

PANORAMA OF THE EASTERN SLOPES OF THE MASSIF OF MONT DORE.

From a Water-Colour Drawing by M. A. Eusébio.

## LONG EXCURSION TO THE AUVERGNE.

AUGUST 17TH TO AUGUST 30TH, 1901.

*Directors:* M. MARCELLIN BOULE, M. J. GIRAUD, M. PH. GLANGEAUD.

*Excursion Secretary:* D. A. LOUIS.

(*Report by C. G. CULLIS and D. A. LOUIS, with notes and original contributions by M. Giraud, M. Glangeaud, and M. Pierre Marty.*)

### PREFATORY REMARKS.

THE geological excursions in the Auvergne and neighbourhood, forming the subject of this report, occupied fourteen days. The first eight of these were spent in the Department of the Puy-de-Dôme, and during this period the party worked under the guidance of M. Ph. Glangeaud, who conducted the excursions of the first, third, fourth, fifth, and sixth days, and of M. J. Giraud, who undertook the direction of the second and eighth days. The seventh day was directed by M. Giraud and M. Glangeaud conjointly. In drawing up the report of this part of the excursion the writers have been greatly assisted by notes and contributions, kindly supplied by both of the Directors; and it is to be understood that the geological matter in the reports of the first, third, fourth, fifth, sixth and part of the seventh days is mainly due to M. Glangeaud, while that of the second, eighth and part of the seventh days is to be credited in the main to M. Giraud.

During the remaining six days, of which four were passed in the Cantal, one in Corrèze, and one in the Puy-de-Dôme, the guidance of the party was, with great kindness, undertaken by M. Marcellin Boule. The report of this latter half of the excursion is based upon notes taken during its progress by the writers, and by Mr. E. E. L. Dixon.

The two panoramas which accompany the report are from water-colour drawings by M. Eusébio, sent by M. Glangeaud, who, in addition, lent the photographs for Plates XIII and XIV, and also supplied drawings for many of the figures which occur in the text; figures 39, 40 and 49 are reproduced, with permission, from his Monograph on the Volcano of Gravenoire. Figures 41 and 51 are from sketches by M. Giraud, and the three beautiful illustrations of fossil leaves are from original drawings made for the report by M. Pierre Marty.

### REPORT.

A party of members of the Geologists' Association and their friends, together numbering thirty, and including five ladies, left London on the evening of *Thursday, August 15th, 1901*, for the Auvergne.

Travelling *via* Newhaven and Dieppe they reached Paris early on the following morning. The drive across Paris from the Gare St. Lazare to the Gare de Lyons, in the fresh morning air, was an agreeable change from the confinement of the night's journey. At the Gare de Lyons they were joined by a few members who had travelled in advance, and by a representative of M. Desroches, the agent, to whose care had been entrusted the travelling and housing arrangements of the party while in the Auvergne. The journey southwards from Paris occupied the whole of the day, but its tedium was much relieved by the facilities for communication afforded by the corridor carriage which the party occupied, and by numerous altercations arising from the defence of the reserved compartment against aggressive intruders. Late in the afternoon the first glimpse was obtained of the distant volcanic hills, and these momentarily growing clearer were watched with keen interest during the remainder of the journey. Clermont Ferrand was reached shortly after six o'clock. M. Desroches was in attendance to welcome the somewhat jaded travellers, who were soon conveyed from the station to the Grand Hotel de la Poste, where it was ascertained that the casualties of the journey had not been serious, one member and one bag, only, being missed.

M. Glangeaud and M. Giraud joined the party at the hotel and were welcomed on behalf of the members by the President, Mr. Whitaker. After dinner M. Glangeaud announced the programme for the following day and distributed a daintily illustrated summary from which each member could gather the chief facts of geological interest to be studied. This practice he followed on all occasions when acting as Director. He also announced that many invitations had been offered by public bodies and others to the members of the party, and these kindnesses, having been duly acknowledged, were accepted on the understanding that they should not interfere with the working programme.

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## EXCURSION TO THE VOLCANO OF GRAVENOIRE AND TO THE MINERAL SPRINGS OF CLERMONT AND ROYAT.

*Director* : M. PH. GLANGEAUD.

At six o'clock on the morning of the *first day, August 17th*, the members began to be on the move, and shortly afterwards, in brilliant weather, the work as set forth in the programme was commenced. Proceeding from Clermont to Royat the party saw rising before them the volcano of Gravenoire, which was to be the

object of their morning's study. Before commencing this work in detail, however, the more prominent physical features of the region were pointed out by the Director, and the geological causes explained to which these features owe their origin. Standing at Royat and looking eastwards, the members saw stretching before them the great plain of the Limagne, formed essentially of Tertiary sediments. Looking westwards they saw running to right and left, and sloping steeply up from them, the great furrowed escarpment of the ancient crystalline rocks against which the faulted Tertiary sediments abut; and grafted as it were upon the lower slopes of this escarpment they saw the tree-clad and somewhat conical hill whose structure and geological details they were about to investigate.

The more prominent facts relating to the geology of this volcano were set forth in the summary which M. Glangeaud had presented to the members on the previous evening, and of which the following is a somewhat free translation.

\* The volcano of Gravenoire is situated upon the western border of the Limagne, and is backed by the elevated crystalline region which supports the Chain of Puy. It overlooks, to the north and to the south, two valleys considerably more than a thousand feet deep, which have been scored in the granitic escarpment which dominates the Tertiary basin—the valleys of the Tiretaine and Artière.

The volcano is installed upon the great western boundary-fault of the Limagne, which has produced the escarpment, and along which the Oligocene strata, inclined and folded in Mio-Pliocene times, are let down. Through this fracture, widened into a fissure, issued all the materials forming the present cone, and the lava-flows which extend from it, on the one hand towards Royat, on the other towards Boisséjour.

Upon the parallel faults by which the Tertiary strata, and the lavas of the ancient (? Miocene) volcano of Charade have been depressed in successive steps towards the centre of the Limagne, there have arisen, in the vicinity of Beaumont, at least three little volcanoes. Of these, two have yielded lava-flows, one, the cone of Mont Joly, sending a stream towards Clermont-Loradoux, the other, the cone of Beaumont, sending a stream towards Aubière. (Fig. 39.)

The pressure exerted by the faulted masses at the foot of the crystalline plateau, was doubtless one of the principal causes which led to the issue of these lavas. They ascended along faults which had been developed at the close of the Miocene period. The genesis of these volcanoes recalls, therefore, that of the analogous volcanoes described by Keilhack

\* "Monographie du Volcan de Gravenoire," Bull. des Services de la Carte Géol. de la France, &c. 1901.

and Thoroddsen in Iceland, and of the volcanoes of Latium as explained by Portis.

The lava-currents from Gravenoire and from the volcano of Beaumont flowed along valleys of Upper Pliocene age, filling them up more or less completely. The floors of these

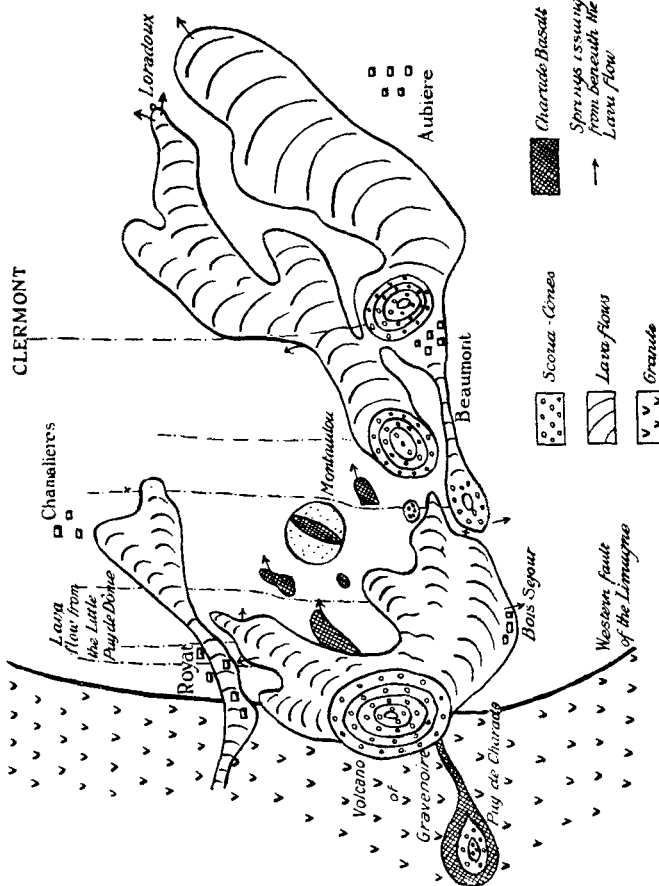


FIG. 39.—MAP OF THE VOLCANOES OF GRAVENOIRE, CHARADE, AND BEAUMONT.

ancient valleys, covered with alluvium surmounted by the basalt-flows, are still traversed by streams, and it is they which give origin to the springs of Boisséjour, Beaumont, St. Jacques and Loradoux. Since the time of the emission of these lavas, erosion has dug on either side, the valleys of the Tretaine and the Artière, between which the basaltic sheets now form an elevated plane sloping gently down to the Limagne.

The metamorphism produced by these lavas varies according to the materials with which they have come into contact. Sometimes, as in the baking of clays and their conversion into veritable "brick", and the rubefaction of sands and arkoses, the changes are not profound; but, at other times, as in the absorption and recrystallization of blocks of limestone and masses of crystalline rocks brought up from below, the changes have involved a more or less complete chemical and mineralogical reconstitution. The alteration of quartzose or quartzo-felspathic rocks has often led to the production of augite, andesine, sillimanite, spinellids, and zeolites. The conversion of limestone into garnet, wollastonite, augite, anorthite, etc., recalls that of the Italian volcanoes of Latium and Somma. The action of volcanic vapours upon blocks torn from below has resulted in the formation of such minerals as hematite, magnetite, pseudobrookite, augite, aegerine-augite, biotite, labradorite, anorthoclase and apatite. This assemblage of minerals is analogous with that in the tuffs of Nocera, Vesuvius, and Santorin. Volcanic activity has not yet entirely ceased in the district. It still continues to manifest itself in the existence of numerous hot springs which emerge along the outcrops of the so-called volcanic or hydrothermal faults (springs of Royat and Clermont). Moreover, the exudation of bitumen from these faults is not uncommon (Puy de l'Ecorchade, Puy Chateix); and exhalations of carbon dioxide, either alone (mofettes) or in association with heated waters, are very abundant.

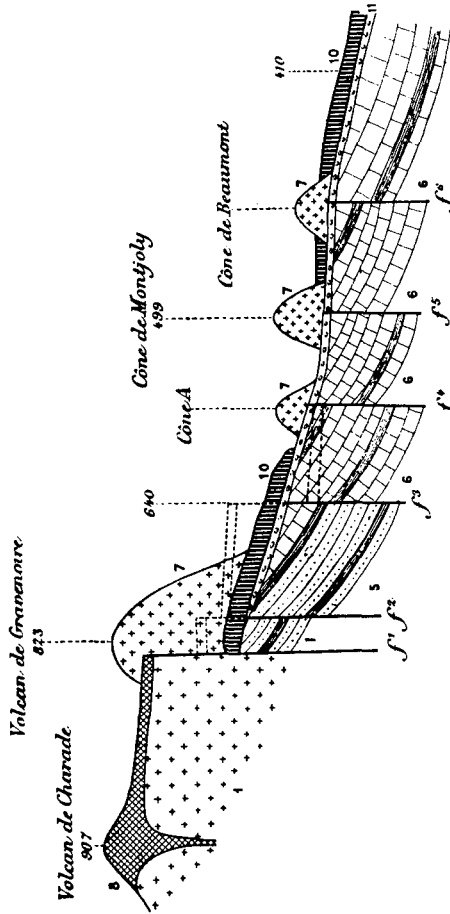
The eruptions of the volcanoes of Gravenoire and Beaumont took place in early Quaternary times.

During the morning the members saw for themselves all the leading facts and many of the details of this volcano, which notwithstanding its smallness is one of the most interesting in the Auvergne. They ascended its eastern slopes to a point whence a fine view of the plain of the Limagne was obtained, and a glimpse of the volcano of Charade, which is perched behind Gravenoire upon a higher part of the sloping escarpment of the crystalline rocks. During the ascent a number of quarries and natural exposures were visited, and in these the lavas and dark-coloured ashes of which the hill is composed were seen. Sometimes they were fresh, sometimes characteristically altered by fumarolic action; their gentle slope outwards and downwards from the summit was often plainly visible, and in one exposure the ashes, which are quarried for "gravel", were seen resting directly upon the underlying granite.

Descending then to the level of the plain, the road passing through Beaumont was followed, in order that a closer inspection might be made of the little eruptive cones and lava-flows in that vicinity. It was here, through the courtesy of M. Mourlevat, who

kindly permitted them to enter his garden, that the members saw the remarkable section illustrated in Plate XII. It is a cliff-like termination of a basaltic flow from Mont Joly, one of these tiny cones; the lava lies in the hollow of a little valley of Upper

FIG. 40.—DIAGRAMMATIC SECTION OF THE VOLCANOES OF CHARADE, GRAVENOIRE, AND BEAUMONT.

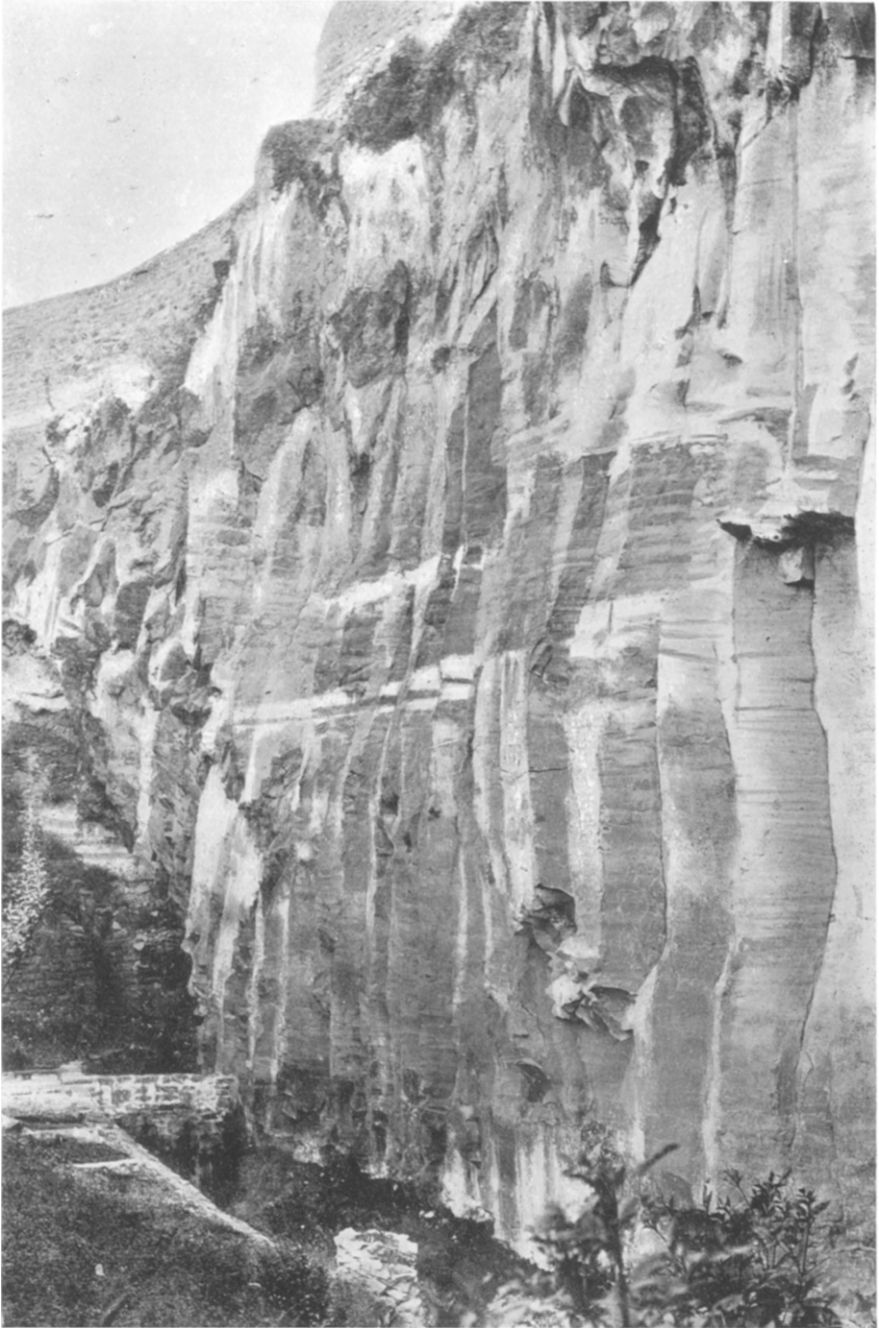


1. Granite; 5. Arkoses and clays (Upper Sannoisian); 6. Marls, marly limestones, and arkoses (Stamplian); 7. Scoria-cones; 8. Lava-flow from the Charade Volcano; 10. Lava-flow from Gravenoire and from the Cones of Beaumont; 11. Sub-basaltic Alluvium (Lower Quaternary); *f* 1 *f* 6 Volcanic and hydro-thermal faults.

Pliocene age, and rests upon alluvium which carpets the valley-floor and through which a stream of clear water, filtering its way, emerges into the garden at the foot of the lava-wall.

From Beaumont the party returned to Clermont, where, having lunched, they appreciated the short rest which their indefatigable Director allowed before resuming work.

In the afternoon a visit was paid to the famous encrusting



QUATERNARY VALLEY FILLED BY A COLUMNAR FLOW OF BASALT FROM MONT JOLI,  
NEAR CLERMONT-FERRAND.

*(From a Photograph by Professor Armstrong.)*



springs—the so-called petrifying springs—of St. Alyre. Owing to the large amount of carbonic acid which they hold in solution, the waters of these springs are exceptionally rich in carbonates of iron and calcium ; and it is to the presence of these salts and their precipitation as the carbonic acid is gradually given off, that their “petrifying” properties are due. These properties are utilized in the establishment of St. Alyre in the following manner : The water is first conducted along conduits containing shavings and twigs ; upon these it deposits the greater part of its iron and other carbonates, and passes on with practically only calcium carbonate in solution. It is then made to descend, cascade-fashion, over a series of wooden shelves upon which are placed a variety of small objects which it is desired to “petrify,” and which soon become hermetically sealed within an investment of calcium carbonate. The colour of this coating varies from yellowish white, on the upper shelves, to pure white on the lower, owing to the presence at first of a little residual iron, which is however completely precipitated before the water reaches the bottom of the series. Besides the encrusted nests, fruits, eggs and the like which are so commonly offered to the traveller in districts where petrifying springs occur, there are produced at St. Alyre, medallions, cameos and bas-reliefs of considerable artistic merit, which are made by allowing the water to flow over gutta-percha or sulphur moulds taken from carefully executed carvings. In the grounds around the springs, petrifications of a variety of large animals, even of human beings, were seen, but it was generally agreed that these were more curious than beautiful. The natural bridge of travertine which spans the little stream, and which is figured in Scrope’s “Volcanoes of Central France,” is a feature of some geological interest, inasmuch as it is entirely composed of calcium carbonate deposited by these waters.

The mineral springs of St. Alyre belong to a group of twenty-two which rise in Clermont, or its immediate vicinity, along the course of one of the hydrothermal or eruptive faults already alluded to. The waters of all these springs are effervescent, and the carbon dioxide evolved is of such purity as to be largely used in the locality for the manufacture of Seltzer water. The salts held in solution are chiefly calcium, magnesium and sodium carbonates and sodium chloride. The amount of the last salt is so great that at certain points small marine floras have established themselves and thrive around the springs. All the waters are utilized as beverages—locally for the most part, although some are exported. Their use for baths has been but little developed, owing no doubt to the proximity of Royat, with its superior resources.

From St. Alyre the party proceeded by electric tram to Royat.

They first visited the newly instituted lapidary establishment of Royat, where they were shown, under the courteous direction

of M. Demarty, all the stages in the cutting and polishing of a variety of precious and ornamental stones. Many of these, amethyst, opal, agate, jasper, fluor-spar and others, were from Auvergne localities, a fact which increased their interest for the party. Excellent specimens of these local minerals were placed at the disposal of the members, most of whom availed themselves of this kind offer, to add to their collections. After seeing the detailed processes of cutting, grinding, and polishing, by which the finished gem is gradually evolved from the mineral in its rough state, the members ascended to the show rooms. The collection of finished articles there displayed was much admired, and it was with the greatest difficulty that the ladies were prevailed upon to terminate their inspection. This at last having been effected, however, the visit concluded with a vote of thanks by the President on behalf of the members and an expression of good wishes for the continued success of the enterprise.

A few minutes' walk then brought them to the "Etablissement Thermal de Royat." Here they were most courteously and hospitably entertained by a number of gentlemen who had assembled to receive them. The President of the Board of Directors, Doctor Fredet, one of the Directors, M. Fernand Ventre, and M. Dionis du Séjour, the Director of the establishment, were formally presented, and there followed an exchange of civilities, in the course of which Dr. Fredet spoke on behalf of the hosts, and Prof. Bauerman, representing the guests, replied.

The visitors were then conducted over the great establishment, and were enabled to see the many ingenious modes in which the heated waters and the carbonic acid gas are employed in the treatment of a variety of ailments.

The most important of the springs is the famous Eugénie spring. It is to this spring in the main that Royat owes its prosperity. It rises bubbling to the surface along one of the hydrothermal faults to which the attention of the members had been called during the work of the morning. It discharges 220 gallons of water at 34° C. per minute, and 176 cubic feet of carbon dioxide, and alone furnishes 120 baths with a constant and never-failing supply. The spring of St. Mart, which is near it, is colder, having a temperature of 28° C. There are in addition four other mineral springs in Royat, and 332 in the province.

The waters of all the springs are effervescent; they are also charged with various chlorides and carbonates, and are ferruginous. Their curative effects are secured by drinking, gargling, spraying and bathing, and they are regarded as especially beneficial in arthritic affections—rheumatism and gout—in diseases of the respiratory organs, and in anemia and chlorosis. The virtues of the waters seem to have been well known and appreciated by the Romans, for in the park at Royat there are remains of extensive Gallo-Roman baths.

At the close of their most interesting tour of inspection, the members, taking leave of their distinguished guides, returned to Clermont.

At dinner it was announced that the party was invited by the "Compagnie Générale des Eaux Minérales de Royat" to be present that evening at a gala performance to be given at the Casino. Thither they repaired in due course and witnessed pleasing representations of two little plays. Both were in verse, and the gentle cadences of the performers, combined with the previous exertions of the day had a very soothing effect upon many of the visitors, which was rendered evident by nodding heads.

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EXCURSION TO GERGOVIA, AND THENCE  
BY THE PUY DE CROUEL BACK TO CLERMONT.

*Director, M. J. GIRAUD.*

The *second day, August 18th*, was devoted mainly to the study of the stratigraphy and characters of the pépérites and associated rocks of the Gergovia plateau. An early start was made from Clermont, and by combining driving and walking, an excellent impression was obtained of Gergovia and the surrounding country.

On the way the contour of the country was shewn to indicate that from the period of the flowing of the lava from the cones of Beaumont, to the Reindeer age, erosion to the extent of 66 feet in depth had ensued, and during this period the alluvium of the plain of Sarliève had been deposited. Further along the Issoire road there were seen exposures of marls with *Cypris*, associated with limestones containing *Helix ramondi*, *Limnæa*, *Planorbis* and mammalian remains (*Anthracotheurium*, *Dremotherium*, *Cainotherium*).

An excellent view of the whole structure of the Gergovia plateau was obtained at a bend in the road. At the lowest level the marls and limestones of the upper beds of the Middle Oligocene could be distinguished, with a mass of basalt and its overburden of pépérites resting on them. Above these the escarpment assumed a gentler slope where marls with plant remains, and *Melania* and *Unio* formed the surface, whilst capping all was a second mass of basalt.

In connection with Gergovia considerable discussion and difference of opinion has been ventilated in reference to the lower mass of basalt. Poulett Scrope, Croizet and Julien regarded it as a flow, and the pépérites as the result of the ejection of the volcanoes falling into Oligocene lakes. Pomel and Michel Lévy, on the other hand, view the lower basalt as an intrusion of later date and the pépérites simply as a vein phenomenon. This matter has been studied by M. Giraud, and he freely

placed before the visitors his evidence and his views, but of course, with such a very cursory inspection of only two or three masses of pépérites they were not prepared to pass any definite opinion themselves. M. Giraud indicated particularly the following features, which were followed with considerable interest by the members, who moreover collected many specimens. The lowest basalt was encountered first near the last

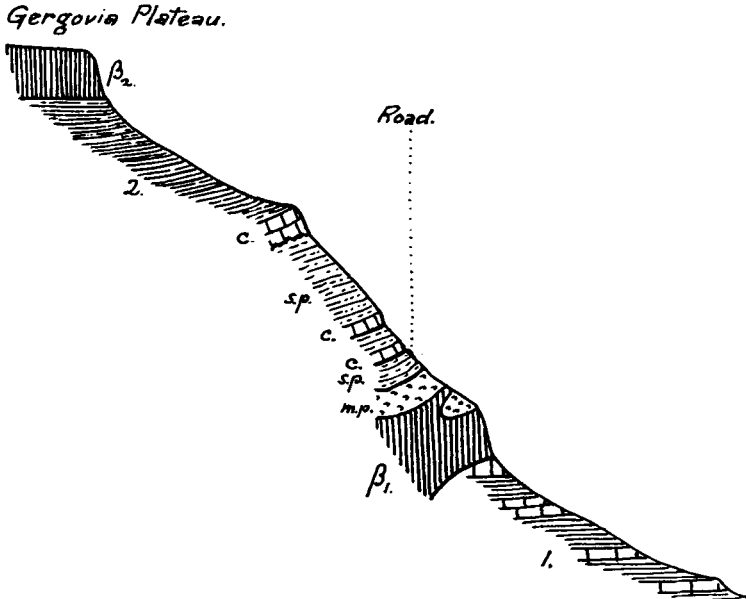


FIG. 41.—SECTION OF THE GERGOVIA ESCARPMENT.

1. Marls and limestone with *Cypris* and *Helix*. Upper part of Middle Oligocene.
2. Marls with plant remains and *Melania lauræ*, *Melanopsis hericarti*, *Unio*, etc. Upper Oligocene.
- $\beta_1$ . Lower basalt (intrusive dyke).
- $\beta_2$ . Upper basalt (flow).
- m.p.* Massive pépérites near the basalt.
- s.p.* Pépérites in beds parallel to basaltic dyke.
- c.* Marmorised limestone; under surface with little pits containing fragments of intruded basalt.

houses in Gergovia; it was much disintegrated, and was being worked for use as gravel. It rested unconformably on the Oligocene sediments, had ramifications projecting into them, and had baked the marly limestones which had assumed a columnar structure at the contact, both above and below. Following the exposure to the north-east, it was lost just to the south of a

ravine, where it was cut by another basaltic dyke striking north-west, and of more recent date. The lowest basaltic mass was again exposed a little further on in the ravine, where the marly limestone was again baked and rendered columnar, whilst the basalt at the upper part lost its hardness and passed imperceptibly into pépérites, so that no line of demarcation was visible between the two formations. Moreover at this point the basaltic mass was inclined, and cut the Oligocene strata very obliquely, see Fig. 41. These pépérites were compact and destitute of stratification in the vicinity of the basalt, whilst away from the latter they were more earthy, were apparently bedded and had a very variable dip frequently exceeding  $30^{\circ}$ . Their colour varied from grey to brown; their composition, according to M. Michel Lévy, is fairly uniform. They consisted of an earthy, clayey cement with much decomposed basaltic débris and a moderate abundance of secondary calcite. They were intersected by veins of aragonite and opal (semi-opal), whilst in the mass of pépérites there were many bedded masses of limestone displaced from their normal position and exhibiting evidence of metamorphism both on the upper and lower surfaces. The limestone, in fact, had been baked and marmorised. M. Giraud particularly pointed out that some of these displaced masses of limestone appear to have been penetrated by basalt from below, and pieces of basalt were found in cavities on their under surface. The pépérites of Gergovia were observed to cease at the upper marls. The overlying limestones were tilted to about  $30^{\circ}$ , were marmorised and pitted on the under surface as in the cases just cited.

From these facts, and as a result of his investigations amongst other pépéritic masses in the Limagne, M. Giraud has come to the following conclusions:—

(1). The pépérites always occur in association with basaltic dykes. (2). They are produced by the disintegration and alteration of the Oligocene marls by the intrusion of basalt. (3). In proximity to the basalt they are devoid of stratification, whereas at the outer surface a stratification parallel to the surface of the dyke is occasionally developed, on account of the great compression exerted; moreover the pressure developed has been sufficient to cause the pépéritic mass to ooze out at certain points, and to flow like a true volcanic stream. (4). The pépérites and the basaltic dykes which produced them were formed at a period between the Upper Pliocene and the commencement of the Middle Quaternary; they were an accompaniment of the final subsidences which produced the basin of the Limagne. The pépéritic mass of Gergovia really consists of three basaltic dykes in juxtaposition with their associated pépérites; the lowest mass, the one regarded by some as interstratified, strikes N.E., the second, seen in the ravine, strikes N.W., the third, which breaks away from the lowest at the cross of Gergovia, strikes N.N.E.;

all three were inspected by the members on the way to the top of this famous eminence.

Moreover the Upper Oligocene marls of Gergovia were examined, especially the beds with plant remains, worked by the Abbé Boulay. *Melania laurie*, var., *Melanopsis hericarti*, *Unio*, *Planorbis*, &c., were observed, whilst on the top of the plateau, pebbles of Jurassic siliceous limestone were also collected. They have been derived from the Jurassic beds of the Ardèche and the Lozère, and probably represent the alluvium of rivers of Upper Miocene age.

The afternoon was devoted to the examination of some other pépéritic masses dispersed over the Limagne, in the neighbourhood north and north-east of Gergovia, and involved some pleasant and interesting drives and walks. At one of the pépéritic masses, the Puy de Crouel, prettily situated among peach orchards and vineyards, and from the top of which a delightful view was obtained, pépérites were seen passing by gradual transition into basalt. At another, known as the Puy de la Poix, a bituminous spring exudes from very compact pépérites associated with a vertical basalt dyke, the transition from pépérite to basalt being again gradual. It may be remembered that this particular class of pépérite was regarded by Scrope as the result of local volcanic eruptions through soft calcareous mud, which at the time formed the bottom of a lake.

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## EXCURSION FROM CLERMONT TO THE PUY DE DOME AND BACK.

*Director:* M. PH. GLANGEAUD.

The details of this day's proceedings will be found at the end of the following general account of the physical geography and geology of the Chain of Puys, which has been most kindly contributed by M. Glangeaud, and which includes observations which he has made and conclusions at which he has arrived during a study of the region extending over several years.

### The Chain of Puys.

BY M. PH. GLANGEAUD.

#### PHYSICAL GEOGRAPHY.

The Chain of Puys lies a little to the N.E. of the massif of Mont Dore. As its name implies, it is a string of small volcanoes. These, which are sometimes spoken of collectively as the Dôme Mountains (Monts Dômes), are more than sixty in number, and extend with a general north and south align-

ment over a narrow tract of country some fifteen miles in length, by three or so in breadth. In its width the chain usually presents two eruptive cones, rarely three and occasionally only one.

The volcanoes themselves rest upon a foundation of ancient and mainly crystalline rocks, which has an average altitude of close upon 3,000 ft. This elevated region overlooks to the west, the valley of the Sioule, and to the east, the Tertiary basin of the Limagne, both of which, like the Chain of Puys, pursue a general north and south direction. The slope of the ground towards the Sioule however is gentler than towards the Limagne.

*Form and Arrangement of the Volcanoes in the Chain.*—The mean height of the puys above the level of the sea is 3,775 ft.; a few of them exceed 3,900 ft. (Puy de Clerzou 3,935 ft., Puy de Montchier 3,970 ft., Puy de Pariou 3,970 ft., Puy de Laschamp 4,134 ft., Little Puy de Dôme 4,158 ft.), and the giant of the chain, the Puy de Dôme, leading by more than six hundred feet, attains an altitude of 4,808 ft.

As regards external form, it is possible to recognise among the volcanoes of the chain two very distinct types; domitic volcanoes, which are more ancient; and cratered volcanoes, which are more modern. The former are the remains of Pliocene volcanoes; they often constitute imposing masses and present a variety of forms, some being irregular (Puy de Dôme, Puy Pelat), others regular and characteristically dome-shaped (Puy de Sarcoui, Puy de Clerzou). The latter, which are of Quaternary age, are for the most part remarkably well preserved, the craters, which sometimes descend to depths of 300 ft. or more (Puy de Pariou), often remaining practically unimpaired.



FIG. 42. THE PUY DE CLIERZOU.

The Puy de Côme (Fig. 43) and the Puy de Pariou shew two craters concentrically arranged, and several others present two or even three associated craters, which must have been in action either successively or perhaps simultaneously. Some, like the Puy de la Nugère



FIG. 43. PROFILE OF THE PUY DE CÔME, WITH ITS TWO CONCENTRIC CRATERS.

and the Puy Louchadière (Fig. 44) have been in part demolished by the destructive escape of lava, and the Puys of La Vache and Lassolas, which are classic instances, have been breached to their very base, and in such a manner as to expose

to view the actual vent through which the molten matter issued.

*Lava-flows.*—To the east of the Chain of Puy, and running roughly parallel with it is a tract of elevated ground, occupied by the crystalline rocks already mentioned, which rises at least 300 ft. above the



FIG. 44. PROFILE OF THE PUY DE LOUCHADIÈRE (CRATER PARTLY DEMOLISHED).

base-level of the puy themselves. The continuity of this great bank is here and there interrupted by gaps which have been cut across it by erosion, and through which have flowed westwards from the volcanic chain, streams of lava descending the steep eastern face of the crystalline massif to the Limagne below.

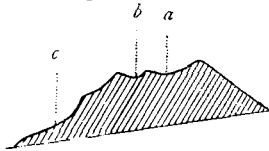


FIG. 45. PROFILE OF THE PUY DE BARME, WITH THREE CRATERS IN LINE.

a. First crater. b. Second crater. c. Third crater.

The Chain of Puy therefore is not situated upon a plateau, nor yet upon the crest of the crystalline region, which separates the Limagne from the Valley of the Sioule,

but to the west of that crest and well below it. A consideration of these facts enables us to understand why it is that on the western side of the eruptive chain, where they met with no barrier to their advance, the lava-streams are most extensive—indeed, by their lateral coalescence they have given rise to a great sheet of lava almost continuous from end to end of the chain—while on its eastern side they are much restricted, their progress having been arrested by the great axial ridge, except where ways had already been cut through it by erosion.

On the west the individual lava-streams sometimes cover very large areas, being both broad and long. As instances, may be mentioned the flows from the Puy de Côme, the Puy de Barme, and the Puy Louchadière, which are two and three miles wide, and five or more long, and descend sometimes to the Sioule itself. On the east however they are rarely broad, being usually confined to the bottom of narrow, deep and often steep valleys, and forming as it were long winding tracks of molten matter, which widen out only on reaching the level plains of the Limagne. Of this type are flows from the Puy de la Nugère, the Puy de la Raviole and the Little Puy de Dôme.

Some of the lava-flows, the so-called *cheires*, constitute arid and chaotic regions, veritable rocky deserts, upon which grows but little vegetation, except lichens and mosses, and whose



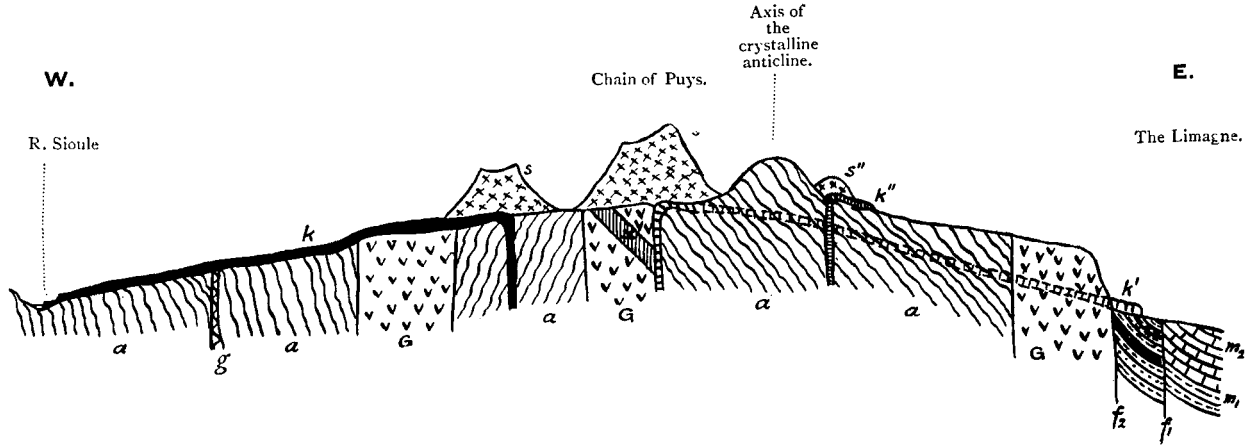


FIG. 46.—SCHEMATIC SECTION ACROSS THE CHAIN OF PUYS.

G, granite. *g*, Muscovite granite. *a*, Archæan metamorphic rocks. *x*, ancient sedimentary rocks (? Cambrian). *s*, *s'*, *s''*, scoria-cones. *k*, *k'*, *k''*, lava-flows. (The lava-flow *k'* occupies the bottom of a valley of a Pliocene age, cut in the crystalline rocks.) *f*<sub>2</sub> western boundary fault of the Limagne. *f*<sub>1</sub> hydrothermal fault. *m*<sub>1</sub> Oligocene arkoses. *m*<sub>2</sub> Oligocene limestones.

barren and desolate aspect is in strong contrast with the more fertile tracts near at hand, where rocks of other kinds occupy the surface of the ground. Such are the cheires of Aydat, from the Puy of La Vache and Lassolas, those of Louchadière and Pariou, and especially that of Côme, which covers an area of several square miles.

*Hydrology. Natural Ice-houses.*—As may be inferred from what has already been said, lava-flows were frequently directed into valleys occupied by running water. It is possible to imagine however that the lava need not interfere with the drainage of the valley, but that it might serve simply as a roof or vault, beneath which the stream would still continue to flow. This is indeed what is often observed to be the case. At the end of most of the lava-flows these streams may be seen emerging as springs. The waters of such springs are remarkably fresh and clear, owing to the filtration which they have undergone in passing beneath and through the more or less porous lava. The springs of Royat issuing from the end of the lava-flow from the Little Puy de Dôme, and those of Nohannet from below the lava-stream from the Puy de Pariou are illustrative instances.

In connection with these lava-covered water-courses a singular phenomenon may sometimes be observed. At points where the lava-sheet is unusually thin, the water from below rising by capillarity through the porous rock, reaches the surface, and is subjected to evaporation. If the weather be hot, this evaporation may be so rapid as to produce a fall in the temperature of the water occupying the hollows and cavities just below the surface sufficient to cause it to be frozen. The formation of ice in this way, paradoxical as it may at first seem, only occurs during the hottest days of summer, *i.e.* when the evaporation is most rapid: it is necessarily restricted also to the thinner and more porous portions of the lava-flows. The phenomenon may be observed at several points, as for example in the neighbourhood of Pontgibaud, in the lava-flow from the Puy de Côme, and near Aydat in that from the Puy de la Vache.

#### GEOLOGY.

*Fundamental Rocks.*—The foundation, upon which the Chain of Puy reposes, consists of granites, Archæan gneisses and schists, and Cambrian sediments. This ancient complex is traversed by innumerable veins of muscovite-granite, pegmatite and microgranite. Locally also veins of mica-porphyrite, kersantite, diorite and diabase occur (Aydat, Volvic, &c.).

The region lying to the west of the puy of Pariou and

La Nugère is almost wholly formed of (? Archæan) gneiss and of mica-schists showing various degrees of metamorphism, and containing cordirite in abundance, and sometimes garnets. Isolated patches of these schists are often found enveloped in the granite.

The Cambrian rocks, which are practically unfossiliferous—up to the present time the only specimens of possible organic origin which have been found in them are certain rare impressions, believed by some to be the remains of algæ—are of considerable variety. They include quartzites, chistolite-slates, spotted-slates, amphibole- and pyroxene-schists and green hornstones. The hornstones present a remarkable development in the neighbourhoods of Aydat, Verneuges, and Saint-Gènes-Champanelle where they are associated with diorites and diabases.

All of these fundamental rocks have been affected by folds and fractures bearing N.N.E. and N.N.W., and having therefore the general directions of the old Hercynian chain. The veins of igneous rocks have a similar orientation. Moreover the rocks are also traversed by numberless joint-planes—often rendered conspicuous by quartzose infiltrations—and these frequently extend in the same directions. These facts have a significance which will appear later.

*Geological History.—Tectonics.*—The works of Lecoq, of M. Julien, and especially of M. Michel Lévy, have shown that, at the end of Eocene times, the region which now forms a foundation for the Chain of Puys was very level, and formed a kind of peneplain which extended across what is now the Limagne to the Forez Hills. But at the end of the Eocene period there commenced the formation of a syncline, with a N. and S. direction—the future Limagne. On the east this was bounded by the anticline of the Forez Hills, to the west it was limited by the anticline which now forms the support for the Chain of Puys, while to the west of this again, began to appear the syncline of the Sioule. (Fig. 46.)

During the Oligocene period these folds continued to increase in amplitude. Step by step with its progressive descent the syncline of the Limagne was filled with lacustrine deposits, at first arkoses, and then more or less marly lime-stones. These sediments, although accumulating, according to M. Giraud, under shallow water, at least during the earlier stages, nevertheless attained a thickness of more than 3,000 ft., as has been proved by borings at various points (petroleum boring at Riom, etc.).

*Miocene Eruptions.*—The elevation of the Alps, as M. Michel Lévy has shewn, was not without its effects upon the massif of Central France. It further accentuated these N. and S. folds, and in doing so raised the Tertiary sediments on

the flanks of the anticlines to altitudes of three thousand feet and more. But, according to M. Giraud, it was probably not until the end of Upper Miocene times that the fractures were produced, through which the great sheets of basalt—the so-called Plateaux Basalts—of Chanturgues, Gergovia, and the Hills of Clermont, rose to the surface. Besides these Plateaux Basalts, there are others, which I believe to be of the same age, occurring up on the crystalline region—*e.g.* those of Berzet, Charade, Prudelle and La Serre; and it is not unlikely that a considerable part of that region too was then deluged with great basaltic flows. Moreover similar movements and eruptions proceeded simultaneously in the Cantal, where, as demonstrated by M. Boule, a great variety of rocks of the same geological age exist.

The movements continued during the Pliocene period, and finally resulted in the production of a number of great step-faults striking parallel with the axes of the folds and having a downthrow towards the synclines. All the formations of the region, crystalline rocks, Tertiary sediments, and basaltic flows alike were affected by these dislocations. The basalts of Gergovia, Chanturgues and the Hills of Clermont are broken by them into a series of steps descending towards the middle of the Limagne, and the same is true of the basalts of Charade, La Serre, &c. The displacement of these basalts by the great N. and S. faults is one of the proofs of their great antiquity; their altered character is another.

*Early Pliocene eruptions. Domitic volcanoes with craters.*

—At the commencement of the Pliocene period, and for a great part of it, owing no doubt to the movements described above, vulcanicity became active in the south; and it was mainly during this time that the grand volcanoes of Mont Dore and the Cantal were formed, although their first eruptions—at least in the latter case—probably occurred in Miocene times (M. Boule).

In all probability it was also during the Pliocene period that the eruptions occurred, which gave rise to the domitic volcanoes of the Chain of Puys. These are in reality dismantled volcanoes, only the bases of which remain. That they once were cratered volcanoes is proved by the alternation of lava-flows and beds of ashes which is exhibited by them. (Fig. 47.) They are found resting in some cases upon the crystalline rocks, in others upon sheets of basalt of Upper Miocene age, plentiful specimens of which rock may be found among their ejectamenta.

Erosion has often entirely removed the imperfectly consolidated portions of these volcanoes, and has left behind only the harder and more solid parts. These frequently

assume the form of a dome or inverted cauldron owing to the nature of the melted domitic material, which, being very viscous, and therefore incapable of flowing freely, solidified before it had travelled far from its point of issue. The Puy of Sarcoui (Chaudron) and Clerzou are of this type. The Puy de Dôme seems to be the remains of a great domitic volcano which extended northwards across the area now occupied by the Little Puy de Dôme, as far as the Puy de Manson,—itself in great part composed of domite—and which must have attained an altitude of at least 6,000 feet. The steep rocky part of the Puy de Dôme is the neck of this great Pliocene volcano. The mass of débris at its base is at least equal to that of the mountain itself; this is also true of the other domitic puy (Sarcoui, Clerzou, Chopine) and is at once an indication of the reduction which they have suffered by erosion and a proof of their antiquity.

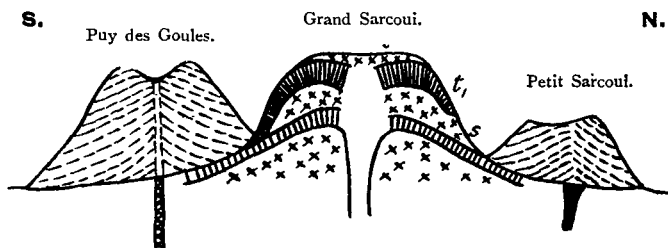


FIG. 47.—SECTION OF THE PUY DE SARCOUI (CHAUDRON) shewing the alternating sheets of stratified scoriae (s) and flows of domite (t), of which it is made up. This Pliocene domitic puy is flanked by two Quaternary volcanoes, with well preserved craters.

Domitic ejectamenta extend northwards as far as the Puy de la Nugère, and southwards as far as the Puy de la Vache. All the more recent volcanoes occurring within these limits include domitic fragments more or less abundantly in their projections, shewing that such materials underlie them, and also demonstrating the wide extent of the domitic region which they so largely conceal from view.

The age of these domitic volcanoes is not yet fixed with any great precision. The known facts, however, some of which have been enumerated above, seem to point to the conclusion that their eruptions were contemporaneous with those of Mont Dore, and consequently that it may be regarded as Lower or Middle Pliocene.

*Late Pliocene Eruptions.—The Little Chain of Puy.*—On the western slope of the Valley of the Sioule there occurs a series of small volcanoes (Banson, Neuffond, La Vialle, Le

Chalusset, etc.), which, like the Chain of Puys, have a general N. and S. alignment. Up to the present they have been but little studied, but they appear to have arisen under conditions essentially similar to those which led to the elevation of the Chain of Puys; indeed they may be regarded as a diminutive counterpart of that chain in relation to the Valley of the Sioule. For this reason I have suggested the name Little Chain of Puys for this series of volcanoes.

They rest upon an alluvium, which besides containing pebbles of the various crystalline rocks of the region also includes examples of all the volcanic rocks of Mont Dore. They are of later date therefore than that great volcano. On the other hand they would seem to be of rather earlier date than the cratered volcanoes of the Chain of Puys, for

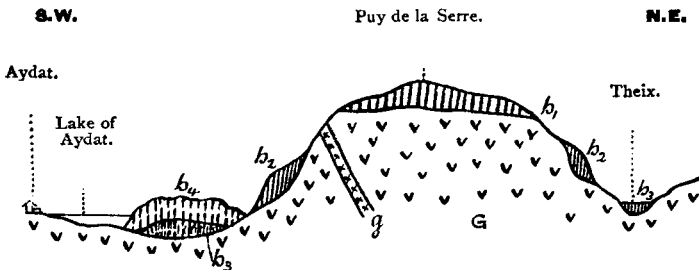


FIG. 48.—SECTION PASSING THROUGH THE LAKE OF AYDAT AND THE PUY DE LA SERRE, AND SHEWING BASALTIC FLOWS OF FOUR DIFFERENT AGES.

$b_1$  Miocene basalt.  $b_2$  Upper Pliocene basalt.  $b_3$  Lower Quaternary basalt (from the Puy de Mey).  $b_4$  Upper Quaternary basalt (from the Puy de la Vache). G Granite. g Muscovite granite.

their state of preservation is inferior, the craters themselves being either very imperfectly preserved or entirely obliterated. I am led to conclude, therefore, that the Little Chain of Puys is of Upper Pliocene age.

These were, however, not the only Upper Pliocene eruptions. There are reasons for believing that the basalts coating the flanks of the little hill of La Serre and of the Puy de Berzet, and associated with obscure remains of eruptive cones, are of the same age.

*Quaternary Eruptions.—Cratered Volcanoes of the Chain of Puys.*—The eruptions which gave birth to the cratered cones of the Chain of Puys took place after the close of the Pliocene period. They enveloped the domitic volcanoes, which were already considerably worn, sometimes modifying and in great part obscuring them, sometimes covering them up entirely.

Their lavas, which were basic in character, ascended mainly through the reopened N.N.E. and N.N.W. fractures, which had previously given passage to the more acid Pliocene lavas—the domites. These quaternary eruptions were on a larger scale than those of the preceding period and extended farther towards the north and south.

Fractures also opened upon the partly demolished flanks of Mont Dore, and gave rise to eruptive cones grafted upon that massif, and from each of these issued lava streams of varying extent. (Servière, Guèry, Montchalm, Montcynère, etc.)

It is now long since any eruption occurred, but from the discoveries of Pomel and Pommerol, who found two "stations" of the Reindeer age established at the end of a lava-flow from one of the most recent volcanoes (Volcan du Tartaret) and which were apparently but little posterior to the issue of the lava, it seems not improbable that man of the Chelean epoch may have witnessed some of these latest eruptions of the region.

*Genesis of the Volcanoes.—Cause of the eruptions.—*

I have shewn that the volcano of Gravenoire is situated upon a fault, the great western fault of the Limagne, which caused the Tertiary beds to abut against the fundamental crystalline rocks; and that the little volcanoes of Beaumont are installed upon parallel faults by which these sediments and the Miocene basalt of Charade, have been depressed in a series of eastward-descending steps. These are not features of merely local occurrence however, but apply to the whole region under consideration, which as has already been explained, was folded in Mio-Pliocene times and broken by faults into a series of terraces, which have since been robbed of some of their distinctness by the action of erosion. The Chain of Puys is situated upon one of these terraces, at the foot and to the west of that highest of them all which overlooks the base of the volcanic series by a height averaging 300 feet, but at places exceeding 400 feet.

The elevated region seems then to constitute the axis of an anticline whose flanks slope on the one hand towards the Limagne and on the other towards the Sioule, as shewn in Fig. 46. And although evidence of the presence of the parallel faults is less abundant in the crystalline region than among the Tertiary sediments, satisfactory proof of their existence is nevertheless forthcoming. The peculiar topography of the region, the occurrence of definitely orientated igneous veins, and the emergence of mineral springs along the common boundary of two terraces (as in the Limagne, where such a boundary can be proved to be the trace of a fault-plane) are some of the facts from which

their existence may be inferred. Everything points indeed to the conclusion that the region upon which the Chain of Puy is placed is part of a faulted anticline, whose formation, moreover, was connected with the earth-movements which led to the elevation of the Alps.

The Chain of Puy and the Little Chain of Puy occupy symmetrical positions with regard to the Valley of the Sioule. Each is placed at the base of the keystone of an arch; and their lava-flows converge towards the axis of the syncline which lies between them and along the bottom of which flows the Sioule. The lava-streams which flow from the Chain of Puy towards the Limagne have taken this direction simply because the axial ridge behind that chain was here and there breached by eastward-descending valleys which locally conducting the molten material down the eastern slopes of the anticline, prevented them from taking their more normal course, which was down the western slopes towards the Sioule.

Volcanoes do not occur exclusively to the west of the crystalline axis. A number of small eruptive points are situated to the east of it, the volcanoes of the neighbourhood of Chanat, but they only gave rise to small cinder cones and meagre lava-flows. The volcanoes of Bannière, near Volvic, of Gravenoire and of Beaumont, are also situated east of the anticlinal axis, but upon much lower terraces, as may be seen from Fig. 40.

The foregoing geological considerations afford an explanation of the peculiar topographical features of the region.

I have already mentioned that the whole of the fundamental formations are cut up by numberless N.N.E. and N.N.W. joints, which were in all probability produced during and by the elevation of the Hercynian chain. Now the Chain of Puy as a whole has a general N. and S. alignment, which was determined by Tertiary movements—the elevation of the Alpine chain—but the component volcanoes amongst themselves are disposed along N.N.E. and N.N.W. lines. It is permissible therefore to conclude that they are installed upon fractures such as I have described, fractures which must have played a part at a variety of epochs. Some of them had already conducted domitic lavas to the surface in Pliocene times. They re-opened in Quaternary times and permitted the escape of basic lavas; but at the same time new ones appeared, which had not previously taken part in the eruptions. These fractures were directions of least resistance, and it was consequently through them that the molten matter made its way. Its escape must have been favoured by the sinking of the lateral elements of the great faulted anticline, like the



slipping of the stones of an arch ; indeed it is possible that herein lies one of the principal causes of volcanic eruptions. Bearing in mind that all the eruptions in this region, Miocene, Pliocene, and Quaternary, are associated with movements of the ground, is it not reasonable to conclude that these movements must have determined the issue of the deep-seated magma, and that, at least for the Chain of Puys, there is no necessity to call in the aid of liquid masses—which did not exist—to produce the volcanic phenomena ?

*Order of the eruptions.*—It may be said of the Quaternary volcanoes, that their eruptions frequently commenced with the emission of basic lavas—the lower basalts. This is true of the Puy de Pariou, which gave birth to a lava-flow, which up to the present is undescribed. So it is of the Puys of Côme, Louchadière, la Nugère, &c. Afterwards more acid lavas escaped, sometimes andesites, sometimes labradorites ; and finally there was a recurrence of basic lavas—the upper basalts.

The number of flows issuing from a volcano is sometimes only one, but more usually it is two or three (Puys of Côme, Pariou, la Nugère). The volcanoes of Barme and Montgy have emitted at least four, each of a slightly different character from the others, and all of a remarkable freshness.

*Petrography.*—For our knowledge of the chemistry and petrography of the lavas of the Chain of Puys we are mainly indebted to von Lasaulx and to M. Michel Lévy, especially to the latter.

The rocks belong to two series, the domites, and the andesites, labradorites, and basalts. The domites are trachytic rocks with silica ranging up to 62 per cent. ; they are light in colour, being white or grayish, and usually contain a black mica and hornblende. The andesites, labradorites and basalts—lavas emitted by the Quaternary volcanoes—have a silica percentage varying between 58 per cent. and 50 per cent. ; they are dark in colour, owing to the abundance of ferriferous minerals—magnetite, biotite, augite, hornblende, olivine, &c. In certain instances some of the crystals are sufficiently large to produce a distinctly porphyritic structure, but generally the rocks are so fine grained and compact that their component elements can only be distinguished by the aid of a microscope.

*Minerals.*—During their eruptions the volcanoes sometimes threw out well formed crystals as well as the more ordinary ejectamenta, and at various points it is possible to collect these from among the cinders. The Puys of la Vache, Lassolas, la Rodde, Montgy, and Combegrasse are prolific localities for crystals of augite and hornblende. I do not know any spot where isolated crystals of olivine are to be

found, but olivine nodules are common in certain basalts of Miocene age, such as that of Mont Rodeix, and large crystals occur embedded in the porphyritic basalt of Charade.

The minerals of fumaroles are naturally abundant, the commonest of which is hematite, beautiful crystals of which may be collected from the fissures of several of the puys. In the lavas of the Puy de la Nugère martite occurs and with it are associated black mica and occasionally hypersthene. Finally in a number of the volcanoes the cinders are coated with hyalitic opal.

On the *third day, August 19th*, the party made their first acquaintance with the Chain of Puys. The leading feature of the day's excursion was the ascent of the Puy de Dôme, from the summit of which, the meteorological conditions being most favourable, it was possible, by looking to north and south, to see this wonderful trail of volcanoes from end to end, and thus to obtain an excellent idea of the chain as a whole, and of some of the facts of form and arrangement presented by the individual cones of which it is composed.

Departing from Clermont at an altitude of 1,300 feet, the party drove to Royat. Thence following an ancient Pliocene valley cut in the crystalline rocks and carpeted from near Clermont to the foot of the Puy de Dôme by a basalt flow from the Little Puy de Dôme, they gradually ascended the great escarpment, and at an altitude of 2,600 feet emerged upon the surface of the crystalline foundation which supports the Chain of Puys. Driving then across these rolling uplands to the foot of the Puy de Dôme, and climbing to its summit, they finally reached an altitude of close upon 5,000 ft. (4,808).

Geological observations commenced at the viaduct at Royat. At this point there is an exposure showing Oligocene beds, forming part of a series let down successively towards the centre of the Limagne by a number of step-faults (see fig. 49). These beds which abut against the granite at the foot of Puy Chateix are highly inclined in the neighbourhood of the fault  $f_1$  and consist of fine sands and of variegated and more or less argillaceous arkoses, which, according to M. Giraud, are of Sannoisian (Lower Oligocene) age.

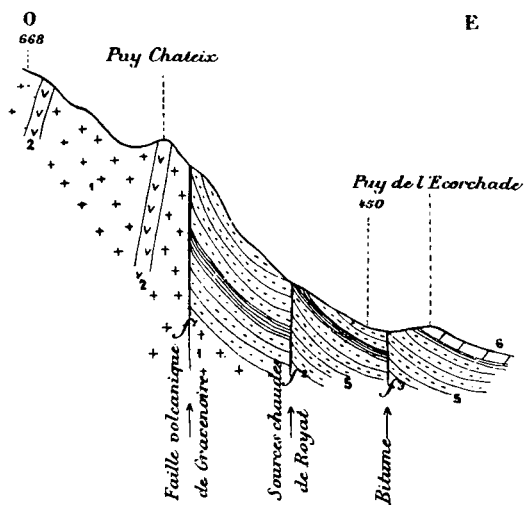
As the beds, which at the fault have an inclination of more than  $45^\circ$  are followed eastwards, they become continually less inclined, until the fault  $f_2$  is encountered, when they suddenly dip once again at a high angle. This fault is the one which gives passage at Royat to the heated waters of the Eugénie spring, which the members saw on the first day.

Followed towards the viaduct the beds again become less inclined, and marly limestones belonging to a higher horizon than the arkoses (probably Stampian) make their appearance. These in turn become highly inclined at the Puy de l'Ecorchade

in contact with the fault  $f_3$ . It was along this fault that the bitumen which impregnates the rocks of this little bituminous mamelon, and which has been tentatively exploited, ascended from below. Still farther eastwards towards Clermont, other faults of the same hydro-thermal character occur, and these continue successively to depress the Tertiary sediments in such a manner as to cause the newest beds of this region to occupy the centre of the plain of the Limagne.

The two sides of the valley in which the party stood are of different geological constitution. The side in which the Oligocene

FIG. 49.—SECTION OF THE NORTHERN SIDE OF THE VALLEY OF THE TIRETAINE AT ROYAT.



1. Granite; 2. Veins of Muscovite Granite (granulite);  
5. Arkoses; 6. Marly Limestones.

beds just described are seen is the north side. Turning now so as to view the south side, they saw a wall of black scoriaceous rock running along the length of the valley, and bearing upon its upper surface the majority of the houses of the town of Royat. It is the basalt flow from the Little Puy de Dôme, which made its way from the uplands above, down the valley of the Tiretaine. The river has cut its bed between the lava and the arkoses, and farther down it flows between the lava and the granite. The ascending road follows this lava stream for nearly five miles, to Fontanas.

Opposite the church at Royat, there issue from the alluvium

which lies beneath the basalt, and which covers the bottom of the ancient valley, the copious springs which are appropriated for the water supply of Clermont. The underground stream by which they are fed flows beneath its vault of lava from Fontanas to Royat.

Passing onwards through Royat, the party soon left the Tertiary beds behind and entered a deep and characteristically V-shaped granite valley. The porphyritic granite was seen at numerous points during the ascent, sometimes traversed by veins of muscovite granite.

Before reaching Le Pont des Soupirs these rocks were seen to be replaced for a little distance by much contorted gneiss, with dull blue cordierite and pink garnets. Nearer to the bridge the granite was again encountered, and a mass of plicated sediments (? Cambrian) was seen enclosed within it. At the bridge the lava stream was crossed; later it was recrossed, and the winding road exhibited in succession the granite cut by veins of muscovite granite, masses of cordierite gneiss and finally numerous thin veins of mica-porphyrite. Just before Fontanas, the basalt of the flow exhibits spheroidal weathering.

At Fontanas an elevation of about 2,500 feet was reached, and the general features of the valley just ascended, a deep furrow in the crystalline escarpment, were shown with great distinctness.

A little less than a mile beyond the Font de l'Arbre, the diminutive Puy de Chuquet Genestoux was reached. This interesting little eruptive centre is the point of origin of a miniature stream of basalt which flows towards Enval. In the midst of the scoriæ and volcanic bombs of which the cone is composed, numerous enclosures of granite were seen, all more or less baked or superficially melted, and often recrystallized. The mica has been bronzed, and the orthoclase, fused and vitrified, has the appearance of sanidine. In the cracks and fissures, apatite, opal, and zeolites are to be found.

The view from the summit of this hillcock enabled the members to appreciate the fact already described, that the level of the base of the Chain of Puys is considerably lower than the crest of the crystalline anticline. This latter was seen to the east, where it rises to an altitude of 3,380 feet, while the base of the volcanic chain nowhere rises much above 3,000 feet. Looking towards the Chain of Puys, they were confronted by the imposing mass of the Puy de Dôme, to the north of which were seen the elegant crescent of the cratered Puy de Pariou and the rounded dome-like Puy de Sarcoui, while to the south rose successively the Puys of Manson, Montchié, Laschamp, and others.

Quitting Chuquet Genestoux they then proceeded towards the Puy de Dôme travelling for nearly a mile upon the surface of two superposed flows of labradorite issuing from the base of that great volcano; afterwards approaching still nearer and passing along

the foot of a talus of domite they eventually reached the Col de Ceyssat, at which point it was necessary to leave the carriages.

The ascent of the Puy de Dôme (Pl. XIV., Fig. 1) from the Col de Ceyssat was easily made on foot in less than an hour, by following the excellent zig-zag path which leads to the summit.

During the ascent abundant exposures permitted the study of the petrological constitution of the mountain. It is mainly composed of a massive dyke of the light coloured and porous variety of trachyte to which the name domite has been applied. This dyke-like mass is enveloped on all sides by domitic ejectamenta, in the midst of which occur numerous blocks of basalt, granite, and ancient sedimentary rocks projected by volcanic action from below. The dyke of domite probably represents the neck of the original volcano. The mountain is now, however, no more than a ruin of its former greatness, for at the time when it first arose it must have possessed a crater rising to about 6,000 feet. Erosion has removed most of the comparatively loose and incoherent scorixæ, and has left only the hard resisting core of lava which still rises to an altitude of 4,808 feet.

The view from the summit of the Puy de Dôme, which is regarded as one of the finest in Central France is truly magnificent. Towards the north and south extends the remarkable linear series of volcanoes, many of the craters being still open and well-defined. Issuing from its base may be seen the numerous streams of lava, whose eastward and westward courses can be traced across the country by the grey and barren character of their surface, which so strongly contrasts with the fertility of the surrounding and intervening areas. Towards the east, at the foot of the escarpment of the crystalline rocks, stretches the rich plain of the Limagne, beyond which, upon the distant horizon, rise the Forez Hills continued southwards as the heights of Velay. Beyond the southern extremity of the Chain of Puys arises the great volcano of Mont Dore whose double slope is still clearly discernible. The eastern horizon is bounded by the granitic uplands of the Limousin. The members were fortunate in seeing this beautiful panorama to full advantage, thanks to a sunny day and clear atmosphere.

They also had the pleasure of inspecting the remains of the Temple of Mercury, concerning which M. Audollent, Professor in the Faculty of Letters in the University of Clermont, under whose direction excavations were being carried out, very kindly gave some interesting details. Moreover, they had the good fortune to hear an account of the famous barometric researches which the eminent French philosopher Pascal conducted upon the Puy de Dôme and in the surrounding neighbourhood in the year 1648. M. Brunhes, Professor of Physics in the Clermont University, to whom the members were indebted for this courtesy, then graciously presided at a reception

in the Puy de Dôme observatory, of which he is the Director. The toast of the welfare of the Geologists' Association which M. Brunhes proposed, was cordially responded to by Mr. Whitaker, who proposed in his turn the prosperity of the University of Clermont, which was represented at the time by three of the members of its staff. At the conclusion of this pleasant little ceremony the members, much refreshed, commenced the descent of the northern slope of the mountain. On the way down they passed the Little Puy de Dôme, which is a Quaternary basaltic volcano, grafted upon the northern flank of the Puy de Dôme. Its crater is fairly well preserved, and it has given origin to that long lava flow which the party had followed during the morning's journey from Royat up the valley of the Tiretaine. To the east of this volcano, which has arisen in the midst of the domite, is another which flanks it in turn, and has likewise yielded a lava flow which up to the present time has not been described.

Passing near the foot of the Puy de Pariou, the concentric craters of which had been well seen from the summit of the Puy de Dôme, the party proceeded towards the Fontaine du Berger, which hamlet they reached after having crossed the two lava streams emitted by the Puy de Pariou; the first of these is of basalt, and has not yet been described, the other which overlies it is a voluminous flow of andesite.

After lunch at the Fontaine du Berger, a number of the more active members walked to a point whence a good view was obtained of Sarcoui (the Cauldron) with its smooth and rounded profile. Sarcoui, like the Puy de Dôme, is a Pliocene volcano with a partially dismantled crater, and formed of flows of domite alternating with beds of scoriae (Fig. 47). Erosion has removed a part of these ashes, but has been arrested by the domitic lavas which are more resisting. Quarries opened upon the flanks of the mountain reveal very clearly its internal structure. Two Quaternary volcanoes—the Puy des Goules and Little Sarcoui—flank it towards the south and north in much the same manner as the Little Puy de Dôme is attached to the Puy de Dôme.

After this little *détour* the carriages were once more resumed, and the return drive to Clermont was commenced. The road follows the course taken by the great andesitic flow from Pariou. At La Baraque the flow bifurcates, one half continuing towards Durtol and Nohannent, the other descending to near Chamalières in a series of veritable cascades of lava. The Cap de Prudelle, formed by a flow of Miocene basalt exhibiting a very well-marked columnar structure, and associated with a dismantled eruptive cone, separates these two lava currents. By dismounting from the vehicles and walking to the outstanding point of this promontory, the members obtained an admirable view over the city of Clermont lying below, and of the Limagne beyond.

The descent from the Cap de Prudelle to the Limagne is very

rapid, and the drive in the cool evening along the splendidly constructed winding road down the escarpment was keenly enjoyed. At Durtol, the western boundary fault of the Limagne being recrossed, the low-lying fertile region of Tertiary sediments was once more entered. Here a short digression was made in order to afford the members an opportunity of seeing the peculiar *Phryganea* limestone in situ; the exposure was pointed out by M. Giraud, who also gave an account of the rock and its probable mode of origin. It is made up almost entirely of the tubular cases of the larva of a Caddis-fly. The tubes themselves consist of agglutinated fragments of calcareous or other sand or of tiny calcareous shells. The rock occurs in isolated masses in the midst of felspathic sands deposited on the bed of an ancient river. It is found at several stratigraphical horizons, but it is best developed in the Upper Oligocene beds of the southern end of the Limagne.

Having obtained excellent specimens of this extraordinary limestone, the members resumed their places in the carriages, and after a rapid drive across the level, reached Clermont about seven in the evening

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#### EXCURSION FROM CLERMONT TO MONT DORE.

*Director:* M. PH. GLANGEAUD.

The object of the excursion of the *fourth day, August 20th*, was to study the southern extremity of the Chain of Puys and the northern flank of the massif of Mont Dore. Leaving Clermont soon after seven, the carriages followed at first the Ceyrat road, which, running for some miles in a general southerly direction, gradually approaches the crystalline escarpment up which it eventually winds its way, and leads into the midst of the volcanoes forming the southern end of the Chain of Puys. At a little more than a mile from Clermont, rising somewhat rapidly it crosses the lava-stream from Mont Joly near Beaumont, and afterwards the flow from Gravenoire, both of which had been studied by the members on the first day.

At the Pont de Ceyrat the crystalline escarpment is reached, along the base of which runs the fault, the eruptive fault of Gravenoire, which has let down the Oligocene strata against the granite. Near the bridge two slightly metalliferous veins of muscovite-granite containing galena, pyrite and barytes are exploited. Farther on, beyond Saulzet, the fault was crossed, and here it was seen that the fault-plane itself is coincident with a vein of muscovite-granite, and a very well-marked friction breccia was seen exposed in the road cutting. From the muscovite-granite vein numerous fine ramifications extend into the granite, which is itself porphyritic, and readily undergoes disintegration into a coarse sandy product.

Ascending the escarpment from this point, the party, passing through a region of crystalline rocks pierced by innumerable veins of muscovite-granite and pegmatite, at length reached Theix, at an altitude of about 2,600 feet. Here facing them on the south was the long Miocene basaltic hill of La Serre (Fig. 48). Upon its flanks rest basalts of Pliocene age, while in the valley bottoms to north and south are two flows of basalt, one from the Puy de Mey, passing by Theix and extending as far as Fontfrieide, the other from the Puy de la Vache descending to St. Amende Vallende. The hill is particularly interesting therefore, inasmuch as it exhibits basaltic horizons of four distinct ages, Upper Miocene, Upper Pliocene, Lower and Middle Quaternary, presenting four different relations to the present topography of the district.

At Fontfrieide was seen a flow of labradorite, which comes from the Puy de Mey, and overlies the basaltic flow, from the same volcano, which passes by Theix. The labradorite is a handsome grey stone, and is quarried as a freestone for building and ornamental purposes.

Just beyond the Fontfrieide quarries the carriages entered the tunnel of La Cassière. On emerging, the road skirting the lake of La Cassière was followed, which takes its undulating course for more than a mile across the wild and chaotic *cheire* of Aydat, formed by the confluent lava-streams from the Puy of the La Vache and Lassolas, which together have supplied the materials for this tumultuous sea of lava. It is to the damming of two valleys by these outpourings that the formation of the picturesque lakes of La Cassière and Aydat is due.

On arriving at the lake of Aydat a halt was made for lunch, which was taken in the open air, under the grateful shade of trees, and within a few feet of the water's edge.

The environs of the lake are mainly composed of granite, which is pierced by numerous veins of diorite, diabase, porphyrite, and muscovite-granite, and contains, besides, many enclosures of ancient sedimentary rocks (Cambrian?), which it has caught up within itself. M. Michel Lèvy has shewn that the granite has undergone a variety of endomorphic changes, depending upon the lithological characters of these inclusions, being converted into hornblende-granite, diorite, or even diabase. Pyroxene and amphibole-schists and eclogites have resulted from the metamorphism of masses of limestone by the granite. Several of these facts were practically demonstrated to the members by the Director.

On the western side of the lake there is an isolated patch of breccia with blocks, often of great size, representing all the rocks of Mont Dore, trachytes, trachy-andesites, hornblende-andesites, andesites with haüyne, phonolites, basalts, &c. This deposit is the remains of a formation which once spread over the slopes of the great volcano of Mont Dore, and which was transported in



Upper Pliocene times to a distance of more than ten miles from its place of origin, either by ice or by mud eruptions. To-day the volcanoes of the southern end of the Chain of Puys are interposed between this patch and Mont Dore, and they must therefore be of posterior date.

On resuming the carriages the party set out for Mont Dore, passing by Verneuges, and afterwards between the Puys of Charmont and Vichatel, beyond which were seen the splendid breached craters of La Vache and Lassolas.

At Randanne, and at a number of points in the vicinity of the lake of Aydat, deposits of diatomaceous earth (randannite) are found. The earth, which alternates with beds of peat, is extracted for use in the manufacture of dynamite and tripoli.

Passing through Randanne, the lava streams from the Puys of Montgy were seen, which descend cascade-fashion between the Puys of La Taupe and Montchal. Continuing towards the south, the Puys of Boursoux and Combegrasse and the Puy de l'Enfer were passed in succession, the last of which exhibits a dried up crater lake, which was formed as the result of an explosive eruption, by which at least one half of the volcano was destroyed.

After passing the Puy de l'Enfer, the southernmost member of the Chain of Puys, the invasion of a new territory, that of the massif of Mont Dore, was commenced, and as the day wore on, the grand panorama of the Chain of Puys, continually receding, became less and less distinct, while that of the heights of Mont Dore, ahead, became, every moment, more and more impressive.

From Randanne onwards there were seen, towards the west, great basaltic plateaux trenched by valleys of sufficient depth to display the underlying formations, which consist of cinerites and other volcanic ejectamenta more or less rearranged by water. These basalts, which extend towards the north for several miles, are the products of the last eruptions (Middle Pliocene) of the volcano of Mont Dore, which was then, as it were, enwrapped in a continuous mantle of basalt, a covering which has since been broken up by erosion. During the gradual ascent of the northern flank of the massif of Mont Dore, the party had opportunities of seeing these patches of basalt isolated by denudation, and the cineritic beds beneath them.

Leaving the carriages to follow the road the members subsequently made their way to the lake of Servières, which lies in a depression between the Puys of Servières and Comperet, two little basaltic volcanoes of Quaternary age, resting upon this flank of Mont Dore.

Rejoining the vehicles the ascent was continued. After a long detour, the road mounts to the foot of the trachytic Puy de l'Ouire where it attains an altitude of 4,100 feet. At this point a halt was called in order that the members might admire for the last time the incomparable panorama of the Chain of Puys,

which, here seen from a distance, is presented in its entire length. Continuing once more the volcanic chain soon disappeared from view, and half a mile further on the two imposing piles of columnar phonolite, the Roche Tuilière and the Roche Sanadoire, were passed (Plate XIII.). A descent was made from the road to the flanks of the latter mass in order that specimens of the phonolite, which contains visible crystals of hæüyne and sphene, might be collected. The issue of these phonolites in the form of dykes at several points in the northern part of Mont Dore preceded that of the basalts and was posterior to that of the labradorites and the hornblende, hæüyne and nosean andesites, which are found on the western shores of lake Guéry. Beyond this lake, which was passed by the party a few minutes later, the road cuts through a basaltic flow coming from one of the numerous small quaternary centres of eruption. The basalt, which is markedly columnar, was soon left high on the sides of a deep valley cut into the soft cinerites upon which it rests. Near the Saut du Loup Cascade the cinerites include a bed of lignite, which some attempt has been made to work, and which, yielding a flora of Middle Pliocene age, is one of the fossiliferous strata which have served to fix the date of the Mont Dore eruptions.

The winding road rapidly descends to the mouth of the valley, beyond which a glimpse was seen of the cross-valley of the Dordogne, separating the massif of the Banne d'Ordanche to the north from that of Sancy to the South. Turning suddenly into the main valley, and travelling towards its source, the members saw before them the great volcanic cirque, upon the verdant floor of which the town of Mont Dore is picturesquely situated; and after a rapid drive down the valley-side they were soon in the heart of this famous little health resort, where very comfortable quarters had been secured for the whole party by M. Desroches at the Hotel Sarciron-Rainaldy.

An announcement was made in the evening that an invitation and offer of hospitality had been received from the "Compagnie des Eaux Minérales de la Bourboule" for the next day. This was duly acknowledged and accepted.

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## EXCURSION FROM MONT DORE TO LA BOURBOULE AND BACK.

*Director:* M. PH. GLANCEAUD.

*The Massif of Mont Dore.—General Description.*—The Massif of Mont Dore, which is close upon twenty miles in diameter, is a volcano or group of volcanoes of Miocene and Pliocene age, in great part dismantled, and deeply scored by



THE TUILIÈRE AND SANADOIRE ROCKS, NEAR MONT DORE.

valleys, which penetrating to the very core of the mass, permit the study of its structure in some detail.

Topographical and geological considerations lead to the belief that in the building of the massif there were at least two principal eruptive centres, one situated at or near the Pic de Sancy, the other at the Banne d'Ordanche. From these two centres lava streams radiate outwards in all directions, and form two more or less distinct massifs, which may be spoken of as the volcano of Sancy, and that of the Banne d'Ordanche. Both of these massifs are pierced moreover by dykes of considerable variety. These which are mainly trachytic in the Sancy volcano and phonolitic in the Banne d'Ordanche volcano, have greatly affected the regularity of structure of the two massifs, and have much increased their complexity.

The volcano of the Banne d'Ordanche offers a greater variety of rocks than that of Sancy and includes a certain number of types so far unknown in the latter massif, such as rhyolites, perlites, andesites with hæüyne and nosean, certain types of basalt, curious micropegmatites, and others. The remarkable development of phonolites must also be borne in mind.

In the midst of the volcanic ejectamenta, which constitute a great part of the mass of the Sancy volcano, beds of alluvium and lignite occur, the latter yielding plant remains which are usually regarded as of Middle Pliocene age. On the other hand the formation of which the mountain of Perrier is composed, and which includes nearly all the rock-types of Mont Dore, contains a fauna of Middle Pliocene age. The massif of Mont Dore was in great part constructed therefore at the end of Middle Pliocene times.

During the Upper Pliocene epoch the massif of Mont Dore was clothed in ice, which carried away rocks torn from the high peaks, giving rise to distant moraines, such as that of the Valley of Chaudefour and those in the glaciated region between La Tour d'Auvergne and Bort.

In Quaternary times small basaltic volcanoes, occasionally emitting well-marked lava-flows, arose on the flanks of the massif, and it is interesting to bear in mind that these are of the same age as the cratered volcanoes of the Chain of Puy and were due to the same causative movements.

On the *fifth day, August 21st*, an early start was made for a drive down the valley of the Dordogne to La Bourboule. The itinerary of the morning comprised the study of the eruptive rocks of the Banne d'Ordanche, which differ in so many striking respects from those of the volcano of Sancy. Between these two massifs is a great trench, the valley of the Dordogne, which is also the site of issue of numerous hot springs, and

which M. Michel L evy believes to have been determined in the first place by a great fault. Some little way down from Mont Dore the valley is traversed by a well-defined frontal moraine, which has been cut through by the river and also by the road. Grooved and striated blocks of a variety of rocks, chiefly trachytes and andesites, were found in abundance.

A little way below the moraine the party visited the Croizet warm spring, which is the property of the "Compagnie des Eaux de la Bourboule." The visitors were received by a number of the officials who had assembled to give them a preliminary greeting. The spring was discovered in an alluvium of trachyte and perlite pebbles. The waters, which are rich in salts, and have a temperature of 43  C., are to be conducted to La Bourboule.

The drive down the valley was continued until the Ravin de l'Usclade was reached. Here a great variety of rhyolites—red, white, grey, and black, and often exhibiting unmistakable flow-structure—were seen, and their intercalation in the form of flows in the lower cinerites of the Banne d'Ordanche was pointed out by the Director. Besides specimens of these, the members also

collected excellent specimens of perlite, basalt, and micropegmatite. Veins of trachyte, phonolite, andesite, and basalt were also observed traversing this remarkably varied series of lavas. From this petrographical hunting-ground the party then proceeded to La Bourboule.

The waters of La Bourboule, like those of Mont Dore, were known to the Romans; but it was not until the illustrious chemist Thenard detected arsenic in them in considerable quantity that they began to acquire a reputation which is now world-wide. They rise to the surface along the boundary of a mass of granite (Fig. 50) against which abut the

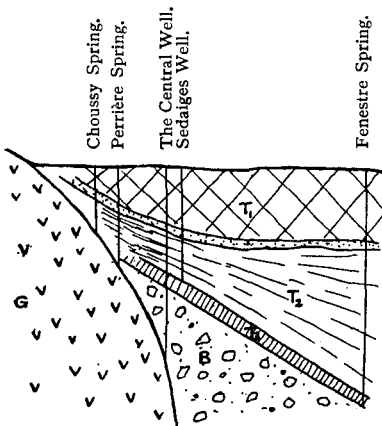


FIG. 50.—GEOLOGICAL SECTION SHEWING THE DISPOSITION OF THE HOT SPRINGS OF LA BOURBOULE, AFTER BONNEFOY.

G. Granite, B. Breccia, T<sub>1</sub>. Hard Tuff, T<sub>2</sub>. Laminated Tuff, T<sub>3</sub>. Plastic Tuff.

trachytic cinerites of the volcano of Mont Dore. This face of granite, which is clearly seen behind the "Etablissement Choussy," is probably a fault-plane. The borings by means of which the waters are collected descend either to the granite surface (Perri re spring) or penetrate into fissures in the mass

of the granite (Choussy spring). Others penetrate deeply into the cinerites, but do not come into contact with the granite at all. In such cases the mineral waters which follow the course of the bands of tuff are much cooler, and have lost a good deal of their mineral constituents (Fenestre and Sedaiges springs). The arsenic in the waters probably exists in the form of sodium arseniate, which attains a proportion of twenty-eight milligrams to the litre, and is said to render the waters of especial benefit in intermittent and malarial fevers, scrofula, rickets, rheumatism, diseases of the skin, and diabetes.

Powerful pumping engines raise the waters from below, and conduct them to the bathing establishment. The party, guided by the courteous administrators, made a most interesting and exhaustive tour of inspection of the ingenious appliances with which the famous baths are equipped. Many of the members availed themselves of the offer of their guides to test for themselves the effects of the nasal and pharyngeal sprays, and found them to be most pleasant and soothing. Not content with the kindnesses with which they had already received their guests, the administrators then added the further courtesy of entertaining the party, with the utmost hospitality, at a sumptuous lunch, during which a number of cordial toasts were proposed and responded to on both sides. At its conclusion the members, bidding adieu to their hosts with many expressions of goodwill, drove back to Mont Dore, where they arrived in time to make the ascent of the Capucin before dinner.

Ascending by the funicular railway, they first inspected the elegant hall of the Capucin, and admired the view commanded from this elevated point. They then proceeded to collect specimens of the enclosures, with cordierite, hypersthene, and tridymite, which occur in the dyke of trachyte which forms the summit of the steep rocky mass. Time pressing, the return to Mont Dore was then made without delay.

In the evening at the close of dinner the party had the pleasure of a visit from M. Michel Lèvy, who was enthusiastically greeted and was formally received by the President. Subsequently M. Glangeaud presented a number of the younger geologists of the party to M. Lèvy, an honour which pleased them greatly, and which they did not fail to appreciate. The remainder of the evening was enjoyably spent at the theatre, where places had, with characteristic hospitality, been placed at the disposal of the members during their stay in the town by the "Société des Eaux du Mont Dore."

EXCURSION FROM MONT DORE TO THE PIC DE SANCY AND BACK, AND VISIT TO THE HOT SPRINGS OF MONT DORE.

*Director:* M. PH. GLANGEAUD.

The *sixth day, August 22nd*, was mainly devoted to the ascent of the Pic de Sancy, from the summit of which it is possible to obtain an excellent general view of the Mont Dore massif, and of much of the surrounding volcanic region of Central France.

The start from the town of Mont Dore was made very early in the morning. The coaches slowly ascended the beautiful valley of the Dordogne, which is strewn with abundant débris from the magnificent heights ahead and on either side. Near the point where the slope becomes too steep for the carriage-way to continue, the point where the rivers Dore and Dogne unite to form the Dordogne, an interesting example was seen of an avalanche cone, which had resulted from the melting of the winter's snows, and which in its torrential descent had felled and swept before it many of the great coniferous trees, which, here and there, clothe the valley sides, and had carried them with a great amount of mud and rocks across the road, entirely obscuring it for several hundred yards and rendering it for a time quite impassable.

The long, but by no means difficult climb to the Sancy peak, was made by the majority on foot. By many windings the path mounts to the Marsh of the Dore, which presents all the characters of a glacial cirque. It is surrounded by the crags and buttresses of the Puys of Cacadogne, Ferrand, and l'Aiguiller, which are, as it were, guarded from above and behind by the Pic de Sancy (Pl. XIV, Fig. 2). This peak, the summit of which was eventually reached, is the highest point in Central France, 6,122 feet, and is situated at the centre from which all the lava flows of the Sancy volcano diverge. It is composed of a handsome porphyritic trachyte, the phenocrysts of which are large and well defined crystals of sanidine, which occasionally weather out of the rock whole, and may be picked up from among the scree below.

The massif of Sancy is scored by profound valleys which have laid bare all of the rocks of which it is composed, exposing to view their arrangement and sequence, and thus enabling the geologist to determine the order of succession of the eruptions by which it was gradually piled up.

In Upper Pliocene times glaciers installed upon the flanks of the massif carried an abundant debris of rocks from the frost-riven peaks down into the valleys, where they still lie forming



1.—THE PUY DE DÔME, SEEN FROM LASCHAMP.



2.—THE PUY DE L'AIGUILLER, SHOWING CRESTS FORMED BY VEINS OF ANDESITE.



moraines such as that which had been seen in the valley of the Dordogne the previous day.

The view from the summit is magnificent; and the visitors were again fortunate in the weather, which, if perhaps a little too hot for perfect comfort, was nevertheless very favourable for an extensive panorama. Towards the north, beyond the valley of the Dordogne, the Banne d'Ordanche was seen, and it was interesting to note how suddenly the lava streams from Sancy terminated in that direction, being met by the opposing flows from that apparently independent centre of eruption. Beyond and behind the Banne d'Ordanche were seen Lake Guéry and the Tuilière and Sanadoire rocks, while in the distance, and receding to the north-eastern horizon, appeared once more the linear Chain of Puys. To the east spread the green carpet of the Limagne, bordered on its further margin by the Forez Hills. To the south the grand volcano of the Cantal raised its blue and hazy mass in profile against the distant sky-line.

The various features of this most extensive of the many beautiful panoramas seen during the Auvergne excursion were pointed out by the Director, and their geological significance was explained; many facts of interest were also contributed by M. Giraud and others who accompanied the party.

Descending a little way from the summit the members then partook of an excellent luncheon, which, with no little trouble, had been conveyed from Mont Dore under the superintendence of M. Desroches, whose successful management of all matters relating to the commissariat contributed so greatly to the comfort and enjoyment of the party.

After lunch a walk was taken along the ridge of the Puy Ferrand to its extreme point, whence an excellent view was obtained of the little Quaternary volcanoes scattered over the southern slopes of Mont Dore, and down into the steep-sided valley of Chaudefour, barred, at its lower end, by the volcano of Tartaret, at the foot of which spreads the sheet of Lake Chambon. After as long a stay as could be allowed at this point, the return journey was made to Mont Dore. The majority descending to the carriages, returned by the road, but a few, following the crest of the Puy Cacadoigne and the Roc de Cuzeau, visited the Grande Cascade of the Dore, where they saw the section which was first figured and described by Poulett Scrope.

Later in the afternoon, a reception at the "Etablissement Thermal du Mont Dore" was attended, at which M. Michel Lèvy, Dr. Tardieux, and M. Carré, the Director, welcomed the guests, and accompanied them in their tour of inspection of the hot springs and of the various appliances by which these are utilised at Mont Dore.

There are twelve springs, which have their origin at the foot of the cliff dominating the right bank of the valley. They are

associated with a dyke of phonolite. The total daily output is very great, and the temperature of the water varies between 38°C. and 47°C., except in the case of the Marguerite spring, which has a temperature of 13°C., and is employed for the manufacture of a table water. The waters are feebly calcareous, ferruginous, and arsenical, and highly siliceous. There is also an abundant disengagement of carbon dioxide, a respect in which they differ from those of La Bourboule. Although only slightly mineralized, they have a very energetic action, especially in affections of the respiratory organs; Mont Dore is pre-eminently the spa for singers and public speakers. They are also beneficial in the treatment of rheumatism. The altitude and healthy situation of the Spa no doubt play an important part in promoting the good medicinal effects of its waters. One of the characteristic features of the town, which interested and amused the members, was the early morning procession of bathers, dressed in gaily coloured flannel bathing costumes, some walking, but most being conveyed to and from the baths in sedan chairs, carried at a rapid trot by two porters. At the conclusion of their inspection of the springs and associated premises, refreshments were offered to the visitors, and this opportunity was taken for an interchange of friendly sentiments on both sides, and for an expression of thanks on the part of those who had been so pleasantly entertained.

In the evening, at dinner, special attentions were shewn to M. Glangeaud and M. Giraud, especially to the former, as he was to direct the party for the last time on the morrow. The vote of thanks to him for his kind services during the past days, which was offered by the President, was carried by the members with acclamation. M. Glangeaud replied that he considered himself fortunate if his English confrères were pleased with their journeying in the Auvergne, and if he had contributed in any way to their enjoyment. He had, however, only repaid an outstanding debt to the Geologists' Association, with which some years ago he had the pleasure of visiting Devon and Cornwall. He hoped that his confrères amongst whom he had passed five days so pleasantly, would not forget their way to the Auvergne, where they would always be received in the same hospitable manner as were their eminent compatriots Poulett Scrope, Murchison, Lyell, Sir Archibald Geikie and others, who had published such interesting works upon the geology of the district. He concluded by raising his glass in honour of the Association. A vote of thanks was also proposed by Professor Armstrong to M. Giraud, who replied in a characteristically graceful speech. A number of other speeches having been delivered the party broke up for the evening, some availing themselves of their invitation to the theatre, others amusing themselves by watching the animated groups in the Casino.

## EXCURSION FROM MONT DORE TO CHAMPEIX.

*Directors* : MM. PH. GLANGEAUD AND J. GIRAUD.

On the *seventh day, August 23rd*, at five o'clock in the morning members were astir in preparation for their long drive of the day. The Clermont road, traversed by the party on the fourth day, was retraced for about two miles, where it was left for one crossing the north-eastern region of Mont Dore, a region formed of various ejectamenta resorted by water and pierced by numerous trachyte dykes, or covered by masses of trachytic lava.

The laborious ascent was made round the sides of the trachytic and cineritic Puy de la Tache, whence was obtained once more a fine view of Lake Guéry and the Tuilière and Sanadoire rocks. Circumventing the Puy de la Croix Moyrand, formed of a sheet of trachyte surmounted by a table of basalt, the Col de Dyanne between the two trachytic masses was reached, and a rapid descent was made towards Bressouleille.

Before reaching this village there was an excellent general view of the eastern slopes of Mont Dore, in which the Pic de Sancy, the Puys Ferrand and Cacadoigne and the Roc de Cuzeau could be seen clearly separated by a deep trench from the composite mass of the Puy de l'Angle, Puy du Barbier and Puy de la Tache. It is at the foot of the deep trench and over the other side that the Grande Cascade of the Dore is situated.

At Bressouleille the granitic foundation of the volcanic rocks was reached, and in this is cut a deep and picturesque ravine leading to the village of Chambon, whence a fine view of the valley of Chauffour was obtained. Towards the east was seen the Quaternary volcano of Tartaret, barring the valley of the Couze Chambon, and giving rise to the lake of Chambon. Just beyond the lake a stop was made to examine the high rock-wall, the Sault de la Pucelle, a mass of lava coming from an open fissure in cinerites which contain plant-remains of Middle Pliocene age. The fissure must have been in part filled with fragments derived from the underlying formations, granite, schist, trachyte, &c., or the mass may have arrived from the depths below in a brecciated form, as may be inferred from the cores of cinerite caught up in the mass and the metamorphism undergone by the cinerite at the contact with the wall of the vent. M. Giraud inclines towards the second view and regards the breccia as contemporaneous with pépérites, from which it is distinguished by being formed by the intrusion of the basalt into cinerites instead of into marls. The whole of the western side of this dyke has been removed by erosion, giving rise to a cirque strewn with enormous masses of débris.

The journey down the valley of the Couze was resumed.

Owing to faulting, Oligocene country alternates with granitic ; in the former the valley is open and broad, in the latter it forms gorges and defiles, giving a picturesque variety to the drive through the district. On approaching Murols, for instance, the granitic platform of Mont Dore is left for the Oligocene sediments which crop out in a dip in the road but are covered by ejectamenta from Tartaret. These sediments are made up of slightly clayey white sands resting on granite, in conjunction with marls, highly decalcified limestones, and red sandy clays. These Oligocene beds occupy the whole of the little basin of Murols, and extend as far as Boissières on the road to St. Nectaire. Many curious little towns were passed through, but at Murols a halt was made for lunch, before which, however, a visit was paid to the fifteenth century castle standing high up on a knoll of Oligocene sediments capped by basalt.

After lunch a visit was made, by invitation, to the charming gardens of the mayor, M. Achille Boyer, and the ladies were presented with flowers; the mayor was heartily thanked for his courtesy and generosity.

The drive was then continued along the road leading to St. Nectaire. It at first traverses Oligocene beds and beyond Boissières enters the granitic valley of the Couraçon, which runs in a narrow defile. Here a complex group of faults brings the Oligocene beds again to the surface and they continue in sight as far as Verrières. At St. Nectaire a number of springs issue along these faults. They contain sodium bicarbonate and are rich in sodium chloride; they also contain arsenic in appreciable amount, and being richly calcareous are utilised in the "petrification" of objects as at St. Alyre. A newly discovered spring, the Papon Spring, was visited and specimens of the aragonite and orpiment which it is depositing were collected. Close at hand, more ancient springs have already deposited silica which has replaced the substance of various vegetable remains and has converted them into opal; they have also deposited chalcidony, dialogite and sulphur.

The celebrated church of St. Nectaire, dating from the 11th and 12th centuries and picturesquely situated on the hill, attracted the attention of some of the members, while others were inspecting the springs.

A little beyond St. Nectaire the big granite cliff of le Puy d'Eraigne terminates abruptly at a fault, then the valley of the Couze Chambon is re-entered and broadens out considerably in the Oligocene country. The bottom of the valley is covered by the basaltic flow from the Tartaret, which in fact continues as far as Neschers, about two miles beyond Champeix, and forms the bed of the river nearly all the way. This flow is of Upper Quaternary age. There are in fact beds with reindeer remains in contact with it at its termination at Neschers. At some places

the Couze forms picturesque cascades, at Pont de Saillant for example, where a good opportunity was obtained for examining the bed of the river. At Verrières a fine granitic defile was entered, and this extends as far as Montaigut. The narrowing of the valley has here had the effect of increasing the accumulation of the flow, so that it attains a thickness of more than 130 feet. The granite defile itself is an interesting example of torrential erosion acting on rocks of varying hardness. The upper part of the defile consists of Oligocene beds protected by a flow of basalt. These were the first exposed to erosion, and in them the slopes are gentle. Lower down the granite is encountered, and the eroded slope becomes suddenly steep, and the valley at the same time narrow. Phenomena of this kind were observed all along the road from Murols to Champeix.

At Montaigut the lower portions of the Oligocene sediments of the Auvergne were examined. Sandy clays and arkoses varying in thickness, according to locality, from 30 to 100 ft., rested directly on the granite; upon these there were fine grained homogeneous yellow limestones, recalling the Jurassic lithographic stones, and containing brackish water fossils, *Nystia*, *Neritina*, *Planorbis*, *Melania*. Some of the forms are similar to those in the lower Hempstead marls, but in general they exhibit affinities with the species described by Fontannes as existing in the valley of the Rhone. Above these lower limestones, known as the *Striatella* limestones, there are detrital formations, sandy clays, grits and arkoses, varying in thickness from 130 to 330 ft.; above these, limestones again occur, with a new set of brackish water fossils, *Potamides lamarcki*, *Cerithium elegans*. It is interesting to note that these formations exist only at Montaigut-le-Blanc, although the upper parts of the limestones with *P. lamarcki* are encountered elsewhere; but these also contain *Limnæa*, and are associated with the *Cypris* marls, which attain a considerable thickness, 2,000 to 2,700 ft., in the northern part of the Limagne.

The road continues in Oligocene beds from Montaigut to Champeix, but there is a hill at St. Julien, a village a little west of Champeix, where the lower limestones (with *Striatella* and *Neritina*) and the red or grey sandy clays are overlain by a heavy deposit of white pumiceous sand, derived from Mont Dore, in which numerous wine caves have been made. The sands are covered by a glacial deposit, consisting of big blocks of trachyte, andesite, phonolite, &c., from the Monts Dore which are embedded in a cement of pumiceous clay. Both pumiceous sands and the moraine are of Lower Quaternary age.

At the wine caves of St. Julien the members of the party were invited to taste the wine of the country. It was universally agreed that both red and white wines were remarkably good.

At dusk, after the last of numerous demonstrations by M.

Giraud of the Oligocene rocks over which the carriages had been passing, the exceedingly picturesque village of Champeix, the halting place for the night, was sighted, and an entry into the little town was soon afterwards made. Champeix is built in one of the granitic defiles, bounded on the east and west by faults. The recent portion of the little town occupies the bottom of the valley, whilst the old part (Marchidial), with the ruins of the picturesque church, is situated high up, near the point where the granite is covered by Tertiary and Quaternary sediments (Fig. 51).

M. Glangeaud took leave of the party on this evening, and most of the members assembled in the market place to see him off, and enthusiastically expressed to him their thanks for all he had done, and their regret at his departure.

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### EXCURSION FROM CHAMPEIX TO ISSOIRE.

*Director:* M. J. GIRAUD.

The *eighth day*, *Saturday, August 24th*, was again in part devoted to the study of the valley of the Couze and the stratigraphy of the Auvergne. Early in the morning, before breakfast, the energetic Director, M. Giraud, and some of the party were seen by others from bed-room windows, scrambling up the heights near Champeix, the object being to examine the sections on the north side of the valley. The sections illustrated in Fig. 51 were the first objects of study.

At the bottom of the valley, which is still covered by the lava flow from Tartaret,  $\beta^1$ , and in which the Couze runs, the altitude is 1,394 ft. The sides are in the granite ( $\gamma$ ) until sands ( $s$ ), continuous with those seen at St. Julien the previous day, are encountered, and here, at an altitude of 1,623 ft., is the small plateau of Anciat, capped by the basalt flow ( $\beta^2$ ), which cuts through the pumiceous sands ( $s$ ) in which bones of horse (*Equus caballus*) are found, confirming the Quaternary age of the beds: they probably date from the beginning of that period. Remembering that the Tartaret flow was Upper Quaternary, erosion to the extent of at least 200 ft. must have taken place during the time between the Lower Quaternary and the Middle Quaternary, and it is practically obvious that the excavation of the valley was complete at the end of the Quaternary period. On the slope opposite Anciat, and visible from the plateau, there is a long hill rising to 1,935 ft. at the east and 2,000 ft. at the west, which consists of pumiceous sands ( $p^of$ ), covered by a thickness of glacial moraine ( $p^g$ ), and this is connected with the moraine of Perrier, known to be of Upper Pliocene age. Therefore, between the Upper Pliocene and the Lower Quaternary, the valley has been cut down more than 330 ft. Similar facts can be observed from different

points of the eastern slope of Mont Dore, and point to the conclusion that the actual topography of the country has been modelled between the Upper Pliocene and the Upper Quaternary, the maximum extent corresponding with the period commencing towards the end of the Pliocene and ending with the Lower Quaternary. The period of maximum excavation, at the end of the Upper Pliocene, coincides with the lowering of the level of the bottom of the plain of the Allier, produced by the last

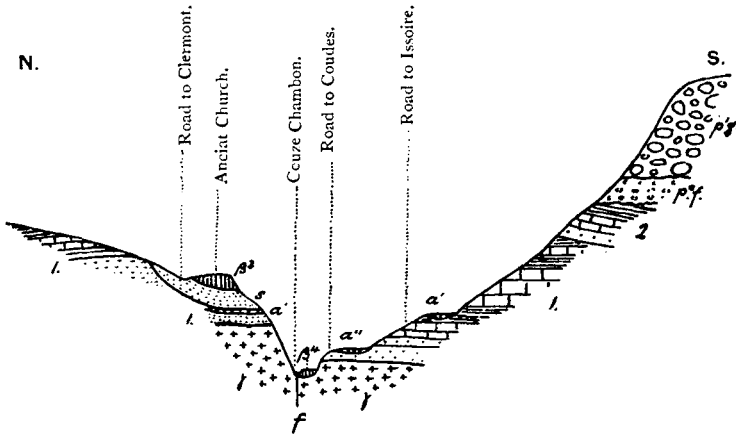


FIG. 51.—SECTION EAST OF CHAMPEIX.

- y. Granite.
- 1. Lower Oligocene—sandy clays, sandstones, marls and sublithographic limestones with *Nystia incasteli*. Nyst.
- 2. Middle Oligocene—sandstone; marls and limestone with *Cypris* and *Cerithium (Potamides) lamarcki* Bryt.
- p'f. Pumiceous fluviatile beds.
- p'g. Boulder pumiceous conglomerate (trachytic conglomerate of Perrier). Upper Pliocene.
- a'. Alluvial beds.
- s. Pumiceous sands (*Equus caballus*) } Lower Quaternary.
- β³. Basalt of Anciat.
- α''. Alluvial beds.
- β⁴. Lava-flow from Tartaret. Upper Quaternary.
- f. Fault.

subsidence of the Limagne. To this period, too, a greater part of the pépérites of the Limagne can be attributed, and perhaps be definitely fixed at a period comprised between the end of the time of *Elephas meridionalis* and the appearance of *Elephas antiquus*, in other words, during the early Interglacial times. Such are M. Giraud's interesting deductions.

The early morning party having returned, the drive to Issoire was commenced. The road to Clemensat, which was followed,

rises at first in the granite, winds through old Champeix and reaches the red clays of the Lower Oligocene. A series of step faults is then encountered, causing the various parts of the Lower Oligocene, the red sandy clays, the calcareous grits, and the limestones with *Limnæa* to abut against one another along the road. Beyond Clemensat the *Striatella* limestone is again met with, and then the granite steeply cut into by the deep gorge of the river Couze Pavin once more becomes prominent. Soon after passing through the picturesque village of St. Floret, the road to Fêlines branches from the valley of the Couze down a collateral valley. The western side of this little valley is formed by a granite cliff which comes to an end at a fault from which mineral waters flow. Near the head of the valley at the side of the road the Lower Oligocene limestones with *Limnæa* are exposed. Intercalated with these limestones are beds of marls with *Cypris*, of which certain beds are full of *Cerithium plicatum*. After the examination of these rocks in a number of interesting sections, the road to Issoire was regained; this follows the Couze Pavin, runs through rich meadow land on the alluvials of that river, and about 5 furlongs before reaching Perrier passes through the tumbled mass which in the land-slip on the 24th June, 1733, fell from the Montagne de Perrier, and carried away part of the village of Pardines. Then following the road leading to Champeix, a hydraulic lime works was visited, where the upper beds of the Lower Oligocene were being quarried. The marly limestones of yellowish white colour, contain *Limnæa brongniarti*, *Potamides lamarcki*, and vertebrate remains; in the intercalated marls there are *Cypris* and abundant spicules of fresh water sponges sometimes forming continuous beds, also bands with *Cerithium plicatum* and fairly well preserved fish remains (*Prolebias stenoura*, Sauvage). Many specimens were collected in this quarry.

In the vicinity of the quarry in a ravine the sequence of beds above these Oligocene sediments could be followed; there were first ferruginous fluvial sands with many quartz pebbles in which the Middle Pliocene *Mastodon arvernensis* is found. The sands are covered by cinerites, transported by the rivers from Mont Dore, and enclosing a Middle Pliocene flora. The trachytic breccia of Perrier lies immediately above these beds. The origin of these breccias has given rise to much dissension and discussion. Some, including MM. Julien, Michel Lèvy, Munier-Chalmas, and Giraud, consider them as deposited by a great glacier coming from Mont Dore, at that time about 10,000 ft. in height, whereas M. Boule regards them as volcanic breccia coming from the Monts Dore in a muddy condition. M. Boule bases his view on the resemblance of these breccias to those of the central mass of the Cantal which are of undoubted volcanic origin. The arguments advanced in favour of the glacial character of these breccias are chiefly: the enormous size fre-



quently attained by the blocks ; the absence of any stratification or regular arrangement of the elements ; the variable nature of the blocks—specimens of all the rocks of the Monts Dore are to be found in the breccia ; finally there are polished and striated surfaces on many of the blocks. Moreover, the formation can be followed continuously from Perrier up to the Monts Dore, on the upper parts of the plateaux.

Again, the examination of the eastern parts of the Monts Dore discloses in many valleys remains of three successive glaciations characterised by identical deposits which are still to be seen. They are :—Firstly, the Upper Pliocene glacial deposits covering heights above the plateau basalt from Mont Dore to Perrier. Secondly, the early Quaternary glacial deposits, such as those of St. Julien and of Neschers at the horizon of the basalt of Anciat. Thirdly, the Upper Quaternary glacial deposits found in the lower parts of the valleys as at Verrières.

Luncheon was served in the garden of the inn at Perrier, and afterwards, in spite of the heat of the day, some members climbed the hill-side to examine these remarkable breccias, but very much as in the case of the pépérites, they could not decide from the one inspection either for the glacier or the volcano.

From Perrier the party drove to Issoire, following the main road, which continues on the alluvium of the Couze. This completed the work in the Department of the Puy-de-Dôme, and great were the feelings of gratitude entertained by all members of the party towards the excellent Directors who had piloted them so efficiently through the interesting neighbourhood. M. Giraud, in concluding his direction of the party, gave an interesting account of what he considered had been the geological history of the Limagne during the Oligocene period. A brief summary of his views is as follows.

A long period of erosion had reduced the Central Plateau to the condition of a peneplane before Oligocene times, but at the commencement of that period earth movements placed the Limagne in connection with the lagoons then occupying the valley of the Rhône ; so that brackish water molluscs penetrated right into the heart of the central mountain area of France, and furnished the original creatures for the fossils of the *Striatella* limestones of Montaigut-le-Blanc and elsewhere. A period of repose succeeded and gave rise to the red sandy clays, then a fresh depression occurred which allowed the sea of Rhône basin to invade and cover the central region ; the limestones and grit, with *Potamides lamarcki*, *Cerithium elegans*, *Limnæa*, and *Planorbis*, mark this period. Then a slight elevation cut off all the communications with the sea, and a régime of lagoons ensued ; some were isolated and yielded by evaporation deposits of gypsum, salt, &c., others were in connection with supplies of fresh water, and deposited the *Cypris* marls. These lagoons

were shallow, as the abundant plant remains testify; they were also subject to frequent change of position; nevertheless, they persisted for a considerable time, inasmuch as the deposits have attained considerable thickness; near Clermont, for instance, they are over 2,600 ft. thick. Fresh earth movements altered the state of things and gave rise to a new era, characterised chiefly by lacustrine and fluviatile deposits which, according to circumstances, were either the lacustrine limestones, with *Helix ramondi*, *Limnæa*, *Planorbis*, and vertebrates, or were the sands in the midst of which are encountered the isolated masses of the *Phryganea*-limestone; or else they took the form of marls with plant remains and fluviatile shells, *Unio*, *Melania*, and *Melanopsis*, as met with at Gergovia. This condition persisted, and consequently the fluviatile deposits are only found locally where they have been protected by the basaltic flows of Miocene or Pliocene times. It is noteworthy that remains of vertebrates are numerous in the Auvergne Oligocene sediment, the Middle Oligocene limestones yield *Cainotherium*, *Lophiomeryx*, *Dremotherium*, *Amphitragulus*, &c., whilst the upper beds are specially marked by *Anthracotherium* and the species of the celebrated deposit of Saint-Gérard de Puy.

Issoire was reached early in the afternoon and the excursionists were accorded a pleasant welcome by the inhabitants, whilst M. Bielawski, who had accompanied the party for several days, received them at his house, shewed them his interesting collection of Neolithic implements, &c., and, moreover, presented to those assembled copies of various works he has written on his deservedly adored Auvergne and other subjects.

Subsequently a visit was paid to the cathedral, as well as to some other sights of the town. The cathedral is an enlarged *replica* of Notre-Dame du Port at Clermont, and a fine example of the Auvergne Romanesque style. In the evening a cordial farewell was accorded M. Giraud, whose invariable kindness had made a deep impression on the party.

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#### JOURNEY FROM ISSOIRE TO AURILLAC, AND EXCURSION IN THE VICINITY OF AURILLAC.

*Director*: M. MARCELLIN BOULE.

Early on the *ninth day*, August 25th, the party made their way to the station at Issoire, whence at 8 o'clock they departed for Aurillac, their first headquarters in the Cantal. The line at first follows the river Allier southwards over the southern end of the Limagne. About Brassac the Oligocene rests upon one of the small coal-basins which are dotted over the granite and

metamorphic rocks of Central France, and in which the beds are often very highly inclined. Several cuttings in which these steeply dipping Carboniferous beds are displayed were passed through.

Changing at Arvant the journey was continued, and the Limagne was quitted at its southern termination. From this point the line begins to ascend the valley of the Allagnon, a tributary of the Allier, passing through some very wild and beautiful scenery, and making straight for the heart of the Cantal volcano. The ascent of this valley was continued until the tunnel of Le Lioran was entered, when the watershed between the basin of the Loire and that of the Garonne was crossed. On emerging from the tunnel, which is cut right through the neck of the great volcano, the line runs down the valley of the Cère, through volcanic rocks practically all the way to Aurillac, which however stands on the Jordanne just above its point of confluence with the Cère.

Aurillac was reached early in the afternoon, and M. Marcellin Boule and other gentlemen were at the station to welcome the party. A move was at once made to the two hotels, the St. Pierre and Trois Frères, where accommodation had been secured, and soon afterwards a short drive was taken under the guidance of M. Boule to explore some of the geological features of the immediate neighbourhood.

Proceeding first to the Puy Courny, an exposure was seen of Miocene basalt resting upon Oligocene beds and overlain by upper Miocene fluviatile sand and gravel; subsequently the slopes of the Puy de Vaux were reached. Here the carriages were left in order that the various quarries and natural exposures displaying the Oligocene beds of the hill-side might be examined in some detail. The base of the series is constituted by unfossiliferous red clays, followed above by green marls, both belonging to the lowest or Sannoisian stage of the Oligocene. Overlying these are white marls, with interbedded fine grained white marly limestone, the chalk-like appearance of which is rendered very marked by the presence of numerous nodular masses of silica, which in colour and general mode of arrangement are not unlike the nodular flints of the Upper Chalk. In the limestones, and especially in the silica concretions, various fresh-water fossils, such as *Potamides*, *Limnæa*, and *Planorbis*, were seen. These beds, according to M. Boule, comprise the middle or Tongrian stage of the Oligocene. They are finally overlain by massive beds of compact limestone, forming the top of the escarpment, and containing admirably preserved specimens of *Helix*, *Limnæa*, *Planorbis*, *Cypris*, and other land or fresh-water genera. These beds M. Boule relegates to the upper or Aquitanian stage of the Oligocene.

From the level of these highest Oligocene strata a good

general view was obtained of the plain of Quaternary alluvium lying below, through which the lower Cère sluggishly takes its way. The rounded U-like shape of this glaciated valley, in contradistinction to the V-like cross-section of non-glaciated valleys of this region, was pointed out by the Director.

The descent to the base of the escarpment, where the carriages were waiting, was then made, and the return drive along the flat was commenced. About half-way back to Aurillac a short halt was made at Arpajon to enter and examine the great pits there opened in the pebbly Quaternary alluvium. Shortly afterwards the return to Aurillac concluded the geological programme of the day.

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#### EXCURSION FROM AURILLAC TO VIC-SUR-CÈRE AND BACK.

*Director:* M. MARCELLIN BOULE.

On the *tenth day, August 26th*, before six o'clock the conveyances had been drawn up on the Mall in front of the Hôtel St. Pierre, and a few minutes afterwards the party was on its way up the Cère valley. The day was threatening, and very soon rain began to fall and continued intermittently during the whole of the day. The result was that it was not possible to carry out the programme in full detail; but notwithstanding the inclemency of the weather all the more important features were seen in a fairly satisfactory manner.

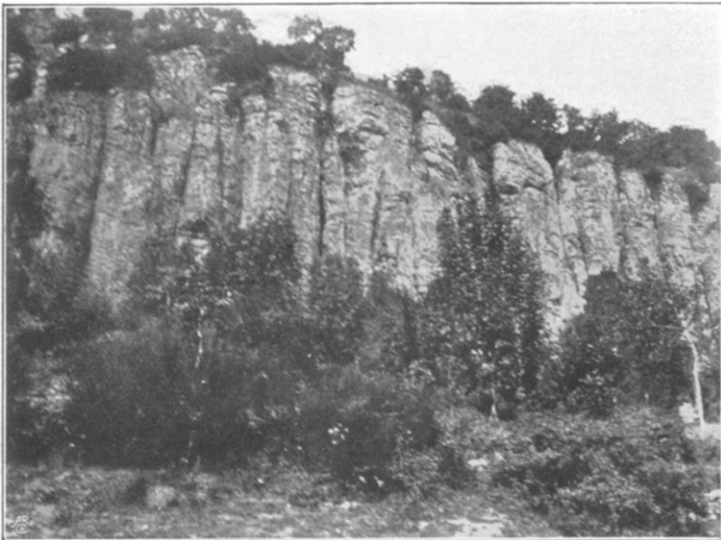
Passing the gravel pits at Arpajon, which had been visited the previous day, the route soon passed through a region of Archæan rocks, mainly mica-schists. A little farther up the valley a glacial moraine was pointed out, spanning the valley, but it was a by no means well-marked feature.

Turning at this point into the valley of a river which falls into the Goul, the schistose rocks were soon succeeded by volcanics. At Cabane a big scarp-like exposure was seen of the andesitic breccia, which is such an important constituent in the massif of the Cantal, and concerning the mode of origin of which such differences of opinion exist. In places it attains a thickness of three thousand feet. By Scrope it was regarded as a torrential deposit. By M. Michel Lévy it is believed to be of glacial origin. M. Boule supports the view that it is a purely igneous rock, a lava in the middle—in this part it has a crystalline matrix—but that in its upper and lower parts transport by water has been an important element in its formation. This view is the one which seems to have secured most favour at the meeting of the International Congress in 1900.

At Carlat the andesitic breccia is thin, and is overlain by a



1.—THE BASALTIC PROMONTORY AT CARLAT, CANTAL.



2.—THE COLUMNAR PHONOLITE OF BORT (LES ORGUES DE BORT).

(Reproduced from "Some Geological Notes on Central France" by Miss M. S. Johnston, *Geol. Mag.*, Dec. iv, Vol. viii, No. 440, p. 59, Feb. 1901.)

thin layer of Pliocene pebble gravel, upon which rests a sheet of plateau basalt. This last forms a flat-topped hill with vertical walls all round (Pl. XV, Fig. 1). Carlat itself is picturesquely situated some way up the steep side of a spur that projects well into the valley. The carriages were left below at the village, while an ascent was made to the foot of the cliff of basalt. The rock shews columnar structure admirably above and below, but in the middle it is traversed only by a series of somewhat curved and roughly horizontal joint-surfaces. By walking round the base of the cliffs, the only point where access to the top is possible by ordinary means was found, and a scramble up the narrow and steep cleft brought the party to the table-like top of the hill, whence a good view was obtained of the surrounding district, including the extensive spread of a great basaltic flow cut into a series of bosses and profound gorges, the effects of post-Pliocene erosion.

Returning to the village, a pilgrimage was made to the grave of J. B. Rames, the famous Auvergnat geologist. It is situated in the grave-yard of a quaint sixteenth century church, in the interior of which is an inscribed tablet recording the demolition of the fortified castle that once stood on the top of the hill.

Lunch was served at the inn. Continuing the drive up the valley of the Goul, a good example of platy phonolite was seen near Jou-sous-Monjou, in one of the small dome-like masses which occur here and there at the base of the volcanic series of the Cantal. The peripheral part of the one here exposed is of vesicular trachyte, which is seen to underlie the andesitic breccia. Proceeding past the Château de Cropières, with its quaint outside staircase, the carriages soon re-entered the valley of the Cère, and at an elevated point on the valley-side, overlooking the watering place of Vic-sur-Cère, they were left, and a walk in rain and wind across heathy uplands to the right of the road led to the Pas de Mougudo, famous for its fossil plants.

Here the party was met by M. Pierre Marty, who, after M. Boule had made a few interesting remarks concerning the broader questions of the geology of the Pass, gave an admirable description of the leaf-bearing beds, and of the remains that have been obtained from them. The following account, and the admirable drawings by which it is illustrated, have been most kindly sent by M. Marty for this report.

### **The Plant-Bed of the Pass of La Mougudo (near Vic-sur-Cère), Cantal.**

BY M. PIERRE MARTY.

The plant-bed of the pass of La Mougudo is situated upon the left bank of the Cère, above the watering-place of Vic.

It appears half-way up the hill, in the face of a cliff, about  
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## FOSSIL PLANTS FROM THE PASS OF LA MOUGUDO.

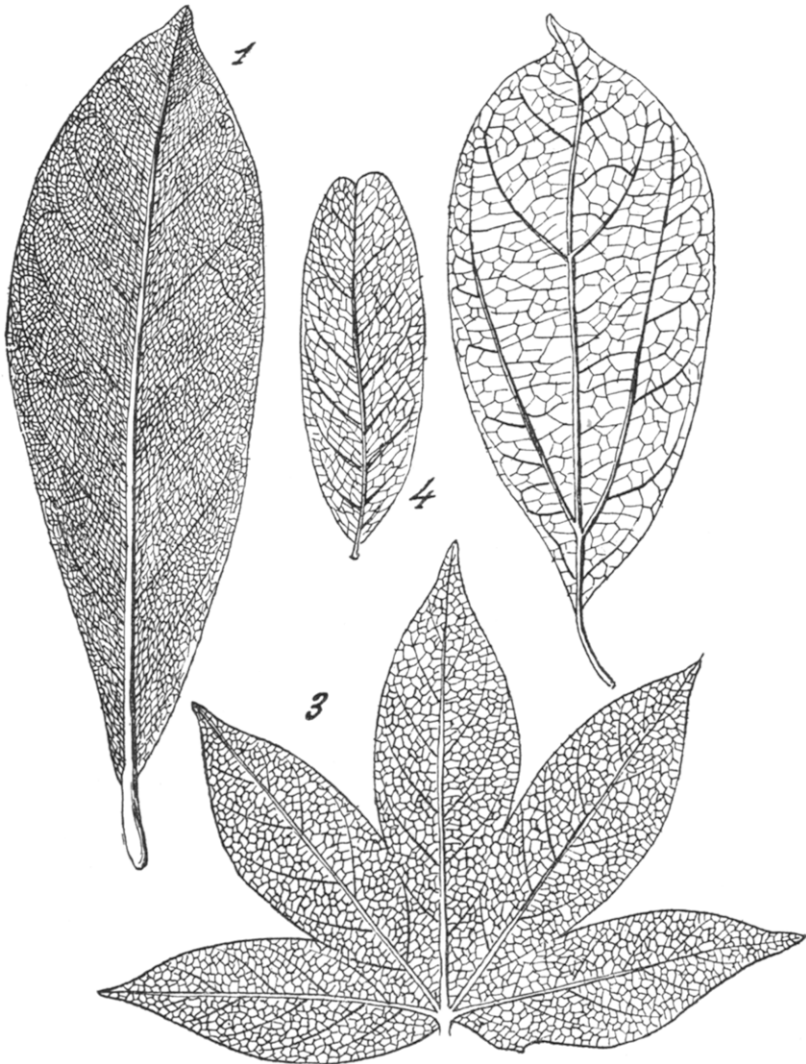


FIG. 52.—MIOCENE AND TROPICAL FORMS.

- |  |   |
|--|---|
| 1. <i>Ficus lanceolata</i> Heer.       | 2. <i>Cinnamomum polymorphum</i> A. Br. |
| 3. <i>Sterculia vindobonensis</i> Ett. | 4. <i>Calpurnia europæa</i> Sap.        |

170 ft. high. Its height above the level of the sea is about 3,000 ft. The face of this cliff is composed of andesitic breccia, cut horizontally by two beds of cinerite, of which the lower only is fossiliferous.

The cinerites nearly always contain the remains of plants—trunks of trees, leaves, flowers and fruits—and in these the original structure and texture are often so admirably preserved as to permit of their most detailed histological study. The fossil plants of the cinerites were mentioned by Elie de Beaumont and Dufrenoy, by Poulett Scrope and others. Rames made a great collection of them, and his specimens were studied by the illustrious palæontologist de Saporta, who paid particular attention to the forms which seemed to him to suggest evolutionary deductions. His intention was ultimately to publish a systematic catalogue of the fossil-flora of the Cantal, but his death prevented the completion of this work. Saporta made known fifty-seven species; my own researches have raised the number to over one hundred, but this cannot be regarded as more than a very small part of the total number of species comprised in the complete flora. Indeed, the excavations which have been made up to the present are comparatively insignificant, in view of the number of fossiliferous bands, their extent, and their prolific character; every blow of the pick brings to light new species. A certain number of species, such as *Abies intermedia* Sap., *Bambusa lugdunensis* Sap., *Fagus pliocenica* Sap., *Carpinus orientalis* Lam., *Pterocarya fraxinifolia* Sp., and *Sassafras ferrettianum* Mass., are common in nearly all the beds. But the florules of the different beds keep none the less a very distinctive character with regard to one another. Thus, an examination of the two best known florules, that of La Mougudo with forty-five species, and that of Niac with sixty species, shows that thirteen species only are common to the two beds. Whether these differences indicate that the florules are not of the same age, or that the plants from different beds grew under very varying conditions as regards altitude, exposure, and physical and chemical assimilation, I, personally, am unable to decide. Be that as it may, however, the differences just indicated, between the various florules would suggest an interesting discussion from more than one point of view. But such a discussion cannot be entered upon here. It will suffice to say, in a general way, that the florules of the beds in closest propinquity to the crater (La Mougudo, St. Vincent) would seem to have somewhat more ancient and tropical affinities than those of the beds from the outskirts of the volcano (Niac, Lasclausades).

Let me describe briefly the characters distinctive of



## FOSSIL PLANTS FROM THE PASS OF LA MOUGUDO.

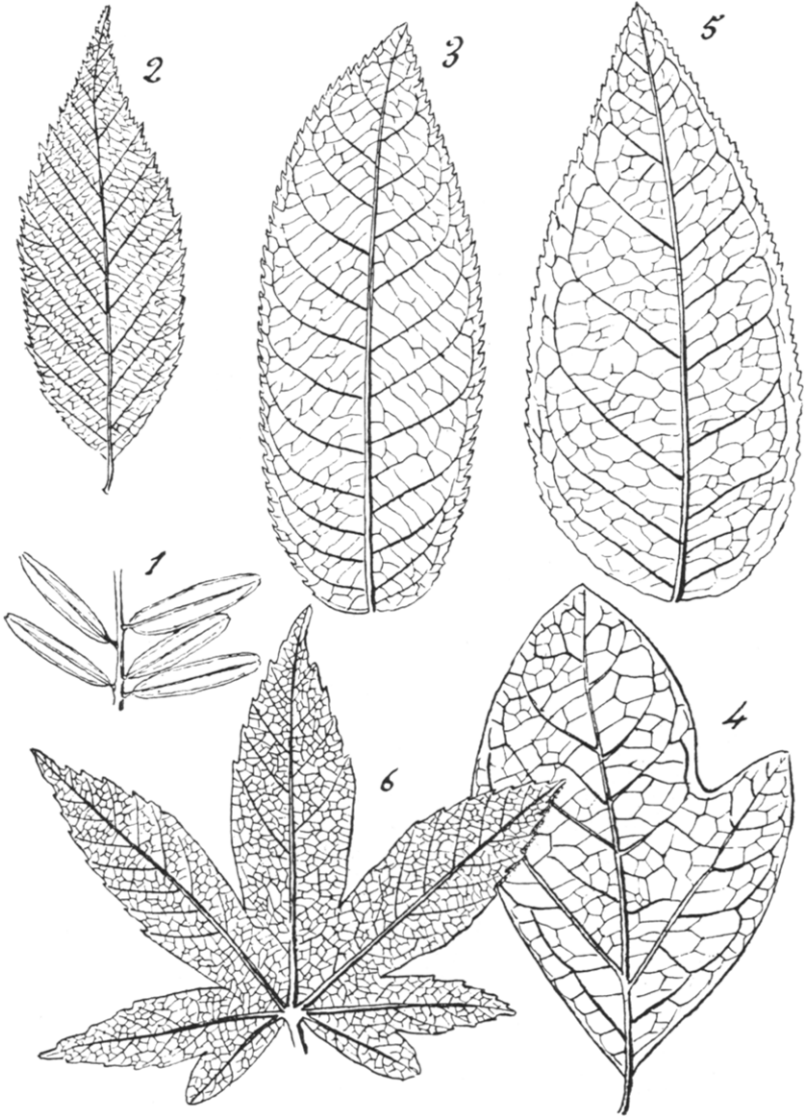


FIG. 53.—PLIOCENE AND SOUTHERN FORMS.

1. *Abies intermedia* Sap.
3. *Pterocarya fraxinifolia* Sp.
5. *Dictamnus major* Sap.

2. *Carpinus orientalis* Lam.
4. *Sassafras ferrettianum* Mass.
6. *Acer polymorphum* Sieb. et Zucc.

the florule of La Mougudo. They will give a fair idea of those of the flora of the cinerites of the Cantal as a whole. The majority of the plant-species of La Mougudo cannot be exactly identified with their homologues of the existing flora. But the slight differences which separate them are not sufficiently important to be regarded as distinct specific characters. It was to indicate these shades of difference that de Saporta, while retaining for many of the species the specific name of their existing homologues, added the qualification var. *pliocenicæ*.

Taking cognisance of this observation, the florule of La Mougudo, considered from the point of view of the geographical distribution of the living homologues of the species which comprise it, falls naturally into three groups :

1. The group of species which are now tropical or sub-tropical.
2. The group of species which have not travelled so far towards the south.
3. The group of species which are still indigenous in the district.

The first of these groups is numerically small. It comprises scarcely any other forms than *Ficus lanceolata* H., *Cinnamomum polymorphum* A. Br., *Sterculia vindobonensis* Ett., *Grewia crenata*, Ung., and *Calpurnia europæa* Sap. ; but it is very interesting, inasmuch as it stamps the whole flora with a character at once tropical and Miocene.

The second group is much more important. The principal species which characterize it are *Torreya nucifera* Sieb. et Zucc., *Abies intermedia* Sap., *Bambusa lugdunensis* Sap., *Quercus gœpperti* O. Web., *Carpinus orientalis* Lam., *Pterocarya fraxinifolia* Sp., *Zelkova crenata* Sp., *Oreodaphne heeri* Gaud., *Sassafras ferrettianum* Mass., *Dictamnus major* Sap., *Zygophyllum bronni* Sap., *Tilia expansa* Sap., *Acer polymorphum* Sieb. et Zucc., *Viburnum tinus* L., etc. Taken as a whole, these forms are at the present time distributed along lat. 35° N., and since the Cantal lies in lat. 45° N. we may say that they have travelled ten geographical degrees towards the south since the time when the cinerites were deposited. A certain number from among them are at present confined to America, but the majority have for their habitat the great zone of mountains, often volcanic, which, from Japan to the Canary Isles, through the Himalayas and the Caucasus, stretches across Asia and Europe. The scattering of the species of La Mougudo along this zone does not imply a former connection between continents now separated by the great oceans. All naturalists know that most of the fossil-plants found in Tertiary strata of our own latitudes have been found in more ancient beds in the Arctic regions ; and

## FOSSIL PLANTS FROM THE PASS OF LA MOUGUDO.

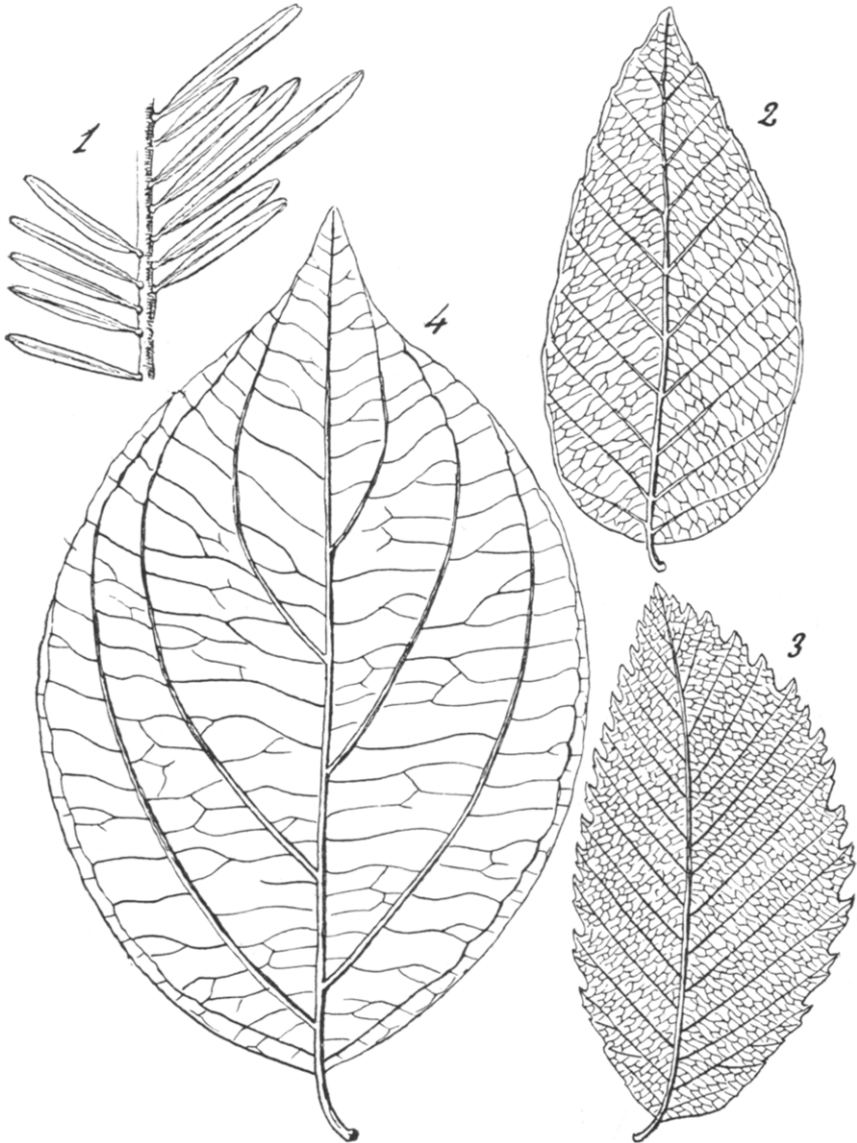


FIG. 54.—EXISTING AND INDIGENOUS FORMS.

1. *Abies pectinata* D.C.  
3. *Ulmus ciliata* L.

2. *Fagus sylvatica* L.  
4. *Cornus sanguinea* L.

it seems that the N. Pole must have been, during a very long period of time, a centre of vegetable creation, whence the species, driven gradually southwards by the increasing refrigeration of the climate, were forced to emigrate in a radial manner to the temperate and warm zones in which they are to be found at the present day.

The third and last group, that of the plants still indigenous in the Cantal, includes *Aspidium filix-mas* Roth., *Abies pectinata* D.C., *Carex maxima* Scop., *Fagus sylvatica* L., *Ulmus ciliata* L., *Urtica dioica* L., *Ilex aquifolium* L., and *Cornus sanguinea* L. This group, notwithstanding its feeble numerical importance, is very worthy of attention, for it shews the arrival, in the middle of the Tertiary period, of the boreal flora, which, favoured subsequently by the Pleistocene climate, succeeded eventually in usurping the soil of this district. It represents the alpine element of the great Tertiary volcano, which, according to geologists who are competent to judge, attained an altitude of close upon 10,000 ft.

The florule of La Mougudo was at first considered by de Saporta to be of Middle Pliocene age, and later it was relegated to the Lower Pliocene. The second of these estimates seems to be the more satisfactory. Indeed, in the flora obtained from the neighbouring clays of Ceyssac, with *Mastodon arvernensis*, not one of the tropical species of La Mougudo, has been recorded; and the fossil plants, from the environs of Vic, present the most striking analogies with those of the Cerdagne, from clays which together with the base of the andesitic complex of the Cantal are dated by the fauna of Pikermi.

At the conclusion of his remarks, M. Marty, who, before the arrival of the party, had had a very large number of beautiful specimens laid out for inspection, informed the visitors that they were free to take away as many as they liked, and added to this act of generosity the further kindness of naming the specimens selected by each member. It is scarcely necessary to say that M. Marty's goodness was keenly appreciated by everyone, and that thanks were freely expressed to him.

From La Mougudo the descent was made into Vic-sur-Cère, whence train was taken back to Aurillac.

In the evening, after dinner, a reception which had been arranged by the "Syndicat d'Initiative du Cantal," and the municipal authorities, was held in the rooms of the "Cercle de l'Union." Although M. le Dr. Fesq, the Mayor, could not receive the party officially, yet both he himself and his colleagues identified themselves with this pleasant attention to the visitors; and he, M. Garnier, the President of the Syndicate, M. Boule, and others made appropriate speeches, whilst Mr. Whitaker and Prof.

Bauerman spoke on behalf of the guests. The entertainment proved very enjoyable, and due expressions of gratitude for it were conveyed by the members to their hosts.

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## EXCURSION FROM AURILLAC TO MURAT.

*Director*: M. MARCELLIN BOULE.

On the *eleventh day, August 27th*, the excursionists were again on their way betimes, and on this occasion M. Boule was accompanied by M. Ch. Puech, the engineer who superintends the maintenance of the excellent road followed during the course of the day's drive. The road, keeping an easy gradient, contours the spurs and recesses, thereby increasing the variety and charm of the delightful scenery encountered during the journey up the higher parts of the valley of the Cère. The ascent of the valley was resumed at Vic-sur-Cère, the farthest point reached on the previous day, a special train conveying the party from Aurillac to this starting point. The day was again marred by heavy, though fortunately not continuous rain, so that the district traversed was only imperfectly seen.

Very striking was the immense extension of the great flow of andesitic breccia, in which some of the blocks were of gigantic dimensions. The gorge of the Cère, however, was the first superlatively striking feature encountered, and was approached shortly after leaving Vic-sur-Cère. It is a deep, cañon-like cleft cut in the middle of a broad U-shaped valley whose floor is carpeted by Quaternary gravels. The cleft must therefore have been cut in post-Pliocene times. The river passes between high walls of the andesitic breccia and alternately collects in placid pools or is bounding over rocks in foaming falls, the varied vegetation of fresh green, the brown of the rocky, lichen-covered walls, and the subdued light filtering down from above through the apparently narrow rift, all combining to produce a remarkably impressive effect.

A little farther on beyond the Pas de la Cère, Thiézac was reached. Here the flanks of the valley are composed of andesitic breccia, overlain by andesitic and basaltic flows which form well-marked escarpments. A small outlying patch of the breccia forms a conical hill rising from the middle of the valley, upon the summit of which stands the conspicuous statue of "La Vierge de Thiézac." The breccia is underlain on one side by Archæan schists, and on the other by a dome-like mass of trachyte and phonolite, and a small patch of Oligocene sediments, partly concealed by the outlier of breccia, lies between them. The carriages were left for a few minutes while an ascent was made to the

statue, from which somewhat elevated point it was possible to make out this distribution of rock-formations, on the floor and sides of the valley.

A little above Thiézac the Cère runs through a number of ravines, together known as the Pas de Compaing, because of the danger of robbers which formerly existed hereabouts for the solitary traveller. Here in the long road-section another example was seen of a trachyte dome underlying the andesitic breccia. The valley, both in the pass and above it, is extremely wild, a succession of ravines, rocks, precipices, rapids, and cascades, overshadowed by the Plomb de Cantal on one side and the Puy de Griou on the other, the whole hewn out of the heart of a group of volcanoes, a bewildering maze of basalts, andesites, trachytes, phonolites, and other eruptive rocks.

As the road is continued upwards, it heads straight for the southern slopes of the Puy du Lioran, which threatens to arrest its further progress, but which is pierced by the wonderful Lioran tunnel. At the entrance of this, a stop was made in order to take a last look down the valley of the Cère, which would not be seen again, and to hear the remarkable echoes which, as the mouth of the tunnel is approached, are reflected from the glazed screens placed some little way within. The tunnel is 4,629 ft. long, over 26 ft. wide, and about 23 ft. high, with a carriage-way and foot-path all through; it is lighted by oil lamps, which are kept burning night and day. On emerging from the opposite end of this tunnel the members found themselves on the northern slopes of the Puy du Lioran and at the head of the valley of the Allagnon.

The change of scene was striking, fine and varied foliage having given place to an almost entirely coniferous vegetation, and pleasant fertility to chill barrenness. A few yards down the valley the Hôtel du Lioran was reached, and here a good long stay was made, permitting the unusual luxury of a very leisurely luncheon, and some exploration of the hotel and its surroundings afterwards. The neighbouring Puy de Griou, with its appearance of inaccessibility and its association with the name of Elie de Beaumont, was seen not far off, but it was not possible without undue delay to make its closer acquaintance.

The drive down the left bank of the Allagnon having been resumed, a fine exposure of another of the Miocene trachytic domes was seen, traversed by numerous dykes of andesite. Later, at the classic quarry of Laveissière, visited by Murchison and Lyell, Oligocene limestones and green clays were seen at the base, covered and separated from the overlying andesitic breccia by a thin carbonaceous layer, possibly an old Miocene soil, all pierced by narrow vertical dykes of glassy basalt. From this point all the way to Murat the road follows the scarp of a great basalt flow of Miocene age.

An early arrival at Murat enabled the members to make a pleasant exploration, under the guidance of M. Boule, of this picturesque town, with its steeply sloping streets, quaint oldhouses, and its church containing many curious pictures and a miracle-working statue of the Virgin, in black stone. Some of the more energetic members also made an expedition to the basaltic hill overlooking the town, in the cliffs of which a fine curved columnar structure is admirably displayed.

The "Grand Hôtel de la Gare et des Messageries" was the head quarters for dinner, but its sleeping accommodation not being sufficient for the whole party, many were quartered elsewhere in the town.

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### EXCURSION FROM MURAT TO THE PUY MARY, AND THENCE TO SALERS.

*Director*: M. MARCELLIN BOULE.

On the morning of the *twelfth day, August 28th*, the members assembling from their various quarters, breakfasted at the hotel. The chief feature of the day's excursion, the ascent of the Puy Mary, one of the highest points in the Cantal, had long been looked forward to with pleasurable anticipations. As the fates would have it, however, the day was by far the most inclement of the whole fourteen spent in the Auvergne, and the torrent of rain that fell during the middle of the day, rendered the climb on foot from the highest point attained by the carriage-road impracticable. Nevertheless, the day was thoroughly enjoyed by most, as the naturally wild and rugged character of the mountain scenery passed through was rendered doubly impressive by the driving rain and mist, which, obscuring the details of crag and ravine, gave scope for the exercise of that fertile imagination which is generally regarded as an especial attribute of the geologist's mind.

The start was made, in closed carriages, up the steep road, winding in zig-zags out of the town and past the foot of Les Orgues, a great cliff of basalt, with hundreds of prismatic columns, some straight, others bent into graceful curves. Thence the valley of the Chevade, with flanks composed of andesitic breccia, basic andesites, phonolites, and basalts, was ascended. At the Col d'Entremont, the head of the valley, a series of superficial workings in a haüyne-bearing augite andesite, which was formerly quarried for roofing slates, was visited. The lava is traversed by closely-packed joints, parallel with the surface of the flow, which cause the mass to split up into thin, flat-sided slabs, and determine its suitability for roofing purposes.

Passing over the col, the valley of the Santoire was entered; and this stream was followed, past the little town of Dienne, all the way up to its cirque of origin at the very foot of the summit of the Puy Mary. During this long and beautiful drive the study of geology had to be almost entirely suspended owing to the very heavy rain, which continued without cessation for several hours. Eventually the source of the Santoire, known in its upper part as the Impradine brook, was reached, and a welcome halt was made at the solitary and remote "Maison de Secours." In the limited space offered by this small habitation, the members sheltered from the pouring rain and comforted by a brightly burning fire took their lunch, which under more favourable circumstances was to have been served on the summit of the Puy. The kind and able manner in which the people of the house received and entertained such a large party under such trying conditions was commended by all.

After lunch a long wait was made in the hope that the rain might cease; but no sign of improvement appearing a start was at length made through rain and mist, this time on foot, as the way was both steep and heavy. In this manner the road which winds round the mountain, not very far from the summit, and keeps roughly along the junction between the andesite of which the peak is composed, and a sheet of porphyritic basalt which lies underneath it, was followed until its highest point, the Col d'Eylac, with an altitude of 5,190 feet was reached. Here it was finally decided to abandon the ascent to the summit which lies 673 feet above (5,863 feet). M. Boule gave an interesting description of the geology of the immediate vicinity, but owing to the adverse atmospheric conditions the features to which he referred were somewhat imperfectly seen.

The descent of the western flank of the Puy was then commenced, the road soon sinking by a number of zig-zags to the level of the andesitic breccia, which was frequently seen exposed, and occasionally was seen to be traversed by dykes of andesite. The lower limit of the cloud of mist in which the upper part of the mountain was enshrouded was soon passed, and a better idea was then obtained of the beauty of the wooded cirque forming the head of the valley of the Mars, down which the party was proceeding. Owing to the heavy rains which fortunately had now ceased, the watercourses were fully charged, and some fine cascades and falls were passed as the carriages, which had by this time overtaken and picked up those on foot, passed rapidly through the luxuriant woods, now steamy and dripping, which clothe the lower parts of the valley.

Later, the road, ascending, passed over into the valley of the Maronne, the right bank of which it follows at a considerable elevation, running in fact along the lower edge of the great sheet of vesicular and slaggy plateau basalt, which in Pliocene times formed a continuous mantle investing the lower



slopes of the Cantal volcano, but which has since been cut through by a system of valleys penetrating into the andesitic breccia below, and radiating from the Puy Mary outwards in all directions.

Cliffs and cuttings of this basalt skirted the right-hand side of the road practically all the way to Salers. To the left and away down, could be seen the river following its sinuous course along the valley bottom. The valley of the Maronne, like many others in the Cantal, shows evidence of rejuvenescence. Viewed from above the slopes on either side are seen to form, at first, part of a broad U-shaped glaciated valley, in the middle of which, however, the river flows in a narrow V-shaped valley, evidently cut down below the level of the original floor within comparatively recent times, and possibly as result of a recent movement of elevation.

The evening was well advanced when the travellers, cold with their long, damp drive, entered the old-world town of Salers. They were soon distributed to their various quarters, many of which were extremely quaint and old-fashioned, and to these they mostly made an early return, after dining in two companies at the two largest hotels of the place.

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#### EXCURSION FROM SALERS TO BORT.

*Director* : M. MARCELLIN BOULE.

Salers is magnificently situated on the edge of the basaltic plateau already referred to, and overlooks the confluence of the valleys of the Upper Maronne and Aspre, and of two smaller rivers, with the main valley of the Maronne, locally known as the valley of St. Paul de Fontanges. It commands an unrivalled view, particularly from the public grounds known as the Promenade de Barrouze. It was here on the morning of the *thirteenth day, August 25th*, that the Mayor, M. le Dr. Guillaume, kindly arranged to receive the party and conduct them to the features of interest, of which Salers possesses a very ample share. Under these auspicious circumstances the party visited various fifteenth and sixteenth century houses, the ancient gates, and the church, also of the fifteenth and sixteenth centuries, in which there is a life-size group representing the entombment. Salers was originally fortified against the attacks of the English. The mediæval character of the town has been retained in a commendable manner, and the inhabitants are justly proud of its well-preserved antiquities.

M. Boule, profiting by the assembly at the Promenade de Barrouze, there gave an account of the geology of the panorama of the western side of the Cantal massif, which is commanded

from that point, and which in the clear air of the sunny morning formed a picture of rare beauty. The valleys cut in the andesitic breccia, trending upwards, narrow as they approach the Puy Mary, which is here hidden from view by the intervening Puy Violan. The flat-topped basaltic plateaux between the valleys are thus triangular in form, widening out as they descend, and having a gentle slope downwards from their point of convergence, by the continuation of which it is possible to reconstruct in the mind the profile of the great volcano before erosion had effaced so many of its original features.

After the exploration of the town the members, having thanked the Mayor for his gracious services, entered the carriages which had assembled near the church, and were soon on their way to Drugeac, whence they travelled by train through Mauriac to Bort.

The journey to Bort was picturesque, the line having the winding character of a mountain railway, taking many curves to avoid steep inclines, and commanding excellent views of the Cantal which was being left behind, of the Cezallier which, lying to the east, was being skirted, and of Mont Dore, which was being approached. The route follows the western margin of the Cantal volcanic massif for some way, passing mainly over the westward extensions of the plateau basalts which here have descended practically to the level of the surrounding region of crystalline rocks. Two or three miles beyond Mauriac, the volcanic rocks are left, and from that point to Bort the line runs over gneisses and mica-schists, except for some little distance, when it touches the southern extremity of the important coal-basin of Commentry and Decaizeville.

Arrived at Bort, which lies in the department of Corrèze, although only just over the border of the Cantal, the members were soon conveyed to their several quarters. The town is prettily situated on both banks of the Dordogne, and at the foot of a small but famous hill, known as the Orgues de Bort. Later in the afternoon this hill was ascended. Its lower slopes are of augen-gneiss, but its table-like summit is formed by a flow of phonolite, the edges of which give rise to a bold perpendicular wall, which dominates the town, and in which are displayed the large irregular polyhedral columns which have given origin to the name of the hill (Pl. XIV, Fig. 2). Between the phonolite and the augen-gneiss are beds of red clay and sand of Oligocene age.

The prospect from the flat top of the hill is one of the most extensive in Central France. It is a panorama of especial interest to the geologist, because it enables him to obtain an excellent view of the two great volcanic massifs of the Cantal and Mont Dore at one and the same time. Towards the south and south-east the horizon is bounded by the jagged profile of the weather-beaten volcano of the Cantal, while the intervening

middle distance is occupied by the wooded flat-topped hills made up of its basaltic flows, with here and there a rounded knoll of trachyte, phonolite or other intrusive mass. Towards the north the similar but more elevated mass of Mont Dore, with flanks, even at this distance, seen to be scored by deep ravines, rears its peaks along the sky line. The eastern horizon between these two volcanic centres is occupied by the rolling plateau of the Cezallier, consisting of the meeting flows of basalt from either volcano. In the immediate foreground are the heath-clad hills of gneiss and schist rounded and smoothed by the glaciers which once descended from the distant heights of the Cantal. Here and there in the valleys are glacial moraines, one of which has deflected the Dordogne, which flows round the base of the hill, from its original course, damming it back and causing it to find exit over a rocky spur, through which it has gradually cut a deep ravine. The linear basin of Carboniferous rocks forms an outcrop running north and south, which may be traced across the country by the isolated wreaths of smoke marking the points where coal is being exploited. Behind, to the west, are the rolling hills of the Limousin, of granite, gneiss and schist.

The day was perfect for the view, and after M. Boule had eloquently described the panorama before them, the members remained a considerable time in order that it might impress itself upon their minds. They then made their way back to Bort, some returning in the carriages, others making the descent on foot.

The dinner, in the evening, being the last of the excursion, opportunity was taken of thanking those still present who had contributed to the success of the meeting. The people of the hotel entered into the spirit of the proceedings and provided fireworks, which produced a spectacular effect much enjoyed by the assembled youth of the town. The use of crackers to punctuate speeches, however, cannot be recommended. Votes of thanks were ably proposed by various members to M. Boule for his kindness in conducting the party through the Cantal; to M. Desroches for the careful and efficient manner in which he had carried out the important duties committed to him during the whole of the excursion; to the President, Mr. Whitaker, for the admirable and dignified manner in which he had presided over the meeting, and for the kind way in which he had, all through, given an epitome in English of the remarks of the Directors, for the benefit of those who were not able to follow the French descriptions; to Mr. Louis who had undertaken the onerous duties of Excursion Secretary; and finally to Dr. Savage, who with the greatest kindness had acted as physician to the party, and to whom many of the members had occasion to be greatly indebted. A purse of money was also presented to M. Lefort, the willing and obliging assistant of M. Desroches, in recognition of his services.

The votes of thanks were carried with an enthusiasm which was only exceeded by that which greeted the replies of the recipients.

Here it may be appropriately mentioned that the reception accorded to the English visitors was everywhere most cordial and gratifying. Not only the Directors, their friends and colleagues, but also the general public, and particularly the local press, welcomed the party in a manner which will remain in the minds of those who had the good fortune to attend the excursion, as a very pleasant recollection.

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### EXCURSION FROM BORT TO MONT DORE.

*Director* : M. MARCELLIN BOULE.

The morning of the *fourteenth day, August 30th*, broke fine and clear. Assembling before the hotel after breakfast the party, now diminished by the departure for England of several of its members, entered the two commodious brakes, and set out in the direction of Mont Dore.

On leaving Bort the road at once ascends to the summit of a well defined but not high plain of Pliocene alluvium, consisting of pebble gravel resting directly upon the old rocks below. This plain is intersected by numerous valleys in the beds of which the ancient formations of cordierite gneiss, mica schist, granite and other crystalline rocks are exposed to view. As the alluvium is followed towards Mont Dore it insensibly passes into morainic material, brought down by the ice which once descended from that great volcano ; the pebbles are striated, and large erratic blocks were seen scattered over the rounded, glaciated surfaces of the crystalline rocks, many being perched in precarious positions upon the slopes of the roches moutonnées. The direction of movement of the ice is clearly shewn by the orientation of the grooves, which are scored deep into the solid rock and are often as fresh as in the bed of an Alpine glacier. Moreover, the hill-slopes which face towards Mont Dore are gentle and smooth, while those which face away are sharp, steep and angular, having remained uncovered by the sheet of ice which apparently was never of any great thickness.

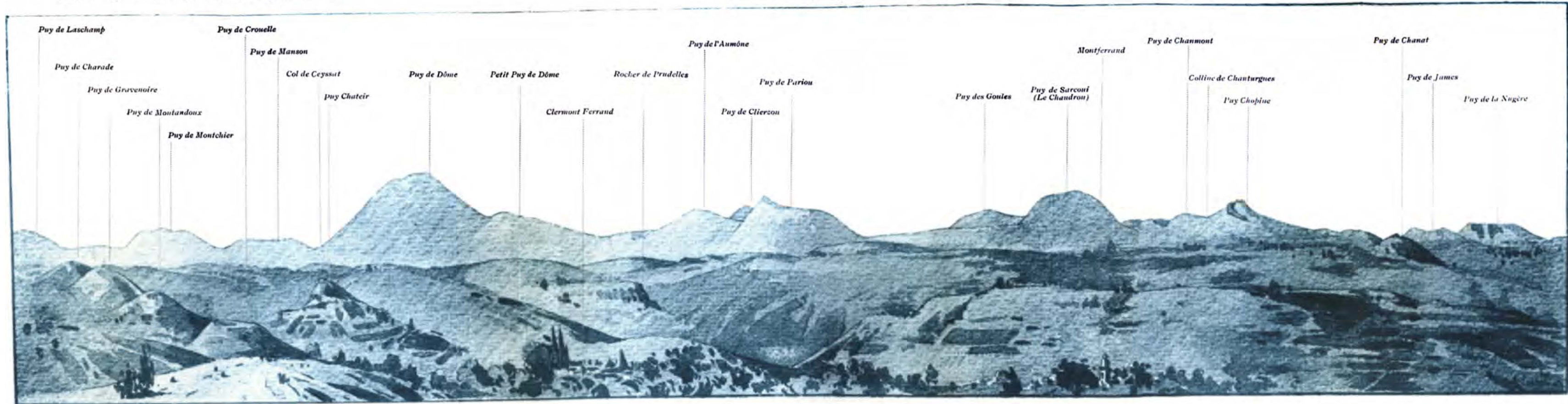
These features are maintained until Latour d'Auvergne is approached, when the volcanic rocks which emanated from Mont Dore begin to be encountered.

At Latour d'Auvergne, an ancient Auvergnat village built upon an outlying promontory of basalt, and lying rather more than half way from Bort to Mont Dore, a halt was made for lunch. During a stroll through the village streets afterwards two or three

examples were seen in the roadside of basaltic walls with remarkably regular columnar jointing. Reassembling at the hotel, the party remounted the carriages and with an enthusiastic good-bye to M. Boule, who was remaining behind to carry on some geological investigations in the district, resumed their journey.

The drive carried the party around the western flanks of Mont Dore, and so completed their circuit of that massif. At first, rising laboriously over broad moorlands, they eventually began to descend through the luxuriant forest belt forming the left bank of the Dordogne. Here they had the good fortune to encounter M. Michel Lévy, who in his specially designed surveying motor car was continuing those researches which have done so much to elucidate the geology and former history of Mont Dore. After a brief interchange of courtesies between M. Lévy and the President, the members saluting the eminent French geologist, continued on their way. Their arrival at the railway station at Mont Dore shortly afterwards brought to a conclusion one of the most interesting and successful excursions ever undertaken by the Geologists' Association.

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PANORAMA OF THE CHAIN OF PUY AS SEEN FROM THE LIMAGNE.

From a Water-Colour Drawing by M. A. Eusébio.