strained, the feldspars being cracked with minute fissures all parallel to each other, the cracks being filled with sericite. The quartz is decidedly granular.

A specimen from Rutherford Island, given to the writer by Dr. Bascom, is evidently of the same type of rock, but in thin section contains a larger proportion of ferro-magnesian constituents and among these a larger proportion of brown hornblende.

The balance of evidence is that these schists are completely recrystallized, highly metamorphic sediments, originally of the composition of arkose. The presence of the augite is the strongest point against this origin.

Turning to the igneous rocks, there is evidence of at least two periods of intrusion. The first of these antedated the metamorphism of the region. In the field these appeared to present all variations in composition, grading from extreme basicity to extreme acidity. Granite-gneiss, diorite, anorthosite, monzonite, gabbro, hornblende schist and peridotite are a few of the varieties. Analysis reveals the fact that these are not so widely separated as they appeared, and that the majority belong among the intermediate types. Cutting the above-mentioned rocks are numerous less metamorphosed pegmatites and aplites which were not studied by us in detail.

Of later age is a series of diabase dikes. These follow joint planes for the most part and belong to two series, one trending N. 85° E. the other N. 10° E. The physiographic effect of these dikes has already been mentioned.

The classification adopted is the quantitative one recently proposed.[1] The following table includes the types found on the Boothbay quadrangle, whose description follows.

TABLE III.

Summary of Rock Types Found on the Boothbay Quadrangle.

Class.	Order.	Rang.	Subrang.	Old Name.
I. Persalane.	4. Britannare.	2. Toscanase	4. Lassenose	Granite
II. Dosalane.	3. Hispanare.	3. Almerase.	4. Sitkose.	Quartz-augite diorite.
	4. Austrare.	3. Tonalase.	4. Tonalose.	Quartz-mica diorite.
			5. Placerose.	Diabase.
	5, Germanare	1. Umptekase.	4. Umptekose.	Monzonite, gabbro and anorthosite.
		2. Monzonase.	3. Monzonose.	
		3. Andase.	2. Lincolnose.[2]	
III. Salfemane.	5. Gallare.	2. Kilauase.	2. Prowersose.	Schist.
		4. Auvergnase.	3. Auvergnose.	Diabase and Hornblende schist.
V. Perfemane.	1. Maorare.	1. Dunase.	1. Dunose.	Peridotite (dunite)

In the following pages the rocks will be discussed under two groups according to age. In one of these groups fall the more or less metamorphosed rocks of all compositions; in the other the younger rocks which according to the old nomenclature would have been called diabases. The great scientific value of the new system of classification becomes evident in a region such as the one under discussion, where two series of rocks differing in age, megascopic and microscopic characters are found to be closely related in quantitative chemical characters and in the possible (but not actual) proportions of certain "standard" minerals.

The authors of the new system expressly state that metamorphic rocks are excluded from their scheme. Nevertheless, in the following pages the system is applied to metamorphic rocks with great significance. It is of course evident that the system is not applicable in cases where there is any doubt of the igneous origin, or in cases where either weathering or percolating solutions have so altered the rock that its original character cannot be determined. In the types in question it was always possible to determine what the original was. The

[1] Cross, Iddings, Pirsson, Washington, *Jour. Geol.*, X, 1902.

[2] New name proposed in this paper.

metamorphism was mainly of the nature of intense crushing, without chemical addition or subtraction. In most cases there were occasional less altered patches, where the original texture and mineralogy could at least be inferred, if not actually observed. It was found that the rocks were invariably originally holocrystalline, usually of granitic texture. The authors of the new system propose various prefixes for the description of texture. These are used in the following pages when the original texture could be observed. When a rock is thoroughly schistose or gneissic the prefix "meta" is employed. Where it is metamorphic, but shows indications of what the texture was before metamorphism, the prefix "meta" is used and also a textural prefix. Thus, "meta-grano-sitkose" is a metamorphic rock in which a former granitic texture is evident, while "meta-auvergnose," is a hornblende schist in which all trace of original texture is lost. In those cases where both metamorphic and non-metamorphic portions were found, the metamorphism is ignored in the nomenclature.

Only one rock in the region was seriously altered by weathering. This was the most basic of the types, being an almost pure olivine rock. It contains serpentine and other alteration products, and in the analysis a notable amount of water and of carbon dioxide was determined. The analysis as a whole could not be recast in terms of the new system because of these extraneous substances. Nevertheless it was perfectly possible to classify the rock, since the alteration products were found on microscopic examination to be all replacements of the olivine. The composition of the olivine could be determined from the analysis, and the alteration products could be ignored in classifying. The only possible chance for error in such a case lies in the doubt about the original proportions between olivine and magnetite, but the mathematical grouping is sufficiently broad for classification to be made in this respect with reasonable certainty.

The tedious labor involved in the production of "superior" analyses necessarily limits the number of them. In this case all of the principal types were analyzed, but many subordinate variations were of necessity examined only microscopically.

The petrographic descriptions of the various types which were not analyzed are given in each case after the discussion of the similar type which was analyzed. It is however realized that there may be errors in the inferred relationships and quantitative development of these unanalysed types. The accurate mathematical estimation of quantities of minerals seen under the microscope is not without difficulty, and is apt to be inaccurate where there are variations in coarseness of grain and where there is a gneissic arrangement of minerals in bands. The problem too becomes the more involved, when the majority of the minerals present are not the ones on which the classification is based. With full regard for the uncertainties involved, calculations were made and the unanalyzed rocks placed with their nearest analyzed allies. In spite of the manifold possibilities of error, it is confidently believed that only by such estimations will the real significance of the metamorphic rocks be appreciated. For example, a dark hornblende schist, consisting mainly of hornblende and plagioclase would in the old system have been reckoned with the gabbros. If any proportions were recorded at all, merely the ratio between hornblende and feldspar would have been noted. In the light of the new system it becomes evident that that ratio has no significance at all, except as regards metamorphism, and the essential and significant conception of the type involves the splitting up of the hornblende into anorthite, diopside and hypersthene molecules which possibly never existed as minerals in the rock, and whose ratios may show more acid affinity than would be supposed on casual inspection. It is not possible to do this without any analysis of the rock, but given one good analysis of a type, it is possible to consider slightly dissimilar types by means of microscopical inspection only.

The acid rocks were the ones which received least attention from us. These were very common and in no way notable, and did not seem of sufficient importance to justify any great expenditure of time on either mapping or analysis. The types will be taken up proceeding from acid to basic within each of the two series. It is, however, to be borne in mind that the acid types are very much the most common.

THE PERSALANES.

Grano-Lassenose. I. 4. 2. 4. (Granite.) *Occurrence.*—This type was found in the form of dikes on Damariscove Island. There were many of the dikes, some running with the strike, some cutting across it at various angles. There was considerable variation in coarseness of grain, and the borders of the dikes were often pegmatitic. The schist was much contorted near the contact and was full of quartz lenses. In fact the whole island was thoroughly injected. Time did not allow of detailed mapping of these dikes. Specimens were collected of all that were found and slides were studied. All of the dikes appeared to be of essentially the same type, so one analysis only was made of them.

TABLE IV.

Chemical Composition and Classification of Damariscove Lassenose.

		Molecular Proportions.	Norm.	
SiO_2	67.59	1.126	Qu	19.56
Al_2O_3	17.41	.171	Or	15.59
Fe_2O_3	.15	.009	Ab	41.39
FeO	2.98	.040	An	14.18
MgO	1.40	.035	Cor	1.33
CaO	3.05	.054	Hyp	6.27
Na_2O	4.89	.079	Mag	2.09
K_2O	2.59	.028	Ilm	1.52
H_2O+	.18		Ap	.34
H_2O-	.04			
CO_2	none			
TiO_2	.83	.010		
P_2O_5	.19	.001		
Total	101.30			

On consulting Washington's tables[1] it becomes evident that lassenose is one of the commonest of rock types, hence a comparison with other regions would be futile.

Microscopic characters.—Microscopically the dikes are found to be essentially alike, differing mainly in coarseness of grain. They contain biotite, brown hornblende, a very little augite,

[1] Prof. Paper, 14., U. S. G. S.

orthoclase, albite, oligoclase, titanite, apatite and quartz. In some cases the dikes were but little metamorphosed, in others they were intensely sheared, and there are all the intermediate degrees of change. In the crushed varieties there is a pale biotite poor in iron, associated at times with ordinary deep brown biotite, at times with the orthoclase. The light biotite is apparently secondary, of deep-seated or metamorphic origin. Frequently the shreds of the secondary biotite are strung out in lines having parallel orientation, giving the rock somewhat of a schistose structure. In the crushed varieties microcline is common, as are undulatory extinction in the quartz, microperthitic intergrowths and some granulation. A few crystals of zoisite were to be seen, apparently derived from the plagioclase as a product of dynamic metamorphism. Reaction rims are frequent between the biotite and the hornblende. It is very common to see a hornblende individual with deeply corroded edges surrounded by a radiating mass of biotite leaves interspersed with feldspar and dotted with magnetite, the whole enclosed in a biotite individual.

The feldspars, particularly orthoclase, contain inclusions of a fine reddish black dust. Some mica is also present as inclusions. The dust is to be seen especially in the central zones, the edges being free from it. This type of inclusion is present in all the rocks of the region. For reasons that will be discussed later (see p. 538) these are thought to be titaniferous, and to consist of several minerals notably perofskite, rutile,titanite and magnetite.

Norm and Mode.—Plagioclase was the commonest mineral; next in abundance, biotite and orthoclase in about equal amounts, hornblende, augite and zoisite were in small amounts. It appears that the norm agrees fairly well with the mode. The disagreements are that there is no anorthite (all the plagioclase being near the albite end of the series) and no corundum, and that the actual percentage of orthoclase is less than the normative. All of these discrepancies are accounted for by the presence of biotite, hornblende, augite and zoisite. These minerals are too variable to admit of accurate recalculation, but it is evident that some potash is in the biotite, and lime in the other three with alumina distributed among them.

Related Types.—On the mainland and neighboring islands are many granitic dikes and bathyliths. Microscopic examination of many of these revealed mineralogical similarity to the type just described, but with some variation between the proportions of constituents. An estimation of these constituents in terms of standard minerals reveals the fact that class and order are evidently the same as for the type just described, but that there is some variation in the relative amounts of alkalies and of lime. The commonest types from the mainland appear to fall into I. 4. 3. 4, yellowstoneose, no analyses of which were made.

THE DOSALANES.

Meta-grano-sitkose. II. 3. 3. 4. (Quartz-augite-Diorite; Actinolite Schist.) *Occurrence.*—The rock thus classified is one of the most remarkable of the whole region. It forms dikes on Fisherman's Island in a country rock of sandy biotite schist. The dikes frequently parallel the structure, and, as they weather into a gray sand and frequently contain inclusions of the schist, they appear deceptively like a sedimentary rock. They are however found unmistakably cutting the bedding at various angles.

Megascopic Character.—In a fresh hand specimen the igneous nature of the rock is unmistakable. Pink with green spots is its general appearance. The texture is moderately coarse to fine. Actinolite and a schistose structure develop in the crushed parts.

Microscopic Character.—In the less crushed varieties the following minerals were observed, in order of abundance: a greenish augite, quartz, plagioclase (albite and oligoclase), zoisite, brown hornblende, titanite, biotite, apatite. In the more crushed varieties actinolite develops almost to the exclusion of the other ferro-magnesian minerals, while there is a marked increase in zoisite; microcline is abundant, and the quartz is completely crushed.

Similar Types.—The rock just described is confined to the general vicinity of Fisherman's Island. On Ocean Point are a few dikes which may be of the same rock, but the actinolite is not conspicuous in them. The dikes on Ocean Point are like most of the dikes of the region in cutting their enclosing rock sharply, in which respect they differ from the sitkose just described.

The latter develop very conspicuous contact zones of actinolite along the borders. The dikes are all small, usually three inches or less in width, and they are not of great length. On the same island are many large granitic dikes, microscopically similar to the lassenose, which are thirty feet or more in width. These granite dikes are entirely distinct from the sitkose. Megascopically the latter seems to contain primarily pink feldspar and actinolite.

Comparison with Alaskan Sitkose.—It is worthy of note that in the only other known locality where this subrang is found, namely in the neighborhood of Sitka, Alaska, the field relations are described[1] as being essentially similar to those above indicated for Fisherman's Island. In both cases the dike rock is involved with sediments in a way that seems deceptively like bedding, and in both there is a crushing of the quartz on a microscopic scale. The essential differences between the two are the much higher lime content of the Maine rock and the dynamic metamorphism of the whole Maine region at a time subsequent to the intrusion of the dike. The analysis of the Sitka rock is here reproduced for comparison.

TABLE V.

Analyses, Molecular Proportions and Norms of Sitkose.

	Composition.		Molecular Proportions.		Norm.		
	I.	II.	I.	II.		I.	II.
SiO_2	67.04	65.94	1.117	1.099	Qu	28.68	30.1
Al_2O_3	11.40	13.74	.112	.134	Or	6.12	10.0
Fe_2O_3	.78	.49	.005	.003	Ab	23.06	23.6
FeO	3.75	5.21	.051	.071	An	15.85	14.2
MgO	3.52	2.33	.088	.058	C		2.0
CaO	7.60	2.87	.136	.051	Di	16.96	
Na_2O	2.70	2.80	.044	.045	Hy	3.96	13.6
K_2O	1.00	1.63	.011	.018	Mag.	1.66	.7
H_2O+	.16	2.59			Ilm	3.19	1.5
H_2O-	.09	.21			Ap	.34	
CO_2	none	.59					
TiO_2	1.68	.80	.021	.010			
P_2O_5	.12	.21	.001	.002			
Total	99.84	99.41					

[1] Becker, *Annual Rept. U. S. G. S.*, XVIII, Pt. III, p. 43.

I. Analysis, molecular proportions and norm of sitkose from Fisherman's Island, Me.

II. Analysis, molecular proportions and norm of sitkose from Alaska, described by Becker; analysis, by Hillebrand. Analysis and norm published in Washington's tables, *Prof. Paper 14, U. S. G. S.* p. 219. (.61% of rare oxides omitted.)

The Maine rock is perfectly fresh as regards weathering; the Alaska one contains notable amounts of water and of carbon dioxide and is described as containing secondary chlorite, calcite and muscovite. The comparison between them cannot therefore be pushed too far. It is well known that in the weathering process the lime is the first constituent to be attacked and that of all the others alumina is the most constant actually, but apparently grows greater because of the percentage decrease in the others. These two analyses would be much closer if a recasting were made because of weathering.

Norm and Mode.—In the less crushed varieties of the Maine rock the mode differs from the norm mainly in the entire absence of anorthite and the presence of various calciferous alferric minerals. Titanite is moderately abundant, thus using up the ilmenite molecule in combination with CaO. There is a very little biotite, which calls for a slight re-arrangement of the potash molecules.

Metamorphism.—As a rule the rock has been greatly sheared. The shearing took place in some instances along the strike of the dike, in some directly across it, and in some obliquely. The result of the shearing is seen in granulation of the quartz, undulatory extinction of quartz and feldspars, bending of the feldspar lamellæ, cracking of the feldspars and the presence of the metamorphic minerals microcline, actinolite and zoisite.

Grano-tonalose. II. 4. 3. 4. (Quartz-mica Diorite). *Occurrence.*—The rock which falls into this subrang makes up the greater part of the island of Southport, where it is found in irregular masses of bathylithic or laccolithic character. The same type of rock occurs to some extent in the form of dikes on the mainland.

Megascopic Character.—It is a fairly coarse-grained light gray rock of granitic texture occasionally gneissoid. In the field it can readily be distinguished from all other granitic types of the region in that its color tones are all of black and white order. The other granites are pinkish, greenish or brownish in tone.

TABLE VI.

Analysis and Norm of Tonalose from Southport.

Composition.		Molecular Proportions.	Norm.	
SiO_2	63.44%	1.057	Qu	17.58
Al_2O_3	18.84	.184	Or	11.68
Fe_2O_3	.16	.001	Ab	36.15
FeO	4.05	.056	An	19.18
MgoO	1.99	.049	Cor	2.55
CaO	4.23	.075		
Na_2O	4.35	.069	Hyp	9.78
K_2O	2.07	.021	Mag	.23
H_2O+	.33		Ilm	2.74
H_2O-	.06		Ap	.67
CO_2	none			
TiO_2	1.41	.018		
P_2O_5	.32	.002		
Total	101.25			

Microscopic Character.—This rock type is too common to make extended comment desirable. It contains orthoclase, plagioclase, biotite and quartz, in order of abundance, with a little accessory magnetite and apatite and a moderate amount of titanite.

Metamorphism.—There is evidence of strain, though not of as intense degree as in the case of the Damariscove lassenose. A little undulatory extinction, a few individuals of microcline and considerable cracking of the feldspar are the evidences of it. There is a little kaolin developed along the cracks in the feldspar, and some chlorite borders the biotite.

The Germanares (II. 5). (Augengneiss; Monzonite; Gabbro; Anorthosite.) In the *Journal of Geology* for April and May, 1906, is a paper by Edson S. Bastin on prowersose from Knox County, Maine. The rock I am about to describe appears to be another occurrence of the same type. The points of similarity will be evident on comparison with Mr. Bastin's description. The Boothbay rock is variable in structure, mineralogy and chemical composition. Of the various types selected by us for analysis and for microscopic study no one is identical with his, yet our types from the same rock mass differ from another in as essential respects as do most of them from his rock. The Boothbay rock is invariably porphyritic, the phenocysts being feldspathic, the ground-mass micaceous. On analysis, the ground-mass only [1] corresponds to Mr. Bastin's analysis and falls into the subrang prowersose. The whole rock of each of our types is more salic, and the various types respectively fall into the subrangs monzonose, umptekose and the unnamed subrang (II. 5. 3. 2.) of which the only analysis given in Washington's tables is that of the augite-minette from the Plauensche Grund of Dresden. Since the Maine rock is of notable extent, and the analysis accurate and from fresh material, it appears justifiable that a name from this locality be given to this subrang of the new system, and the name *lincolnose* is here proposed for it from Lincoln County, Maine.

The Boothbay rock (including umptekose, monzonose and lincolnose) is found in two parallel bands about two miles apart. The eastern band outcrops on Squirrel Island (see map, Fig. 2) and again on Spruce Point. In both localities it has been much cut up by later intrusives. Its strike varies from due N.-S. to N. 15° E. and it may be found at intervals throughout the length of the quadrangle. It forms Mt. Pisgah and there has a width of about a quarter of a mile. This band was traced in the direction of its strike for twelve miles, the width being very variable. It is often concealed by vegetation and sometimes appears to pinch out altogether. The indications point towards a string of lens-shaped masses barely connected with each other and arranged in a uniform direction. The western band is shorter and wider being apparently three miles in length and one in maximum width. Its widest part is found on the south shore of Campbell pond; from there it extends southward rapidly narrowing to the coast. Mr. Bastin's exposures are about forty miles distant in a N. 20° E. direction.

Wherever exposed on the Boothbay quadrangle both bands show a marked difference between core and edges. The core

[1] See Analysis II, Table VII.

consists of a very friable, easily weathered, dark rock, which usually forms a depression. It consists of blue "augen" an inch or less in length in a ground-mass of brown mica and feldspar. The augen are without orientation, and the mica plates also have no uniform arrangement. In the border zones the rock is schistose. The biotite and the augen are arranged with the long axes in the same direction. The latter often being completely crushed and represented by white bands between the mica plates. This border rock resists weathering much better than the rock of the core, hence it usually forms ridges. It is not among the hardest rocks of the region, but it is sufficiently resistant to form hills of moderate altitude. Fresh specimens of the border rock can readily be found, while the core disintegrates so readily that it might easily be overlooked altogether, and fresh specimens are difficult to obtain.

Microscopically the augen are found to be similar to the graphic granite which forms one of the youngest intrusions of the region. They consist of albite, microcline, microperthite and orthoclase, in order of abundance, with sometimes a little quartz. A few scales of mica are to be seen scattered through the augen, especially in the sheared varieties. Zonal structure is common in the feldspars. The augen are essentially similar in all varieties of the rock, differing only in degree of metamorphism. In some instances they are cracked, the cracks being filled with either quartz or muscovite, the former containing dark inclusions. Other occurrences are granulated on a microscopic scale, and still others are so completely crushed that they are drawn out into bands and are white megascopically.

The feldspars contain large numbers of inclusions. Quartz, titanite, perofskite, magnetite and rutile could be identified, the needles of the last-named being usually arranged in two intersecting directions. In the following analysis, care was taken to exclude as far as possible the scales of biotite which are occasionally within the augen. The mica of the ground-mass adheres most persistently to the augen, and particular care was taken to break it away. Considering these precautions, the amounts of iron, magnesia and titanium are very large; they are undoubtedly to be accounted for in the inclusions, as is some of the quartz. The amount is so large that the analysis can be classified as a whole rock, falling into the subrang I. 5. 1. 3, phlegrose. Since the inclusions in these feldspars are of precisely the same type as those in other rock types of the region, the conclusion seems justified that the inclusions described elsewhere are of the same type.

The high alkalies and low lime are noteworthy and correspond with the absence of lime feldspar. This again is a general characteristic of the igneous rocks of the whole region, lime whether great or small in amount being invariably in a ferromagnesian mineral and nearly or quite lacking in the feldspar.

TABLE VII.

Analyses and Molecular Proportions of Monzonite from Spruce Point, Me.

	I.		II.	
SiO_2	65.69%	1.095	55.95%	.933
Al_2O_3	18.54	.181	12.28	.121
Fe_2O_3	.66	.004	.25	.002
FeO	.50	.007	5.61	.078
MgO	.12	.003	9.17	1.48
CaO	.99	.017	4.63	.082
Na_2O	5.55	.090	1.91	.031
K_2O	7.30	.078	6.28	.067
H_2O+	.09		18	
H_2O-	.01		.05	
TiO_2	.55	.007	3.15	.040
CO_2	none		none	
P_2O_5	.25	.002	.83	.006
Total	100.26		100.29	

I. "Augen" from monzonite of Spruce Point, Me. Position in the quantitative system, I. 5.1.3. Phlegrose.

II. Schistose ground-mass of monzonite from Spruce Point. Me. Position in the quantitative system III.5.2.2. Prowersose.

Table VII. gives the analysis of the augen and also of the ground-mass. The distribution of ingredients is evident without especial comment. The potash is noteworthy, being high in both parts and is of course in orthoclase in I and in biotite in II. A more detailed description of the whole rock will be given under monzonose.

Lincolnose. II. 5. 3. 2. As already mentioned this new name is proposed for the soft rock which forms the core of both intrusions. Megascopically it is seen to contain large blue augen set in a ground-mass which is dense and dark except for mica scales.

Microscopic Character.—The augen are found to be in all respects similar to those already described, and are of the least crushed variety. In the ground-mass are found biotite, pyroxene, hornblende, titanite and magnetite, with a very little microcline, and more plagioclase, which is partly labradorite and partly albite, and a little microperthite.

There are three types of pyroxene. One of these is an ordinary colorless or greenish augite, remarkable only for its inclusions. The inclusions are opaque black grains or rods, probably of titaniferous magnetite, and are so abundant as to make the augite appear opaque. Prismatic faces are occasionally present in this augite, but terminal faces are lacking. About the edges there is frequently an intergrowth of biotite along the cleavage cracks, and biotite and brown hornblende together frequently form rosettes which seem derived from the augite by dynamic metamorphism.

The second type of pyroxene is faintly pleochroic from pink to violet and has an extinction angle (measured from C in the plane 010) which varies from 0° to 13°. In addition to the ordinary pyroxene cleavage, a parting parallel to 100 can be plainly seen, and a less distinct parting parallel to 010. These properties seem most nearly to correspond to diallage. This mineral contains great quantities of brownish red inclusions, apparently both rutile and titaniferous magnetite being present. Crystal boundaries are lacking in the diallage. It is usually surrounded by biotite and brown hornblende.

The third type of pyroxene is apparently secondary, the result of dynamic metamorphism of either of the two preceding types, and is usually associated with the rims of biotite and hornblende. It occurs in irregular grains, without inclusions, is frequently twinned, and is occasionally altered to uralite.

The hornblende is reddish brown and occurs in two ways.

As already implied, one of these occurrences is evidently secondary after the pyroxene, it and the biotite being together arranged in rosettes or rims around the augites. The other type of hornblende is also brown, but it forms large individuals and is apparently original. It is rare. Considerable apatite is present in long prisms containing transparent inclusions arranged parallel to the axis.

The biotite is evidently poor in iron, ranging in pleochroism from yellow to reddish brown. As an original mineral it is found in scales, which are frequently bleached at the edges. The secondary biotite consists of small individuals associated with the alteration of the pyroxene.

Chemical Composition.—Analysis I, Table VIII, is of the typical lincolnose from the core of the western intrusion.

Meta-monzonose. II. 5. 2. 3. *Occurrence.*—Bordering the lincolnose on both sides is the schistose portion already mentioned, of which the analyses in Table VII give separately the composition of augen and ground-mass. This differs from the lincolnose not only in having a schistose structure and in being less easily weathered, but also chemically and mineralogically. The augen are similar to those of the lincolnose but are more frequently crushed, especially near the edges of the rock mass. The ground-mass is quite different. It contains mainly biotite with little green hornblende and very little augite, which is surrounded by large rims of secondary brown hornblende. Biotite, microcline, microperthite, albite and a little quartz with titanite and magnetite make up the rest of the rock. There is great strain in the feldspar. The biotite is bleached along its edges. Analysis II in Table VIII is compounded of the two analyses in Table VII in the proportion of two parts of the augen to three of ground-mass, which is the ratio in which they were observed in the slides.

Meta-umptekose. II. 5. 1. 4. In the northern part of the Boothbay quadrangle the rock re-appears about two miles east of South Newcastle. In this locality is found the third type. Here the augen are without orientation and there is little or no schistosity, in which it resembles the type first described (lincolnose). The rock is of moderate hardness and not readily weathered, in which it resembles the second type (monzonose). It differs from both in that the ground-mass is lighter colored, and the general tone of the rock is greenish gray rather than black.

Microscopic Character.—The lighter color is found to be due to the presence of a larger proportion of orthoclase, albite and quartz, with less mica, and the green tone to the presence of green hornblende.

Hornblende is the prevailing femic mineral and is of two varieties, a deep reddish, basaltic variety and a colorless or greenish one. The latter is frequently twinned. Biotite is present, frequently intergrown with the colorless hornblende, in which relationship the biotite appears to be the older. Titanite and apatite are abundant. The titanite is remarkable for having double refraction and slight pleochroism from colorless to reddish. It has deep irregular cracks and polysynthetic twinning. It encloses apatite, and is frequently surrounded by rims of magnetite with the colorless hornblende. Pyroxene is entirely lacking. The analysis of umptekose is given in Column III of Table VIII.

TABLE VIII.

Analyses and Molecular Proportions of Monzonites.

	I.		II.		III.	
SiO_2	55.17%	.919	59.64%	.994	58.74%	.979
Al_2O_3	18.01	.176	14.76	.145	14.61	.143
Fe_2O_3	.08	.001	.41	.003	.48	.003
FeO	5.41	.075	3.57	.050	3.70	.051
MgO	5.29	.132	5.53	.138	5.47	.137
CaO	5.64	.119	3.17	.057	3.34	.060
Na_2O	2.12	.034	3.27	.059	5.70	.092
K_2O	5.48	.059	6.69	.071	3.79	.040
H_2O+	.29		.14		.27	
H_2O-	.01		.03		.17	
TiO_2	2.33	.029	2.11	.026	1.87	.024
CO_2	none		none		none	
P_2O_5	.25		.60		1.00	
Total	100.86		99.92		99.14	

TABLE VIII—*Continued.*

Analyses and Molecular Proportions of Monzonites

Norms.

I.		II.		III.	
Or	32.80	Or	39.47	Or	22.24
Ab	17.81	Ab	27.77	Ab	48.40
An	22.24	An	5.84	An	3.06
C	.31				
		Di	7.06	Di	5.83
Hy	15.55	Hy	13.47	Hy	15.80
Ol	2.34	Il	3.85	Il	3.54
Il	4.31	Mg	.46	Mg	.70
Ap	1.96	Ap	.13	Ap	2.33

I. Monzonite from Campbell Pond, Maine. Position in the quantitative system II. 5.3.4. Lincolnose.

II. Schist. Analyses I and II of Table VII combined in the proportions of 2:3. Position in the quantitative system II. 5.2.3. Monzonose.

III. Monzonite from South Newcastle, Maine. Position in the quantitive system II. 5.1.4. Umptekose.

This group of rocks presents similarities to the shonkinites, yogoites and monzonites of the Bearpaw and Little Belt Mountains, and with the prowersose of Two Buttes, Col. It also has affinities with the ciminites and vulsinites of Italy. It has no close allies near at hand, except the prowersose described by Bastin, which is probably part of the same rock-body.

The similarity with the distant rocks is chemical only. The other types are unmetamorphic and in some cases surface volcanics. The Maine rocks are evidently of deep-seated origin, and highly metamorphic, the resulting mineralogy and structure departing widely from those of the allied types. The mode departs widely from the norm for the same reason, namely that the minerals actually present are in large part the result of dynamic processes, and are in general those of higher specific gravity than the normative ones.

THE SALFEMANES.

Meta-auvergnose. III. 5. 4. 3. Hornblende Schist. *Occurrence.*—Hornblende schists are common on the coast of Maine and common also on the Boothbay quadrangle. They are involved with acid igneous rocks and with mica schists in a very complex way. As a rule the trend of the rock is the same as the strike of the schistosity, but there are occasional exceptions. The way in which it is caught in with other rocks is shown on the small map of Cabbage Island. It was not put on the large map, because the patches of it are so numerous and so small. There are, however, several large and persistent streaks of the rock. One of these is on Southport near Cape Newagen, where a band of it is cut by a large diabase dike. Another very persistent streak extended from near the head of Linekin's Bay northward for about five miles. It was from this band that the chemical analysis was made.

Megascopic Character.—The rock is somewhat variable in color, ranging from black to dark gray. In the black types hornblende is the only mineral distinguishable; in the gray, feldspar and hornblende. The gray portions are very distinctly banded, the bands consisting of alternating streaks of light and dark minerals. The black and the gray portions both show fissility, caused by a parallel orientation of the hornblende.

Chemical Character.—It is evident that the chemical association is with the diabases, though the lime is higher than is usual; the potash lower; and the sum of the alkalies is low as compared with lime.

TABLE IX.

Analysis and Norm of Meta-auvergnose from Bayville, Maine.

Composition.		Molecular Proportions	Norm.	
SiO_2	49.00%	.816	Qu	.48
Al_2O_3	15.46	.152	Or	2.22
Fe_2O_2	2.58	.016	Ab	23.06
FeO	7.98	.111	An	28.91
MgO	6.46	.161	Diop	22.34
CaO	11.83	.211	Hyp	11.71
Na_2O	2.75	.044	Mag	3.71
K_2O	.44	.004	Ilm	6.84
H_2O+	.09		Ap	.67
H_2O-	.07			
CO_2	none			
TiO_2	3.72	.045		
P_2O_5	.30	.002		
Total	100.68			

Norm and Mode.—The correspondence between norm and mode is not close. The lime is not in anorthite, but in ferromagnesian minerals, mainly hornblende. The alumina is not all in feldspar, but also in hornblende giving an alferric mode. Diopside, hypersthene and ilmenite are lacking. The titanium is in titanite. The normative amounts of quartz, orthoclase, albite and magnetite are present.

Microscopic Character.—Green hornblende is found to be the prevailing mineral. It is arranged in parallel leaves, giving the schistose structure. The schistosity is not perfect, but is interrupted by many crumpled areas and by occasional patches where the minerals are without orientation. The texture simulates the granitic. Titanite is abundant. Plagioclase (albite and oligoclase) is moderately abundant, with a little orthoclase and less quartz. There is found to be no great mineralogical difference between the gray and the black types. The gray have been more intensely crushed and the light bands are due to granulated quartz and feldspars. These are present in the black variety also but are less crushed and so do not appear white in the hand specimen. There is a slight kaolinization of the feldspar. The orthoclase has inclusions of the reddish black dust mentioned before. Small amounts of apatite and magnetite are present.

Comparison with Monhegan Rocks.—The close analogy of this rock with those from Monhegan Island described by Lord[1] which fall into the same subrang is so striking that his analyses are reproduced for comparison together with ours. Since some of our later dikes also fall into this subrang, the discussion will be taken up after they have been described. The comparative table of analyses will be found on page 554.

The most conspicuous difference between the Monhegan rocks and the schist of the mainland is that the former contains olivine in both norm and mode, while the hornblende schist does not. Moreover there is a slight excess of silica in the schist, while two of the Monhegan rocks lack silica to the extent of having nepheline in the norm.

Am. Geol., XXVI, pp. 340 and 346.

THE PERFEMANES.

Dunose. V. 1. 1. 1. (Dunite). *Occurrence.*—This rock was found in a single exposure, close to the cross roads where the road from Bayville to Pleasant Cove intersects that from East Boothbay to Boothbay Harbor. The exposure was not large: the rock disappeared on the one hand under a vegetable garden, on the other it was cut off by the highway. The occurrence was apparently a dike.

Petrological Character.—In the hand specimen the rock was dense, black with green talcose spots, and fine textured. It proved on microscopic examination to be somewhat altered, but its origin could so clearly be seen that it is placed in the new system of classification.

Microscopically it was found to be mainly olivine. This is evidently of a very magnesic variety, magnetite and chromite enough being visible to use up all the iron shown in the analysis. There is present a small amount of an alteration product which has the strong double refraction, high interference colors, and low index of refraction characteristic of a carbonate. From the analysis it is evident that it must be magnesite, no lime being present. A little muscovite and a little chlorite are present. The green spots which were in evidence megascopically are found to consist of fibrous anthophyllite with a few small areas of opaline quartz. A few rosettes of serpentine are also to be seen.

These alteration products occupy relatively small areas and invariably occur either along the cracks of the olivine or else they retain the form of the olivine. It is evident that the original rock was pure olivine of the variety forsterite, with small amounts of magnetite and chromite. Fully three fourths of the areas of the slides are now occupied by these original minerals, and since the alteration products retain the olivine form, the inference is safe that no lime can have been lost in the alteration process. There is a little mica which may possibly be original. No feldspar or pyroxene is or has been there.

TABLE X.

Analysis of Dunose from near Bayville, Maine.

Composition.		Molecular Proportions.	Norm.	
SiO_2	37.41%	.623	Or	2.22
Al_2O_3	2.18	.022	Ab	4.19
Fe_2O_3	3.64	.023	Cor	1.02
FeO	3.46	.048	Hyp	1.54
MgO	41.08	1.027	Ol	72.32
CaO	none		Mg	.02
Na_2O	.54	.008	Cmr	.32
K_2O	.41	.004	Il	.30
H_2O+	8.84			
H_2O-	.09			
CO_2	2.03			
TiO_2	.12	.002		
P_2O_5	.08			
Cr_2O_5	.16	.001		
Total	100.04			

THE DIABASE DIKES.

Diabase dikes are well known on the coast of Maine. To the list of localities already reported should be added at least six dikes from the Boothbay quadrangle. The fiord character of the coast makes it impossible to determine whether one dike or several are present when the trend is such that they cross the bays, but wherever the alignment coincided we assumed one dike whatever the variation in width. The topography however is very suggestive of faulting and it is recognized that the alignment may be accidental in some cases. For this reason a series of microscopic slides was made and studied, of every exposure. The distribution of the dikes is shown on the map. The dikes described by Dr. Bascom from[1] the eastern part of the quadrangle are inserted on the map (Fig. 2.).

It will be observed that there are four dikes having a direction of N. 85° E. These dikes are all large, varying in width from thirty to one hundred and fifty feet. The southernmost one outcrops on the coast of Southport Island near Cape Newagen;

[1] "Dikes from the Vicinity of John's Bay, Maine," *Am. Geol.*, XXIII, 1899, p. 275.

the second is Dr. Bascom's, which has two outcrops on Rutherford Island, and one on the east side of Linekin's Neck; the third is the longest of them and outcrops on Cabbage Island, on the east and west coasts of Spruce Point, in the woods about a quarter of a mile inland on Southport, twice respectively on the east and west sides of the promontory of West Southport and in Georgetown north of Five Islands; the northernmost dike crosses Linekin Bay, being exposed on both coasts and on Cabbage Island. These four dikes are closely related in their petrographical characters, being porphyritic olivine diabases, and in their chemical characters, falling into Class III of the new system.

Another large dike is found on the mainland running parallel to the Sheepscot River with a strike of N. 10° E. This differs chemically and mineralogically from the others, being an acid, very feldspathic diabase without olivine and non-porphyritic, and falling into Class II of the new system.

The remaining dikes are small, varying from a few inches to a few feet in width. They are entirely variable in composition, and variable also in direction.

These three series were never found together so the age relations are unknown, but it is believed that there are two, possibly three, types distinct in age, and that this classification holds for other parts of the Maine coast.

Placerose. II. 4. 3. 5. Diabase. *Occurrence.*—The rock which falls into this subrang is the big dike with N. 10° E. trend, already mentioned (see Plate XXXI, Fig. 2). It has a maximum width of about thirty feet, with a length of more than four miles, during the greater part of which it is a conspicuous topographic feature. In two localities it disappears for a short distance, and in one place seems to be represented by three small dikes. It grows narrower towards the south; at its northern end it disappears suddenly. Its location can be seen on the map, where it will be found running parallel to the trend of the shore and a short distance inland.

Megascopic Character.—In the hand specimen the rock is a dense black or gray black, fine-grained trap. A few needle-like black crystals can be distinguished. In view of the apparent basicity, the analysis was a surprise, and so was the position of the rock in the quantitative system. It falls into the same rang as a rock from Southport which in the field was considered a granite. Microscopic examination leaves no doubt that the analysis is correct, the black color being deceptive.

Microscopic Characters.—Thin sections show the rock to have a normal diabasic texture; to be of coarse grain, and to lack phenocrysts. The edges are finer than the center. The principal constituent is plagioclase, appearing as a network of lath-shaped crystals. The extinction angles of these were measured and they were found to be of two kinds: one corresponding to albite of the composition $ab_6\ an_1$, the other oligoclase, $ab_3\ an_1$. A microperthitic intergrowth of albite and orthoclase is of occasional occurrence, and one interesting type of intergrowth was seen, where laths of albite alternated with strips of microperthite. A fine dust of kaolin is to be seen in some of the feldspars. A few broad orthoclases are present. Anhedra of magnetite are common, occupying the interstices between the feldspars. The principal ferro-magnesian constituent is common augite which is entirely xenomorphic, consisting of long strips or of irregular areas between the feldspar laths. The augite is entirely fresh and without inclusions.

TABLE XI.

Analysis and Norm of Placerose from Dike near Sheepscot River.

Composition.		Molecular Proportions.	Norm.	
SiO_2	56.72%	.945	Qu	10.56
Al_2O_3	15.06	.148	Or	3.89
Fe_2O_3	1.73	.010	Ab	39.82
FeO	6.33	.088	An	18.07
MgO	2.58	.064	Diop	9.98
CaO	6.61	.118	Hyp	5.88
Na_2O	4.73	.076	Mag	2.32
K_2O	.69	.007	Ilm	7.55
H_2O+	.51		Ap	.98
H_2O-	.15			
CO_2	none			
TiO	4.04	.049		
P_2O_5	.40	.003		
MnO	.35	.004		
Total	99.91			

Slides of the three smaller dikes into which the large one appears to ramify in the middle of its extent show a similar diabasic structure, but a much finer grain and a porphyritic tendency. They show a felty appearance with fine feldspar needles in a mass of magnetite, with very tiny augite anhedra, and porphyritic plagioclase. The phenocrysts are of essentially the same size as the average crystals of the center of the large dike; the fineness of the ground-mass is the essential difference between the two.

In Washington's tables there are ten rocks within this subrang, none of which comes from eastern America. Several are dikes from California, but the one which is the closest analogue in analysis and in norm is a porphyritic lava from the St. Augustine volcano, Alaska.[1]

TABLE XII.

Analysis of Dike from Eastern Shore of Linekin Bay.

Composition.		Molecular Proportions.	Norm.	
SiO_2	53.01%	.883	Qu	4.20
Al_2O_3	15.54	.152	Or	3.34
Fe_2O_3	1.85	.011	Ab	20.44
FeO	6.09	.096	An	29.75
MgO	7.70	.192		
CaO	10.60	.189	Diop	18.40
Na_2O	2.37	.039	Hyp	18.92
K_2O	.62	.006	Ilm	3.04
H_2O+	.73		Mag	2.55
H_2O-	.47			
CO_2	none			
TiO_2	1.70	.020		
P_2O_5	trace			
S	trace			
Total	100.68			

Auvergnose. III. 5. 4. 3. Diabase. *Occurrence.*—This rock is found in the form of a dike on the eastern side of Linekin's Bay. The dike is about ten feet wide near the shore; it may be followed for some rods inland, until it disappears under vegetation. The most vigorous search did not bring it to light farther east. Westward it re-appears on Cabbage Island, where it has

[1] See Becker, *Annual Rept. U. S. G. S.*, XVIII, Pt. III, p. 52.

a width of thirty-five feet, and again on the western shore, where it is still wider. On this latter exposure are glacial striæ pointing N. 10° W. The slightly inclined columnar structure is evident here as elsewhere among the dikes.

The subrang is a very common one, the most notable thing about it being that within it are to be found four of the rock types described by Mr. Lord from Monhegan Island. Of these, two, malchite and beerbachite, are dikes; two, gabbro and gabbro diorite, are part of the older plutonic mass. The resemblance to the Linekin diabase is chemical only, the mineralogy being quite different.

Microscopic Character.—The Linekin dike has a diabasic texture, in which it is like the Sheepscot River dike just described, but the resemblance is only of a very general nature. The Linekin dike is porphyritic throughout, its principal phenocryst being a broad plagioclase of the variety labradorite; other phenocrysts are augite and olivine. The augite is usually surrounded by secondary hornblende. The ground-mass consists of a network of lath-shaped plagioclases, in the interstices of which are magnetite and augite. This dike is in all respects similar in petrographic character to the one described by Dr. Bascom, hence mineralogical details need not be repeated. Identical with these is the long dike extending from Cabbage Island to Five Islands. All are porphyritic olivine diabases, with slight variations in coarseness of grain according to distance from the edges.

The southernmost of these east and west dikes, which outcrops on the coast near Cape Newagen, shows considerable metamorphism. The dike is the largest, measuring (by pacing) one hundred and twenty feet in width. The original rock was evidently identical with the others, but in places it has been so crushed as to be practically a hornblende schist. Of the six slides examined from different parts of this exposure all degrees were to be observed between a slightly altered diabase with a little green hornblende in addition to the minerals enumerated above, to a true schist with hornblende and biotite as the only ferro-magnesian minerals, and a schistose arrangement of these leaves. The commonest type is a partly altered one containing green hornblende without orientation, with the diabasic texture in part interfered with by the green hornblende which cuts the feldspar boundaries.

As indicated on the map, there is another outcrop of this dike to the west. This is a small area in the woods, no other rock being visible and a few feet only of the diabase exposed. Thin sections show this to be identical with the shore exposure, but of coarser grain. It is evident that a large proportion of the width of the dike is covered by vegetation, since its grain is too coarse to be produced in the width exposed.

An estimation of the contents of these dikes leaves no reasonable room for doubt that they would all fall into the subrang auvergnose. The Cape Newagen dike forms a connecting link between these dikes and the older complex. It is practically intermediate between the diabases and the hornblende schist of this same subrang.

The smaller dikes, although diabases, present notable differences, from all of the above and from each other. On Capitol Island are two, of which one has a nearly east and west, the other a nearly north and south trend. The first mentioned has a strike of N. 80° E. and is exposed on and near the western shore. A gorge on the mainland of Southport indicates that the dike continues there, but no material could be found in the latter locality. Microscopically it is found to be a porphyritic diabase, with phenocrysts of plagioclase with less augite and olivine. In the ground-mass are plagioclase and augite. Its affinity is with the east and west large dikes (auvergnose), but there is a larger proportion of augite in the ground-mass and the diabasic texture is not perfect. The plagioclase phenocysts are older than the femic ones and sometimes are entirely surrounded by them. In such occurrences the edges of the plagioclase are corroded and the femic silicate enters it irregularly, notably along the twinning planes. Titanite and grains of magnetite are present in notable amount. Much of the olivine is altered to brownish green serpentine and a carbonate.

The north and south dike of Capitol Island is exposed in a bay on the southern shore, and after extending about one hundred feet inland the strike turns to N. 20° E. Microscopically it is much finer grained than the other dike, and is a peculiar rock with no ferro-magnesian minerals in evidence. Phenocrysts and ground-mass are both of plagioclase while a dendritic form of magnetite makes up a large proportion of the rock penetrating both phenocrysts and ground-mass. The feldspar phenocrysts show a kind of twinning unusual in this mineral, the laths crossing each other in a manner resembling the twinning of staurolite. Other phenocrysts are H-shaped, the two vertical arms having a similar orientation, the cross-piece being placed at right angles to the others. A few faint outlines suggest augite, but magnetite now makes up their bulk with a dust of a brownish substance which under a high power seems to be a laminated serpentine. It has a cleavage and is probably antigorite. It does not seem to occupy space formerly held by another mineral, but to be redeposited.

On the western shore of Ocean Point is another small dike. The dike itself is only about ten inches wide, but a chasm four or five feet wide has been eroded along it (see Plate XXXII, Fig. 2). The gully on this dike is about two hundred feet long and has a strike of about N. 65° E. The dike rock is a diabase, slightly vesicular on one surface. Microscopically the rock is found to be porphyritic, but the phenocrysts are completely altered. There seem to be three types of alteration product, one of which is kaolin and muscovite and is probably derived from feldspar; another is a green serpentine, probably from augite; and the third a gray serpentine with calcite and quartz, probably from olivine. In the ground-mass is much pyrite and a network of plagioclase with needles of a hornblende which is pleochroic in brown and pink, and a little actinolite. The texture is not typically diabasic, some feldspar occupying the interstices.

Some rods farther north is another dike identical with the last. It is only three inches wide but forms a chasm.

STRIKING PETROGRAPHICAL FEATURES ILLUSTRATED ABOVE.

The magmatic relationship of the trap dikes to the older metamorphic complex is admirably illustrated on the Boothbay quadrangle. The similarities will be apparent after an inspection of the following table to which are added all rocks from the same subrang that have previously been analyzed from the immediate vicinity.

TABLE XIII.

Analyses of Auvergnose from the Coast of Maine.

	I.	II.	III.	IV.	V.	VI.
SiO_2	49.00%	53.01%	46.29%	45.66%	44.79%	47.20%
Al_2O_3	15.46	15.54	17.16	16.26	15.18	18.64
Fe_2O_3	2.58	1.85	2.57	2.97	4.13	1.96
FeO	7.98	6.09	9.87	8.51	8.21	6.82
MgO	6.46	7.70	7.79	10.21	7.93	8.28
CaO	11.83	10.60	12.04	12.25	14.10	11.52
Na_2O	2.75	2.37	2.21	1.34	2.18	2.91
K_2O	.44	.62	.16	.31	.30	.28
H_2O+	.09	.73				
H_2O-	.07	.47				
CO_2	none	none				
Ign			.51	.92	1.33	1.44
TiO_2	3.72	1.70	1.21	1.39	1.84	.84
P_2O_5	.30	trace	n.d.	n.d.	n.d.	n.d.
Total	100.68	100.68	99.81	99.82	99.99	99.89

Norms of Auvergnose.

	I.	II.	III.	IV.	V.	VI.
Qu						
Or	.66	4.20				
Ab	2.22	3.34	1.1	1.7	1.7	1.7
An	23.06	20.44	18.3	11.0	12.6	21.5
Ne	28.63	29.75	36.4	37.5	30.6	36.7
Di					3.1	1.7
Hy	22.77	18.40	19.5	19.3	31.8	16.6
Ol	11.50	18.92	2.4	11.2		
Mt			15.8	11.2	9.5	15.9
Il	3.71	2.55	3.7	4.4	5.8	3.0
Ap	6.99	3.04	2.2	2.6	3.6	1.5
	.67					

I. Hornblende schist from Bayville. (See p. 543).
II. Diabase dike from east side Linekin's Bay. (See p. 550).
III. Beerbachite. Lord, *A. G.*, XXVI, p. 346. Monhegan Island. (Dike.)
IV. Malchite. Lord, *A. G.*, XXVI, p. 346. Monhegan, Island. (Dike.)
V. Hornblende-gabbro. Lord, *A. G.*, XXVI, p. 340. Monhegan Island.
VI. Gabbro-diorite. Lord, *A. G.*, XXVI, p. 340. Monhegan Island.

The general similarity among all six of these types is evident.

All of the chemical ratios are essentially the same, as is of course indicated by the fact that they fall into the same subrang. The similarity is such as to indicate chemical relationship or magmatic unity between the plutonic metamorphic rocks of the older series and the younger diabases. This chemical and "normative" likeness is the more striking in that it is not accompanied by a mineralogical or model similarity. Any recalculation of the analyses of the older rocks in terms of the minerals that are actually there brings about an appearance of greater basicity than the normative relationship warrants. In the hornblende schist the amount of hornblende is so great as to give the rock every appearance of belonging among the basic gabbros. When interpreted in terms of standard minerals it becomes evident that the amount of hornblende has increased at the expense of anorthite molecules and that the rock is practically identical with the diabase.

In Table XIV the analysis of all the Boothbay types analyzed by us are repeated for comparison. It is evident that there is a regular progression in chemical characters from I to IX, and then a great difference when X is reached. It remains for future investigation to show whether types intermediate between IX and X are in existence, or whether X is really not a part of this co-magmatic region. The distribution of peridotite and allied dikes along the eastern parts of the United States is suggestive of other than purely local relationships for this rock. Leaving this dike aside we may thus sum up the chemical characters of the region: the range of silica is moderate and its amount intermediate, 49.00 to 67.59% being its extent. Alumina is moderate in amount and does not show any definite serial relation with other oxides. The ratios between lime, potash and soda are variable, but in general as the basic end of the series is approached, soda becomes in excess of potash, and lime in excess of the sum of the alkalies. Iron and magnesia, as well as lime, increase as the silica decreases; titanium is high throughout. In the majority iron exceeds magnesia, but magnesia increases relatively to iron as silica decreases.

TABLE XIV.

Analyses of Boothbay Rocks.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
	%	%	%	%	%	%	%	%	%	%
SiO_2	67.59	67.04	63.44	56.72	58.74	59.64	55.17	49.00	53.01	37.41
Al_2O_3	17.41	11.40	18.84	15.06	14.61	14.76	18.01	15.46	15.54	2.18
F_2O_3	.15	.78	.16	1.73	.48	.41	.08	2.58	1.85	3.64
FeO	2.98	3.75	4.05	6.33	3.70	3.57	5.41	7.98	6.09	3.46
MgO	1.40	3.52	1.99	2.58	5.47	5.53	5.29	6.46	7.70	41.08
CaO	3.05	7.60	4.23	6.61	3.34	3.17	5.64	11.83	10.60	none
Na_2O	4.89	2.70	4.35	4.73	5.70	3.27	2.12	2.75	2.37	.54
K_2O	2.59	1.00	2.07	.69	3.79	6.69	5.48	.44	.62	.41
CO_2	none	none	none	none	none	none	none	none	none	2.03
H_2O+	.18	.16	.33	.51	.27	.14	.29	.09	.73	8.84
H_2O-	.04	.09	.06	.15	.17	.03	.01	.07	.47	.09
TiO_2	.83	1.68	1.41	4.04	1.87	2.11	2.33	3.72	1.70	.12
P_2O_5	.19	.12	.32	.40	1.00	.60	.25	.30	trace	.08
MnO	n. d.	n. d.	n. d.	.35	n. d.	n. d.	n. d.	n. d.	n. d.	.16 Cr_2O_3
Total	101.30	99.84	101.25	99.91	99.14	99.92	100.86	100.68	100.68	100.04

I. Grano-lassenose, I. 4. 2. 4.
II. Meta-grano-sitkose, II. 3. 3. 4.
III. Grano-tonalose, II. 4. 3. 4.
IV. Placerose, II. 4. 3. 5.
V. Umptekose, II. 5. 1. 4.
VI. Meta-monzonose, II. 5. 2. 3.
VII. Lincolnose, II. 5. 3. 2.
VIII. Meta-auvergnose, III. 5. 4. 3.
IX. Auvergnose, III. 5. 4. 3.
X. Dunose, V. 1. 1. 1.

METAMORPHISM.

Since unaltered dikes and metamorphic masses are clearly derived from the same magma, it becomes possible to estimate the kind and amount of alteration that has taken place in the metamorphic types. A comparison of the mode with the norm among all of the preceding metamorphic types brings out the fact that the difference between mode and norm is of a constant character, and that it is closely similar to the difference between the auvergnose dike and the meta-auvergnose. The presence of titanite seems to be an invariable character of the unaltered mode.

The following are the essential chemical differences between mode and norm in the metamorphic rocks:

1. The presence of alferric minerals, thus affecting the distribution of alumina.

2. The alferric mineral may be biotite, in which case there will be less than normative orthoclase.

3. The alferric mineral may be hornblende or augite of a lime-bearing variety, in which case there will be less than normative anorthite.

4. The quartz content will depend upon whether 2 or 3 takes place, or if both upon the amount of biotite formed. The silica in hornblende and augite is in approximately the same ratios as in anorthite; biotite does not require as much silica as orthoclase, hence more than normative free quartz will be present in the biotite rocks.

5. Zoisite may be present, affecting the distribution of lime and alumina.

6. Actinolite may be present, calling for a re-distribution of lime and iron and magnesia from diopside.

7. Normative hypersthene disappears under these rearrangements.

Soda invariably remains unchanged, in albite. Quartz rarely departs far from the estimated excess of silica.

In addition to these chemical characteristics, there are certain mechanical alterations, such as undulatory extinction, microcline twinning, and granulation.

A consideration of the minerals present and of the chemical possibilities brings out the fact that the mineralogy is characteristic of a zone of considerable depth. The minerals are those of high specific gravity and are almost without exception those that might be formed in igneous rocks under deep-seated conditions. The garnet-staurolite-tourmaline group of minerals, of still higher specific gravity and indicative of more intense or longer continued metamorphism[1] are entirely absent.

Reference should be made to the recent book of Grubenmann, *Die Kristallinen Schiefer*. This book aims to classify the metamorphic rocks on a basis primarily of chemical composition, and secondarily of the place where the metamorphism

[1] See Van Hise, *Monograph XLVII, U. S. Geol. Survey*, p. 183, *et seq.*

occurred. The chemical system used is the artificial one of Osann. From the metamorphic standpoint three divisions are made according to the depth at which the alteration took place, certain minerals being taken as indications of each zone. In its main lines Grubenmann's system is built upon precisely the foundation which is needed for a natural classification of the metamorphic rocks, but in its details it seems to be open to two objections. One of these is the artificial character of the chemical basis; the other, the practical difficulty of recognizing the rock types formed in the respective zones, since the several types of mineral sometimes occur in the same rock. This is especially the case with the middle and lower zones and it appears to be practically an impossibility to know from the minerals only to which of them a given rock type can be referred. The Maine rocks do not fit into either of the zones as defined by Grubenmann, though their resemblances are more nearly with the lowermost. The prefix "kata" is attached to this by him, which seems unfortunate as that has already been used by Van Hise in the word "katamorphism" as a designation of the highest zone.

It yet remains for future workers to determine whether it is possible to build up a system that shall accurately measure pressure, heat and stress by means of the minerals formed. In the present state of knowledge it appears better to attempt no such subdivision, but to designate by the prefix "meta" any kind of metamorphism exclusive of weathering, and to apply this prefix to the subrang name of the quantitative system.

The conception of metamorphism here entertained is that of alteration without addition or subtraction of material. Obviously rocks injected, cemented, weathered or otherwise chemically changed would not be available for classification in this manner. In the region here discussed there is no reason for suspecting any changes in chemical composition, and it is believed that the quantitative system furnishes the most logical method of regarding them.

PLATE XXXI.

PLATE XXXI.

FIG. 1.

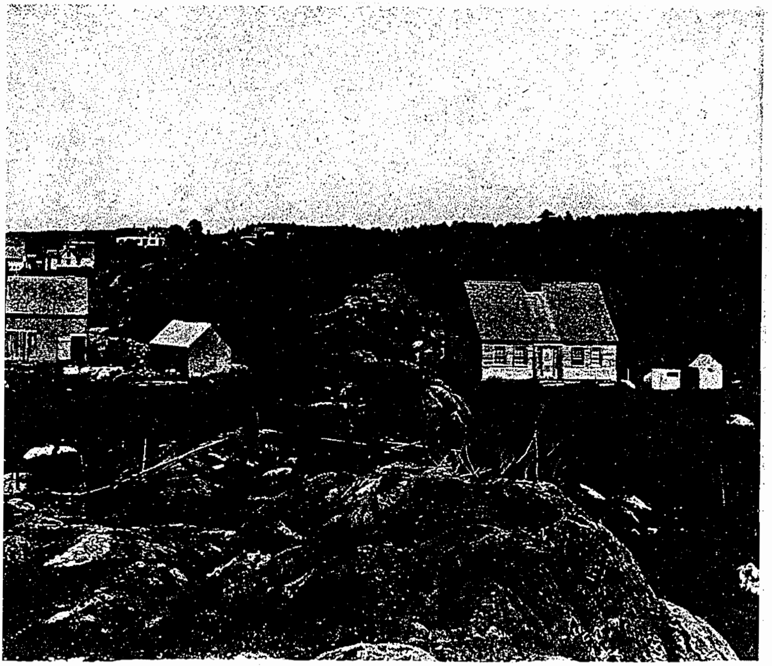


FIG 2.

PLATE XXXII.

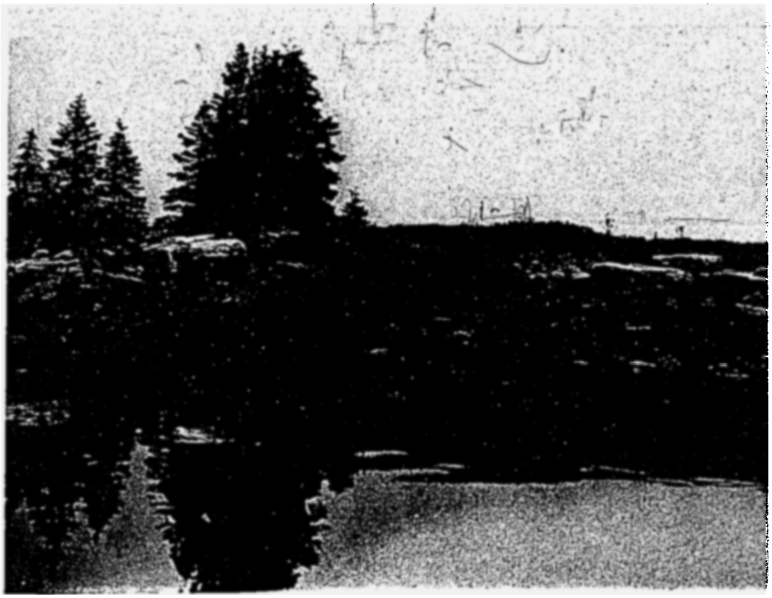


FIG. 1.

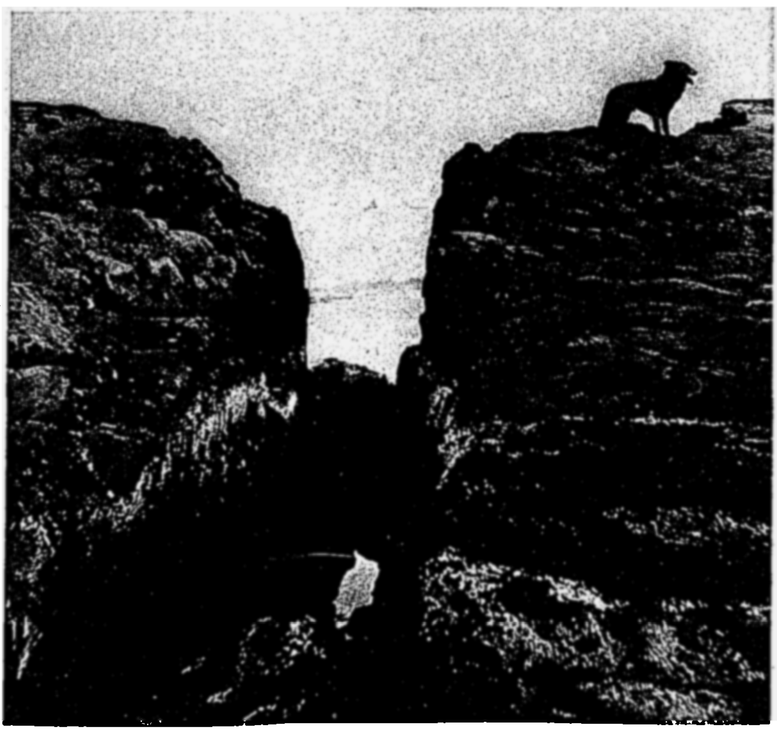


FIG. 2.