

**SKETCH OF THE GEOLOGY OF  
CENTRAL BRITTANY.**  
**WITH SPECIAL REFERENCE TO THE WHITSUNTIDE  
EXCURSION FOR 1899.**

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INTRODUCTION.

HAVING been informed of the desire of the Geologists' Association to cross the Channel once more and to pay a visit to Brittany, the present notice is offered to the members with the object of giving those who will traverse that province a preliminary idea of its geological structure.

The subsoil of Brittany consists of pre-Cambrian and Palæozoic strata, tilted on end, and appearing on a map as narrow bands running parallel with one another from west to east, or rather slightly converging toward the west. These bands are produced by a complex system of co-ordinated anticlinal and synclinal folds, which are intersected by the nearly horizontal plane of the actual surface. Of these numerous undulations the most important are specially characterised by the fact that the

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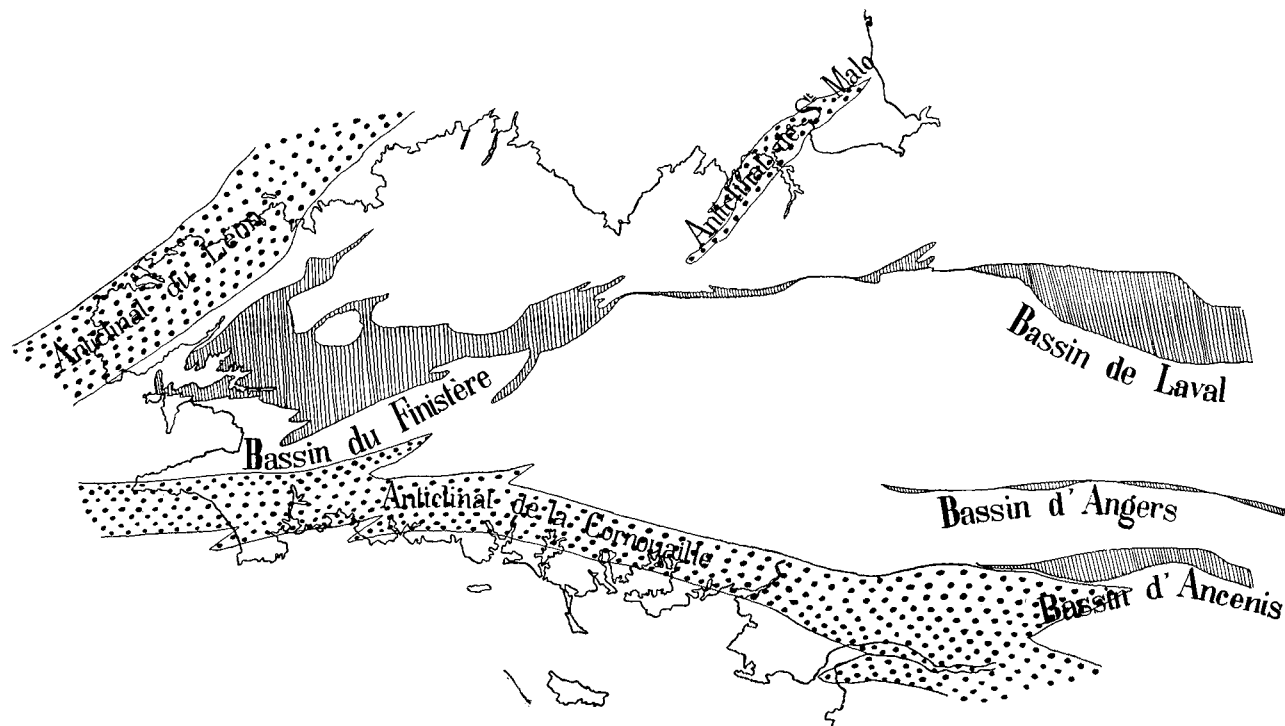


FIG. 1.—SKETCH-MAP OF BRITTANY, SHOWING THE CHIEF ANTICLINALS OF THE COUNTRY AND THE THREE PRINCIPAL SYNCLINALS.

synclinals contain the more recent beds, while the anticlinals expose the older beds.

The sketch-map (Fig. 1) will show at a glance the three principal folds enclosing rocks of Devono-Carboniferous age (the basins of Laval, Angers, and Ancenis), and the two principal anticlinals corresponding with uplifts of pre-Cambrian gneiss (Folds of Léon and Cornouaille).

A number of other less important wrinkles occur corresponding to many undulations of the Silurian and pre-Cambrian formations, but for our present purpose these may be neglected. The most important amongst them is the St. Malo anticline, as seen in the sketch-map.

We may thus acquire a general idea of the structure of Brittany in a single excursion by passing from north to south, and from one anticlinal to another, across the several synclines. It will, however, be preferable to make two parallel traverses, because of the scarcity of exposures, this scarcity forming the principal difficulty in surveying the country, where damp lowlands with a luxurious vegetation alternate with level tracts of bare moorland.

To understand the geology of Brittany, however, it will not suffice to consider only the succession of sedimentary rocks, which have been piled up during the pre-Cambrian and Palæozoic periods to a thickness of many thousand feet. Episodes of contemporaneous volcanicity took place at certain definite epochs during these different periods, and they recall the grand phenomena which have been described by Sir A. Geikie on the other side of the Channel. They will occupy our attention but for a moment, but, in spite of their historic interest, their tectonic importance is small when compared with the position occupied by the deep-seated masses of granite and diorite, and with the rôle which these play in the structure of the country.

In this outline, therefore, it will be convenient to give first of all a rapid review of the succession of the stratified rocks which enter into the structure of the area; we will next consider the contemporaneous volcanic phenomena, and finally give some description of the deep-seated intrusive masses.

## THE LOCAL ROCK-FORMATIONS.

The Tertiary series, from the Eocene to the Miocene, exhibits a fair number of fossiliferous beds which are sometimes very rich, but these deposits are limited to the neighbourhood of the valleys, and it is only the Pliocene which has a wider extension. The Tertiary outliers rest directly on the Palæozoic rocks without any trace or indication that deposits of Mesozoic age ever existed between them.

The following is the succession of the Palæozoic and Archæan rocks :

- |               |  |
|---------------|--|
| CARBONIFEROUS | 4. Shales and conglomerates of Teillé.<br>3. Sandstone of Mouzeil with coal-seams.<br>2. Shales of Chateaulin, with the <i>Productus</i> -Limestone of Quénon.   |
| DEVONIAN.     | 1b. Porphyritic tuffs.<br>1a. Conglomerates and porphyric tuffs.<br>7. Shales of Rostellec.<br>6. Shales of Traouliers.<br>5. Shales of Porsguen.<br>4. Greywacke of Fret.<br>3. Greywacke of Faou { Limestone of Néhou.<br>Limestone of Erbray.   |
| SILURIAN.     | 2. Sandstone of Gahard.<br>1. Shales and Quartzites of Plougastel.<br>4. Nodular Shales with <i>Cardiola interrupta</i> .<br>3. Ampelites of Poligné.<br>2. Phtanites of Anjou.  |
| ORDOVICIAN.   | 1. Sandstone of Bourg-des-Comptes.<br>8. Limestone of Rosau.<br>7. Sandstone of St. Germain-sur-Ille { Redon Sandstone.<br>St. Perreux Shales.<br>6. Slates of Riadan.<br>5. Sandstone of Chatellier.<br>4. Slates of Sion.<br>3. Armorican Sandstone.<br>2. Felspathic Sandstone of Fréhel. |
| CAMBRIAN.     | 1. Conglomerate of Erquy.<br>2. Green or purple Flags.<br>3. Shales and flaggy Quartzites, with dolomitic Limestones.  |
| BRIOVERIAN.   | 1. Conglomerate of Montfort and Bréhec.<br>3. Green Flags of Néant.<br>2. Shales, Limestones and Conglomerates of Gourin.  |
| ARCHÆAN.      | 1. Shales of St. Lo and of Lamballe with Phtanites.<br>3. Crystalline Schists of Groix.<br>2. Mica-Schists and Amphibolites of Audierne.<br>1. Gneiss of Quimperlé.  |

### Archæan System.

The formations referred to the Archæan, crop out in two long east and west bands in Léon and Cornouaille. Three principal lithological divisions have been made, the types of which are taken from the southern band ; these are (1) the gneiss of Quimperlé, (2) the mica-schists of Audierne, (3) the crystalline schists of Groix.

1. *Gneiss of Quimperlé*.—This stage forms a continuous band from Finistere to the Loire, and it will be seen at Auray. It consists of granitic or granitoid gneiss, coarse grained, with white or pink felspar, with much black mica in spots or in gneissic strings, and with granitoid and corroded quartz, the mica being sometimes replaced by fragmentary amphibole. The bands of gneiss alternate with interstratified layers of schist and amphibolite,

and pass into gneissic granites which penetrate them in the fashion of intrusions.

2. *Mica-Schists of Audierne*.—These mica-schists alternate with subordinate beds of fine-grained gneiss, with others of amphibolite, pyroxenite, eclogite, serpentine, chlorite-schist, and mica-schists, and include interstratified masses of intrusive crystalline rocks (fibrous and ribboned gneisses, hälleflintas, and gneissites). These subordinate rocks may have been injected into the mica-schists; they actually form with them long parallel bands, which can be followed from one end to the other of the southern plateau of Brittany, from the Isle of Sein to the Loire. In the Léon district this stage appears to form the base of the Archæan series, and in this, massive bands of a white leptynite alternate with the gneisses, mica-schists, and amphibolites.

3. *The crystalline schists of Groix* are a series of schistose rocks, including micaceous, chloritic, chloritoid, and carbonaceous schists, with sillimanite schists remarkable for the variety and abundance of heavy minerals which they contain (staurotide, garnet, magnetic iron, etc.); there are also subordinate bands of graphitic quartzite, of sericite-quartzite, of cipolin (pyroxenic marble), and of hornstone.

The boundaries of this stage, both above and below, are still very obscure; we have never been able to see them, and indeed their very existence may be called in question. The three divisions can certainly be distinguished by their lithological characters, but their succession is based only upon their constant order of superposition, which is the same in Brittany as in many other countries. No one, however, has seen the Brioverian strata in Brittany resting unconformably upon an eroded surface of the gneissic rocks; and the rocks known to occur as pebbles in the Brioverian conglomerates are not Archæan gneisses, but quartz, granite, granulite, and quartzite, that is to say, rocks identical with those of the Brioverian itself.

It must be confessed that the greater antiquity of the Archæan gneiss, though here admitted, is only a hypothesis. There are even reasons for believing that the theory which regards all the gneisses of Brittany as metamorphic products, dating from the beginning of the Brioverian period, makes a nearer approach to the truth.

### Brioverian System.\*

Above the Archæan gneisses and crystalline schists we find a series of beds which are clearly sedimentary, unfossiliferous shales, sandstones, and conglomerates, which were described by the early geologists under the name of the *Phyllades de St. Lô*. The lower limit of these St. Lô phyllades, which are more conveni-

\* From the ancient name of St. Lo (Briovera).

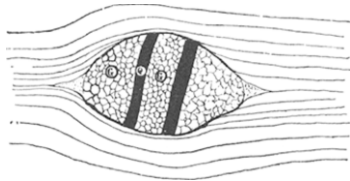
ently termed the Brioverian system, is, as we have seen, unknown. No one has yet been able to discover any unconformity in Brittany between the Brioverian and the more ancient rocks; on the contrary, there appears to be everywhere a stratigraphical and lithological passage from one to the other, so gradual and insensible that the line of division is purely subjective, and has been drawn at different horizons by different surveyors on the staff of the Geological Survey of France.

The Brioverian deposits are succeeded unconformably by the Cambrian conglomerates of Montfort, in which their débris is found as derived pebbles. We agree with Dufrenoy, who founded the system of St. Lô, in thinking that the Brioverian corresponds with the Longmyndian; but only a fortunate discovery of fossils can determine whether we should class the Brioverian as Cambrian or pre-Cambrian.

Whatever may be their relative age, the study of the divisions of the Brioverian presents great interest, because it involves the history of the first sediments and of the first volcanic eruptions in Brittany. This series appears to attain a thickness of five kilometres, and furnishes, moreover, forcible testimony to the power and unlimited extent of contact-metamorphism at a great depth.

Recent researches have shown that the seas in which the

FIG. 2.—A DEFORMED GRANITIC PEBBLE (G), WITH TWO QUARTZ VEINS (Q) IN THE SCHISTOSE CONGLOMERATE OF CESSON.



Brioverian sediments were deposited were already differentiated in Brittany. Three distinct contemporaneous facies can be distinguished in passing from north to south—facies which can be followed indefinitely toward the west and east—constituting the three massifs of Trégorrois, of St. Lô, and of the Basse-Loire.

The *massif of Trégorrois* is confined to the north of Brittany; it includes shales and quartzo-phyllasses, with interstratified eruptive rocks (porphyrites and diabases) and conglomerates. The whole group, however, is often replaced by alternations of micaceous and hornblende-schists.

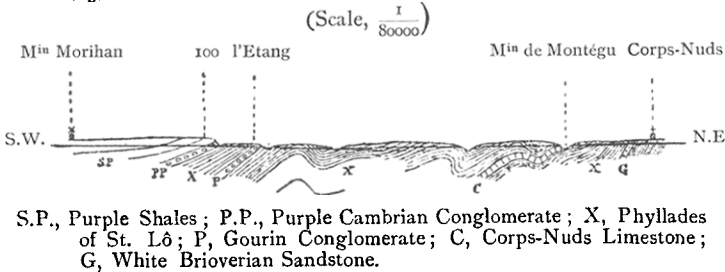
The *massif of St. Lô*, stretching from the Bay of Douarnenez, in Finistère, to St. Lô, in Normandy, exhibits the following divisions in the central area in descending order:

- |                    |   |  |   |                                      |
|--------------------|---|--|---|--------------------------------------|
| Brioverian System. | { | 3. Green flags of Néant ( $x^c$ ).                     | { | 5. Shales.                           |
|                    |   | 2. Shales and conglomerates of Gourin ( $x^b$ ) ... .. |   | 4. Conglomerate of Gourin.           |
|                    |   |  |   | 3. Shales and quartzo-phyllasses.    |
|                    |   |  |   | 2. Limestone of St. Thuriel.         |
|                    |   | 1. Shales of St. Lô and of Lamballe ( $x^a$ ) ... ..   |   | 1. Phyllasses.                       |
|                    |   |  |   | 2. Shales with seams of black chert. |
|                    |   |  |   | 1. Shales, phyllites and greywackes. |

The *massif of the Basse-Loire* presents a great development of argillaceous shales, with intercalated beds of coarse arkose, described under the name of the shales and arkoses of Bains.

These three types will be visited in succession during the course of the excursion; the central and most important massif is not well exposed in the neighbourhood of Rennes, but the section (Fig. 3), taken at a little distance from Rennes, gives a better idea of the various members of the series. The super-

FIG. 3.—SECTION FROM CORPS-NUDS TO THE MORIHAN MILL.



position of the conglomerates of Montfort, as indicated in this section, will be seen in the course of the excursion at Pont Réan, in the valley of the Vilaine (Fig. 4).

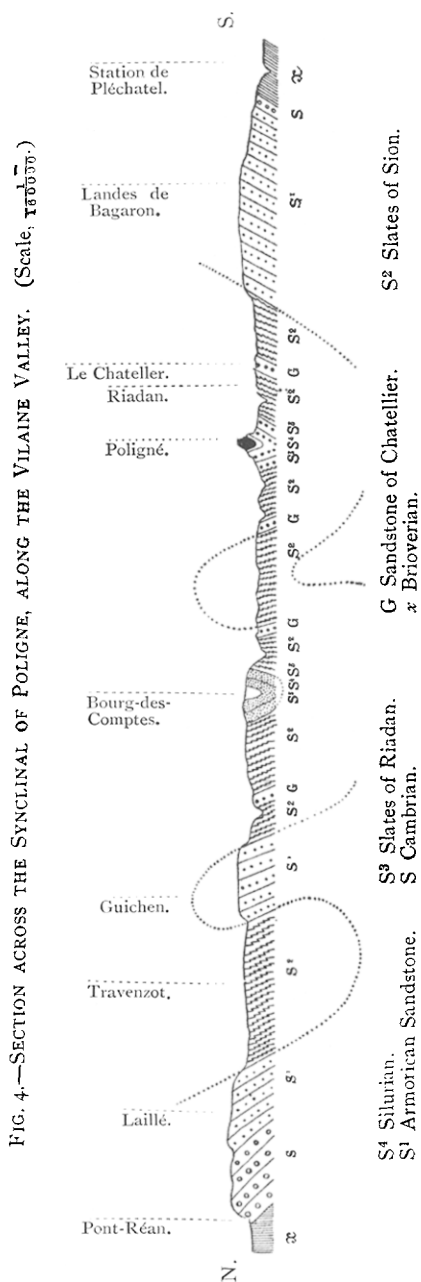
### Cambrian.

None of the Cambrian faunas, neither of *Olenellus*, *Paradoxides*, or *Olenus*, have yet been found in Brittany, and if any deposition of sediment took place at these epochs, they are represented by beds which are destitute of the characteristic fossils. The most ancient fauna hitherto recognised is that of the Armorican sandstone of Ordovician age.

In the absence of palæontological evidence the limits assigned to the Cambrian are necessarily very arbitrary. For a long time the Brioverian was included in it, but at the present day only the following unfossiliferous beds are referred to the Cambrian.

These beds exhibit remarkable local developments in the different massifs with great differences of thickness and of lithological composition. The following are the principal divisions that have been recognised, in descending order:

6. Green and purple shales, and sandstones with *Lingula crisi*.
5. Quartz porphyry of Pors-Even (lava flows).
4. Felstone of Arcouest, consisting of many successive outbursts.
3. Porphyrite of Kerity, with volcanic tuff.
2. Green and purple slates, nodular flagstones, dolomitic limestones and quartzites of Plouézec and Mayenne.
1. Conglomerate of Montfort and of Bréhec.



Both the volcanic rocks and the limestone bands, which occur in this series, are wanting in the Vilaine section (Fig. 4), where the clastic rocks attain their greatest development. We shall see their exposures in the Bréhec section (Fig. 5, Bay of St. Brieuc), but they have their greatest development to the east, in the Coëvrons and the Charnie, where they have been described by M. Éhlert.

### Ordovician.

In the central part of Brittany the Ordovician exhibits three principal divisions, which we will examine in order.

THE LOWER ORDOVICIAN consists of the well-known Armorican sandstone, a mass of white sandstone from 1,600 to 2,600 feet thick, which plays an important part in the orography of Brittany (Fig. 6), but is poor in fossils. It includes several distinct lithological subdivisions.

1. At the base are the *Conglomerates of Erquy*, which contain fragments of hard sedimentary and eruptive rocks derived from the subjacent Cambrian and Brioverian formations.

2. Above these come



felspathic sandstones, coarse-grained rocks without fossils, which will be seen in the neighbourhood of Bréhec. Southward, in the valley of the Vilaine, they are represented by very different sandstones or grits without felspar (grès du Grand-Gouin). These should correspond with the Tremadoc Beds.

3. The *Armorican sandstone* proper (or grès du Toulanguet) consists of sandstones in more distinct beds alternating with some shaly layers. This division is more fossiliferous, yielding *Scolites*, *Bilobites*, *Lingula*, *Dinobolus*, *Asaphus* and various Lamellibranchs (*Actinodonta*, *Ctenodonta*, *Redonia*). A study of the fauna shows more analogies with that of the Arenig than with that of the Tremadoc.

MIDDLE ORDOVICIAN. The stage of the "schistes d'Angers" presents a series of black slates, interrupted by occasional beds of sandstone, the thickness of which sometimes increases at the expense of the slates. The following subdivisions can be distinguished :

4. Bed of oolitic iron-stone.

4a. The Sion slates with *Synhomalonotus tristani*, *Asaphus guettardi*, *Calix murchisoni*. This is the zone of geminiform Didymograpti.

5. The *Chatellier* sandstone; the stratigraphical position of this can be easily determined at Chatellier,

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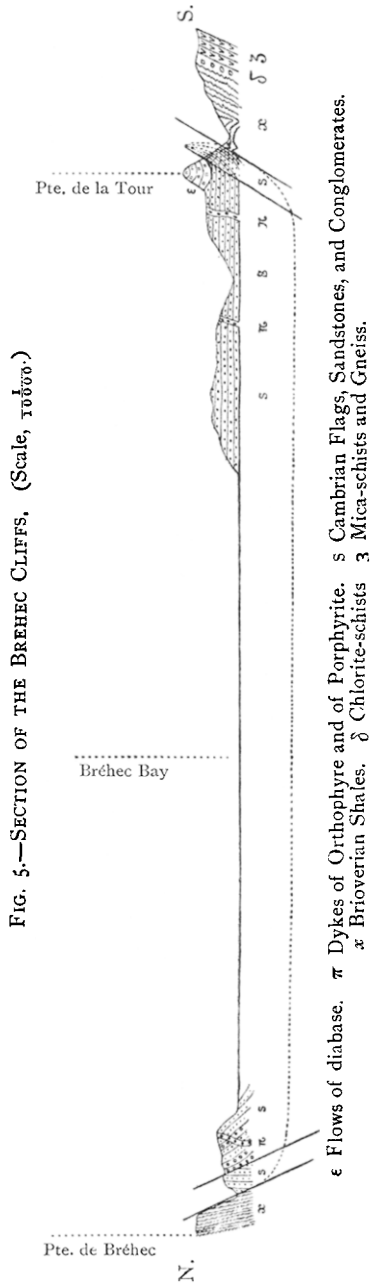
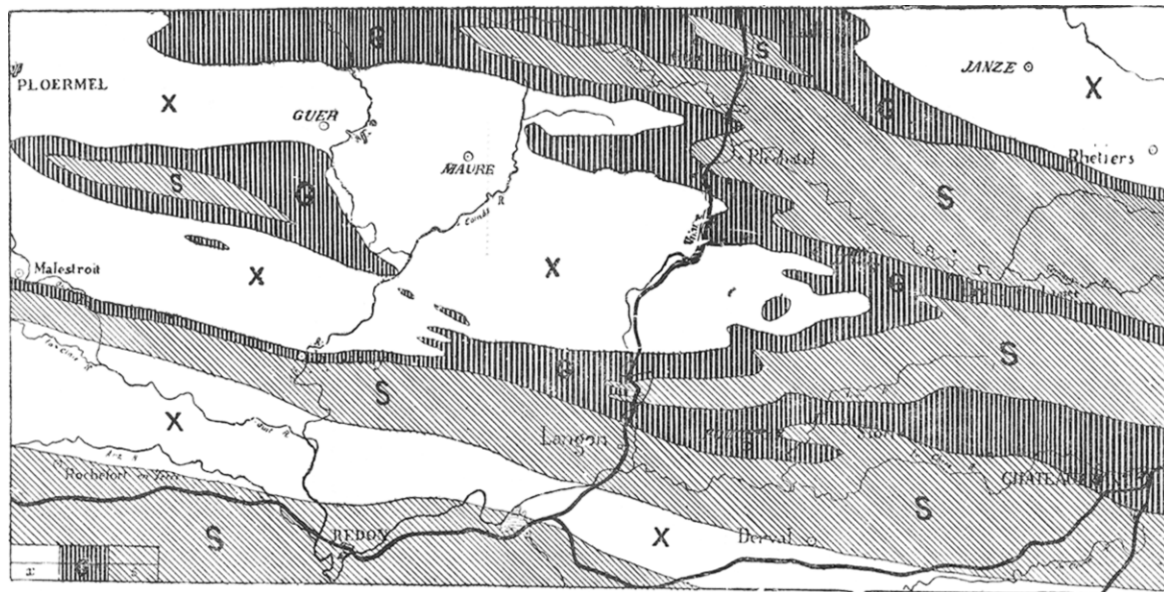


FIG. 5.—SECTION OF THE BREHEC CLIFFS. (Scale,  $\frac{1}{100,000}$ .)

ε Flows of diabase. π Dykes of Orthophyre and of Porphyrite. s Cambrian Flags, Sandstones, and Conglomerates. x Brioverian Shales. δ Chlorite-schists 3 Mica-schists and Gneiss.

FIG. 6.—MAP OF THE ARMORICAN SERIES IN THE VILAINE VALLEY. (Scale  $\frac{1}{500000}$ .)



- X. Brioverian.  
 G. Armorican Sandstone.  
 S. Ordovician and Silurian strata overlying the Armorican Sandstone.

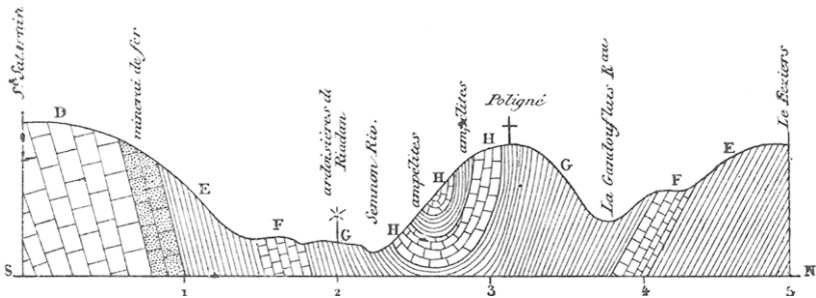
near Bourg-des-Comptes. M. Lebesconte has found fossils in it at Thourie.

6. The *Riadan slates* with *Trinucleus pongerardi*. These slates are not easily distinguished from those below when the sandstone is wanting.

Beds 4 and 4a correspond with the Llanvirn series. Beds 5 and 6 with the Llandeilo.

UPPER ORDOVICIAN (7). *Sandstones of St. Germain-sur-Ille*, of Redon (in part), of Ragunez and Kermeur, with *Acaste incerta*, *Synhomalonotus arago*, and *Trinuclei*; zone of Diplograptidæ. These sandstones alternate with slaty beds of greater or less

FIG. 7.—SECTION OF THE ORDOVICIAN BEDS AROUND POLIGNÉ, BY M. LEBESCONTE.



Ampelites, H, Grits of Bourg-des-Comptes; G, Slates of Riadan; F, Sandstones of Chatellier; E, Slates of Sion; D, Armorican Sandstone, Iron-stone.

(Block kindly lent by the Geological Society of France.)

thickness; they break up more easily than those below into sandy flags with characteristic parallel faces. They correspond to the Glenkiln Beds.

The Upper Ordovician in Finistere has been divided into two portions by M. Kerforne, the shales of Ragunez at the base and the Kermeur sandstone above, divisions which in the centre of Brittany are represented respectively by the red and green slates of St. Perreux and by the sandstone of Redon. It is succeeded directly at Redon and Bourg des Comptes (Fig. 4) by the sandstones and slates of the Upper Silurian, which differ but slightly in their lithological characters. Thus it is very difficult to determine the plane of separation between the Ordovician and Silurian systems in that part of Brittany which will be visited by the Association, but it is much more clearly marked in Finistere and in the Maine-et-Loire, where it is found to coincide with the horizon of the limestone of Rosan. The accompanying section

(Fig. 7) shows how the beds are exposed in the neighbourhood of Poligné.

8. *Limestone of Rosan*, with *Trinucleus*, *Orthis actoniae*, and *Triplisia spiriferoides*, fossils which lead us to regard it as the equivalent of the Caradoc. Interstratified with these calcareous rocks there are lava flows, fragmentary material, tuffs and other contemporaneous eruptive rocks. These are, moreover, limited to this horizon, of which they are characteristic in western Brittany.

### Silurian.

The Silurian of Brittany is easily distinguished as a whole from the slates and sandstones of the Ordovician, by its lithological characters. Coarse, clastic deposits, such as grits and conglomerates, become rare; contemporaneous eruptive rocks are absent, we find thin beds denoting a facies of deeper water, nodular *Orthoceras*-limestones, carbonaceous slates with Pteropods (*Hyolites*) and cherts with Graptolites. The formation thus exhibits that prevailing character of carbonaceous slate with nodular *Orthoceras*-limestones which it maintains throughout the whole of the great central-European area. The number of species, moreover, which it has in common with the Silurian (E.) of Bohemia and of England is greater than in the case of the Ordovician.

The following sub-divisions have been recognised in the Silurian of the valley of the Vilaine.

1. *Sandstone of Bourg-des-Comptes* and of Redon (in part). This is unfossiliferous, and has been confused with the Ordovician sandstone, from which it is hard to separate it when the Rosan limestone is absent. It is penetrated by a larger number of quartz-veins, it is less gritty, and includes thin layers of carbonaceous shale.

2. *Phtanites of Anjou*. Cherts in thin laminæ of a few centimetres thick, but attaining a total thickness of 65 feet. The rock is remarkable for the absence of quartz-grains and of other terrigenous débris, and consists essentially of organic and chemically-formed matter. It contains about 70 per cent. of silica in various states with 10 per cent. of carbon, both equally derived from the remains of contemporaneous organisms, such as Radiolaria with opaline tests and Graptolites with a chitinous polypary. Sections of Radiolaria are sometimes seen in the thin laminæ; the Graptolites are few in number, but are very well preserved; they include *Monograptus lobiferus*, *Diplograptus*, *Climacograptus*, *Cephalograptus*, *Rastrites*; a fauna characteristic of the Llandovery.

3. *Ampelites of Poligné*.—Fine slates, without fossils, containing intercalated beds of ampelitic (carbonaceous) slate with Graptolites.

Such is the zone of Poligné containing *Monograptus crassus*, Lapw., *M. priodon*, Bronn., *M. convolutus*, var. *spiralis*, *Diplograptus palmeus*, Barr. and *Cephalograptus folium*, His., and corresponding to the summit of the Tarannon Beds.

The carbonaceous schists of Menardais and Andouillé belong by their fauna to the Wenlock age—*Monograptus priodon*, *M. galaensis*, *M. riccartonensis*, *M. vomerinus*, *M. continens*, and *Retiolites geinitzianus*.

4. *Nodular slates with Cardiola interrupta*. These are poor in fossils but include some layers of spheroidal siliceo-calcareous nodules with *Orthoceras styloideum*, Barr., *O. subannulare*, Muenst., *Bolbozoe anomala*, Barr., *Cardiola interrupta*, Sow., *Mytilus esuriens*, Barr., *Panenka humilis*, Barr., *Vlasta insons*, Barr., *Pterinea mira*, Barr., and *Dualina secunda*, Barr., and many Graptolites of Wenlock species. It is a fauna of Orthoceratites, Graptolites and thin-shelled Lamellibranchs, and is remarkably deficient in Trilobites and Brachiopoda.

### Devonian.

The higher Devonian beds, which are thin and pelagic in character, occur only at a few places; the lower stages are thicker and consist of coarser-grained rocks.

1. *Shales and quartzites of Plougastel*, a thick mass of alternating beds, less fossiliferous than those above, and attaining their greatest development in the west of Brittany (=Gedinnien).

2. *Sandstone of Gahard*, a white sandstone with layers of iron-stone, containing *Orthis monieri*, *Spirifer pellico*, *Homalonotus*, and many Lamellibranchs (=Taunusien).

3. *Greywacke of Néhou*. Bluish gritty shales alternating with brown greywackes and lenticles of blue limestone; these beds form a continuous band from Brest to Laval. Fossils are abundant in the limestone lenticle of Bois-roux. The Néhou fauna includes: *Spirifer hystericus*, Schl., *Athyris undata*, Deffr., *Chonetes plebeia*, Schnur. (zone of *Spirifer hercyniæ*). The best localities described by M. Ehlert occur near Laval. The limestone lenticles which yield the fauna of Erbray (zone of *Sp. primævus*) are older than that of Bois-roux, and are better developed in the basin of Angers than in that of Laval or of Finistère.

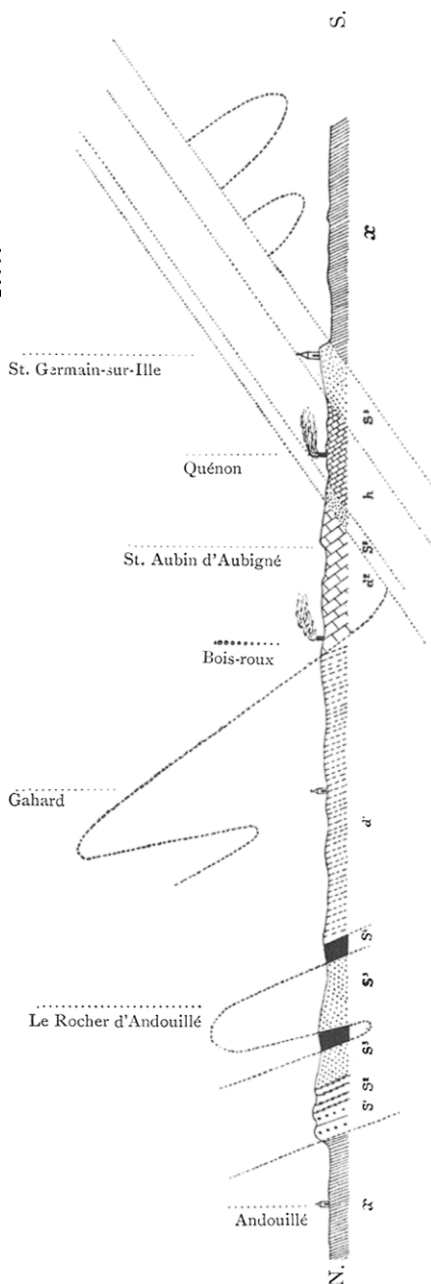
4. *Greywacke of Fret*, with *Phacops potieri*, Bayle, *Spirifer auriculatus*, Sandb., and *Sp. paradoxus*, Schl., is seen near St. Aubin d'Aubigné (zone of *Spirifer paradoxus*).

5. *Slates of Porsguen* with *Anarcestes subnautilus*, Schloth. *Bifida lepida*, Goldf. (=Eifelien).

6. *Slates of Traouliers* with *Rhynchonella pugnus*, Mart., *Receptaculites neptuni*, Deffr. (=Frasnien).

7. *Slates of Rostellec* with pyrito-siliceous nodules, yield

FIG. 8.—SECTION ACROSS THE SYNCLINAL OF ST. AUBIN D'AUBIGNE. (Scale, 4000 ft.)



h. Carboniferous Strata. d<sup>2</sup>. Greywacke of Faou. d<sup>1</sup> Gabard Sandstone. S<sup>4</sup>. Silurian. S<sup>3</sup>. Sandstone of St. Germain-sur-Ille. S<sup>2</sup>. Slates of Angers. S<sup>1</sup>. Armorican Sandstone. x. Brioverian.

*Parodiceras verneuili*, Muenst.,  
*Tornoceras simplex*, v. Buch.  
 (=Famennien)

The portion of Brittany which will be traversed by the Association is unfavourable for the detailed study of the Devonian. To those who may wish to make a more prolonged examination of this formation we should recommend the neighbourhood of Laval or of Brest.

### Carboniferous.

The oldest Carboniferous sediments in Brittany are deposits of eruptive material spread out on the old sea floor. The period is characterised in this region (studied by MM. E. and L. Bureau) by alternations of terrestrial and marine conditions, as well as by grand and powerful



The slates of Chateaulin are represented in the basin of Ancenis by greywacke with plant remains, corresponding to that of Thann (Culm).

3. *Mouzeil sandstone* with coal seams, comprising alternating beds of shale, sandstone, conglomerate and porphyritic tuff (pierre carrée). The conglomerates contain pebbles of quartz, gneiss, diabase, Silurian quartzite, Carboniferous chert, and greywacke. The flora is that of the greywacke of the Culm, *Bornia transitionis*, F. Roem; *Sigillaria minima*, A. Brg.; *Knorria imbricata*, Stern.; *Lepidodendron veltheimianum*, Ung.; *Archæopteris virleti*, Stur.; *Neuropteris antedens*, Stur.

4. *Shales of Teillé*, crowded with plant remains, and alternating with beds of conglomerate, containing pebbles of quartz and Carboniferous greywacke. Fossils: *Cordaïtes borassifolius*, Gein.; *Alethopteris serlii*, Goepp.; *Prepecopteris plumosa*, Grand Eury; *Sphenopteris furcata*, A. Brg.; *Asterophyllites longifolia*, A. Brg. A still higher horizon with *Dictyopteris subbrongniarti*, Grand Eury, has also been recognised by M. Bureau at Ecoulé. The conglomerates of this age at Quimper contain pebbles of granite and of various gneisses.

## II.—ERUPTIVE ROCKS.

As the route was not chosen with the special view of studying the contemporaneous volcanic rocks, the Association will not be able to see much of them during the excursion. We shall therefore confine ourselves to enumerating the principal eruptive episodes, without describing them in detail.

*Brioverian*: Diabases, epidiorites, porphyrites, and variolites of the Trégorrois.

*Cambrian*: 1. Pyroxene-porphyrite of Kerity; flows of porphyritic glass, tuffs, and agglomerates.

2. Orthophyres of Arcouest, comprising many successive outbursts, the veins of which cut and displace one another.

3. Quartz-porphyrity of Pors-Even; microgranulites; micropegmatites; sphærolitic petrosiliceous and rhyolitic porphyries

*Upper Ordovician*: 1. Quartz-porphyrities of the Basse-Loire.

2. Diabases and porphyrites with tuffs and ashes at Rosan.

*Lower Carboniferous*: 1. Quartz-porphyrities, porphyroids, and porphyritic tuffs. 2. Diabases, porphyrites, and porphyritic tuffs.

*Upper Carboniferous*: Dykes of diabase, so numerous that before denudation their lava-flows must have covered the whole country.

## III.—INTRUSIVE ROCKS.

In the number and variety of its granitic masses, in their diversity of structure and composition, in the great faults which have brought deep-seated portions to the surface, and lastly in the



depth to which the country has been eroded since the Carboniferous period, Brittany offers remarkable opportunities for the study of intrusive igneous rocks. The granites intruded at different epochs, ranging from the Archæan to the Carboniferous, do not always show the same relations to the surrounding strata, and a study of these relations throws light on the mechanism of their outbreak.

But while the relations of the granites to the Palæozoic sediments are similar to those of other countries, such as England and Norway, where Palæozoic rocks repose directly on the crystalline schists, we find in Brittany other facts and special conditions between the Cambrian and the Archæan, in a clastic formation more than four kilometres in thickness. In these deep-seated Brioverian sediments the Carboniferous granitic intrusions have here been subjected to very considerable pressure, due to the weight of the overlying sediments, and the modifications produced have consequently been more intense; it is in these beds that the phenomena of metamorphism and injection attain their greatest development.

Putting aside the general problem so ably discussed from such very different points of view by Michel Lévy and Brögger, we shall limit ourselves, in what follows, to the description of mere facts, which may be observed during the progress of the excursion.

(a) *The granite mass of St. Marcan and its granulitic aureole* (Fig. 10).

This mass is circular in form and occupies an area of about 50 sq. kil. It has forced its way into the Brioverian slates and greywackes which have been transformed near the contact into spotted and knotted schists, leptynolites, chiasolite slates, and micaceous greywackes. It is formed of a medium-grained, homogenous, massive rock of a bluish-grey colour, rich in white orthoclase, greenish oligoclase, microcline, and a black mica which is present in excess of white mica. The amount of white mica increases as the margin is approached, and at the margin the rock can no longer be distinguished from a muscovite granulite.\* Smaller masses, Mont Dol, Tombelaine, and Mont St. Michel, consisting of granulitic rocks, aplites, and pegmatites occur as satellites to the main mass in isolated knobs.

This fact of differentiation is better seen round the mass near Dingé, and, better still, round the granitic masses of Gueméné; it is general, but of unequal extent.

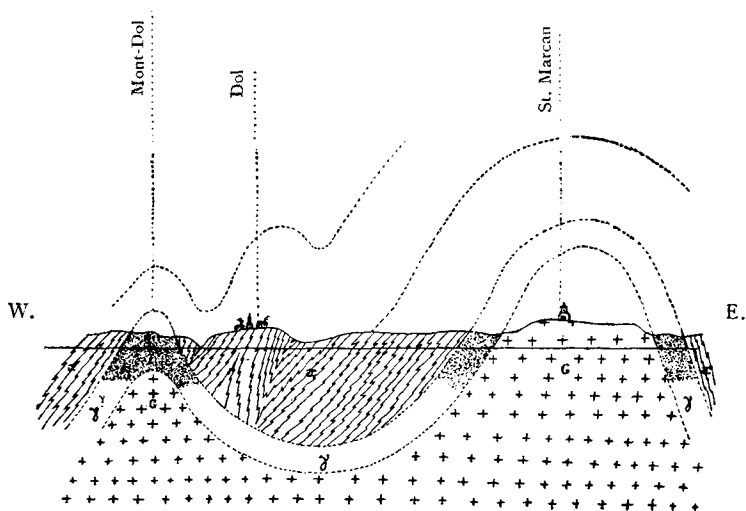
(b) *Granitic masses of the Morbihan.*—Many granitic masses occur in the Morbihan; they are so numerous and so like each other that no doubt can exist as to their genetic relations. Do these different masses represent, as in certain countries, successive

\* It must be remembered that French authors use the term "granulite" for muscovite granite, and even for a granite with two micas.—Ed.

intrusions, emitted from the same reservoir during a process of slow differentiation, or do they, rather, correspond to the different parts of one liquid mass, consolidated at different depths and at different times?

They differ more in the forms of their contours and in their modes of distribution than in their lithological characters. The different masses have many lithological features in common, and share a general tendency to arrange themselves, like beads on a string, in a series of elliptical areas, extending from north-west to south-east. These strings of granitic beads, so to speak, can be

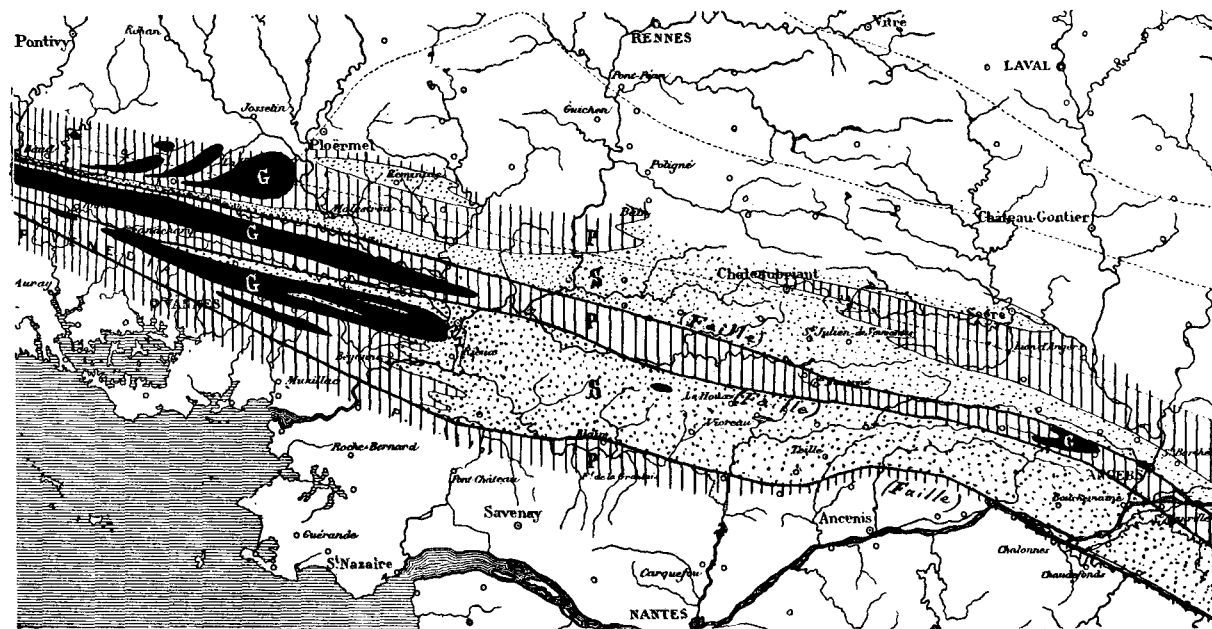
FIG. 10.—SECTION THROUGH THE GRANITIC MASS OF MONT-DOL.  
(Scale, 80000)



x Brioverian. γ Aplites and Granulites. G Granite.

followed for a distance of 300 kil. along the southern margin of Brittany. The direction of the moniliform lines corresponds to that of the folded Palæozoic rocks and to that of the principal tectonic features, such as faults and the crests of folds. But while in the N.W. of the district the granitic masses are exposed in the areas of pre-Cambrian gneisses and mica-schists, in the S.E. they occur also in the Silurian area. It is easier to study them in the Palæozoic districts rather than in the pre-Cambrian area; we shall therefore select the Palæozoic S.E. of Brittany for

FIG. 11.—SKETCH-MAP SHOWING THE EASTERN TERMINATION OF THE THREE GRANITIC MASSES OF SOUTHERN BRITTANY.  
(Scale, 1:200,000.)



P, Pre-Cambrian (Archæan and Brioverian), S, Silurian. G, Granite and Granulite. (The chief faults are traced on the map)

detailed description, and generalise the results so far as the western pre-Cambrian part of the country is concerned.

The field thus limited is represented on the map (Fig. 11), which shows the termination towards the E. of the following three parallel granitic zones :

1. Mass of St. Jean Brevelay.
2. Mass of Lanvaux.
3. Mass of Grandchamp.

The mass of St. Jean Brevelay is the most northerly. It extends, on our map, almost from Ploermel to Pontivy, with an area of about 200 sq. kil.

The mass of Lanvaux, situated to the S. of the one above referred to, and of greater importance, forms a vast ellipse more than 90 kil. in length. Moreover, it does not stop where last seen at the surface, for the granite which appears to the west of Angers, 80 kil. further to the east, may be regarded as an apophysis of the same deep-seated mass. The analogies in composition and structure of the granites of these two masses, the similarity of their action on the surrounding rocks, and lastly their occurrence in the centre of the same anticlinal, establishes this fact of their relationship.

The mass of Lanvaux must therefore be regarded as the longest in the district, for it extends, either at the surface or beneath it, from Lanvaux to Angers, a distance of 200 kil., and therefore from one end to the other of our map (Fig. 11).

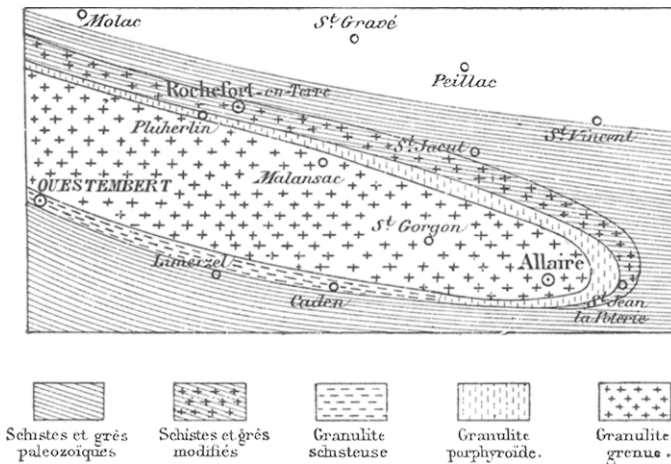
The mass of Grandchamp, situated to the south of the foregoing, extends from Pluvigner to Allaire, with an area of 300 sq. kil. It is shorter than that of Lanvaux, but, like it, reappears after an underground course of 40 kil. in the smaller mass of Nozay, which is lithologically identical with that of Grandchamp, and situated in the centre of the same Silurian synclinal. There are therefore the same reasons for referring the granite island of Nozay to that of Grandchamp as there are for correlating the granite of Angers with that of Lanvaux. The probability of their continuity underground is increased by the curious metamorphism of the Silurian sediments into crystalline schists in the intervening portion of the synclinal as indicated on the State Survey map of St. Nazaire.

The continuity underground of the elliptical masses above referred to is proved both by the similarity in their lithological characters and by their mode of occurrence. It is more difficult, and at the same time more interesting, to ascertain the relations of the three zones to each other. Some light may be thrown on the matter by comparing them with reference to the mode of occurrence of the granite, the age and nature of the metamorphism of the beds traversed, and the structure and composition of the intrusive rocks. But before proceeding to institute this com-

parison it will be necessary to study the three masses in greater detail.

1. *Mass of St. Jean Brevelay.* This mass is formed of a coarse-grained granulite with two micas. Aplitic, fibro-schistose and gneissose varieties may sometimes be observed on its margins. It is situated in an anticlinal band in Brioverian slates, which must belong to the upper part of the formation, because the purple Cambrian slates are regularly exposed on both sides.

FIG. 12.—MAP OF THE EASTERN EXTREMITY OF THE GRANDCHAMP MASSIF. (Scale  $\frac{1}{320000}$ )



A description of this mass has already appeared to which reference may be made (*Ann. Soc. Geol. du Nord*, t. xv., 1887, p. 16).

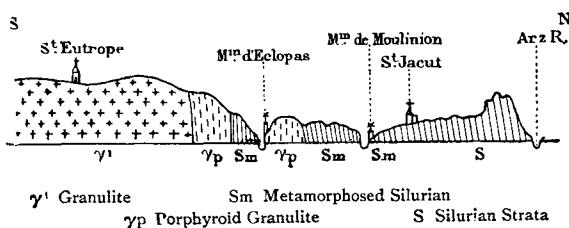
2. *Mass of Grandchamp.* This mass is allied to the former in composition and most of its other characters, but it traverses all the formations of the district from the pre-Cambrian gneiss to the anthracitic slates of the Upper Silurian. The beds are intensely altered with the development of the ordinary contact-silicates, such as black mica, andalusite, fuchsite, garnet and pyroxene. Felspar has not been produced in this outer aureole.

In the centre of the mass the granite is a coarse-grained, massive rock, rich in white mica and containing quartz grains which are generally terminated (granulite, French). Near its margins this rock becomes porphyroid and presents some important endomorphic modifications. On its southern border it becomes foliated, the mica and other constituents being orientated parallel to the foliation. On the northern side the change is somewhat different (Fig. 13); there the black mica becomes more abundant,

the constituents increase in size and the microcline occurs in large Carlsbad twins, four or five cms. across, giving to the rock a porphyritic character. The constituents are not distributed irregularly, for even small exposures show that the porphyritic crystals of microcline are arranged along undulating lines or zones. Aplite sometimes forms local margins (Tertre Windmill), but more frequently occurs as narrow veins.

From the differentiation of the magma and from the orientation of the elements of first consolidation along pseudo-fluidal lines, near the margin, we must conclude that the consolidation was progressive; and that, commencing near the margin in a still moving mass, it proceeded towards the interior across a magma at rest. The foliated granulites on the southern border possess a secondary schistosity, due to orogenesis, superimposed upon a

FIG. 13.—SECTION FROM ST. EUTROPE TO ST. JACUT,  
(Scale  $\frac{1}{80000}$ )



primary phenomenon of fluidity due to the conditions under which the magma consolidated.

In the mass of Grandchamp the modifications of the granite at the contact are not due to interchange of material between the eruptive magma and the surrounding rock; but only to the conditions of consolidation which determined the orientation of the constituents of the granite, their mode of grouping, and the order of crystallisation. The enclosing rocks acted differently as regards the conduction of heat and the transmission of pressure, but they exerted no chemical influence on the eruptive magma. This conclusion, however, is only applicable to this mass and to the one previously described. It does not apply to the mass of Lanvaux.

The neighbouring small circular islets of granulite do not show modifications comparable to those above described. They may be regarded as the apophyses of more important masses existing below.

3. *The granite mass of Lanvaux* forms an elongated area, parallel to the former, but differing in composition and structure. It is usually foliated, and presents many varieties. Massive

granite, rich in biotite, is worked for paving-stones in the eastern portion of the area, near Bains, but the rest of the mass is gneissose, and the dominant black mica is usually present as débris; it is made up of alternating, more or less micaceous bands which possess granular or euristic, gneissose and glandular structures.

The granite of Lanvaux, unlike that of Grandchamp, does not appear in contact with beds so high in the series as Upper Silurian; it is limited to the area of the Brioverian rocks, which form a long, elliptical anticline separating the parallel synclinal troughs of Redon and Malestroit.

The greyish slates alternating with beds of darker slate, greenish grey greywackes, and beds of a white foliated arkose, are exposed from one end to the other of the "Landes de Lanvaux," in the valleys of the Claye and of the Arz. The beds of arkose, near the granite, are remarkable for the development of thick sericitic membranes, which give them a gneissose aspect and surround large grains of quartz (1-2 mms.), sometimes doubly terminated, fragments of orthoclase and oligoclase, and also fragments of black mica. As the granite is approached the slates become nodular, and small plates of black mica and muscovite are developed; moreover, the feldspars of the granite pass out into the contact-rocks and transform them into feldspathic schists containing a little mica. The quartz in these schists is often arranged in continuous ribbons.

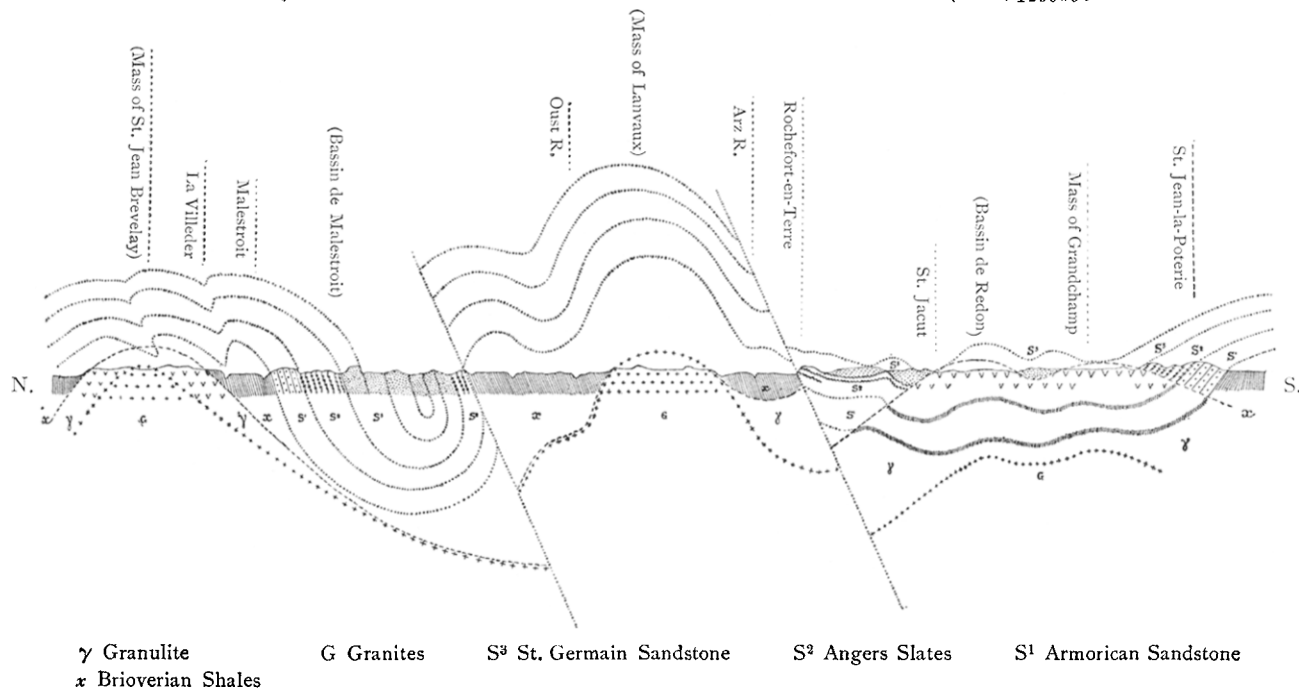
The parallel structure of the granite-mass is in part due to interstratified bands of a greenish grey, somewhat micaceous schist. Repeated alternations of more or less granular, gneissose and schistose bands point to the conclusion that there has been an injection of granitic sills between beds of schist, and do not support the view that the phyllitic and schistose bands have been formed by the dynamic metamorphism of the massive granite.

*Comparison of the Three Granite Masses of the Morbihan.—*

If, on consulting the map (Fig. 11), a comparison be made of the three masses above described, it will be seen that the Lanvaux-mass is enclosed in the deep Brioverian beds, far away from the lines delineating the Silurian series.

The Grandchamp mass traverses Silurian rocks, while that of St. Jean Brevelay is in the neighbourhood of another band of the same age; the map, therefore, shows that the Lanvaux-mass is enclosed in beds older than those surrounding the two others.

If, moreover, we make a section (Fig. 14) across the map it will be seen that the Lanvaux-mass has not reached the general level, but that the block has been brought up by two faults, which have been traced upon the ground. If we recall the ideas already acquired on the distribution of the sedimentary rocks of the district, we are compelled to admit that before its abrasion by atmospheric denudation the rocks forming this anticlinal block

FIG. 14.—SECTION ACROSS THE THREE GRANITIC MASSES OF MORBIHAN. (Scale,  $\frac{1}{120000}$ .)



were covered by the whole thickness of the Silurian rocks now only to be seen in the neighbouring synclinals.

These facts show, beyond all question, that the granite of the masses of Grandchamp and of St. Jean Brevelay were consolidated under almost the same conditions of depth, and those of Lanvaux under different conditions and at greater depths, so it is to these differences of depths, shown in the sections, that the differences of composition and of structure between the granite masses, described above, precisely correspond. There is, therefore, a reason, *founded upon observation alone*, for believing that the differences of composition and of metamorphic action in these granites are to be attributed to the depths at which the consolidation of the various masses took place.

It may be objected that these differences may be due to other causes. Thus it is possible to suppose that the various masses are not contemporaneous, or that they belong to two successive intrusions of a magna undergoing evolution at a great depth. But on comparing the two hypotheses it will be seen that ours has the decided advantage of *resting upon material facts*; although it may not eliminate other objections. No observation actually supports the idea that the three masses described could have been formed by successive eruptions; we find neither débris nor constituents of a first consolidation, mingled with the minerals of more recent formation, nor rolled pebbles of these granites in the various members of the sedimentary formations. Other masses in Brittany have furnished examples of these facts; their absence in the district under consideration is but further proof of the synchronism of these three masses.

The characters of the granite and the extent of its metamorphic phenomena vary with the thickness of the covering cap and consequently with the pressure under which the mass consolidated; they are also in relation with the nature and abundance of the mineralising agents which accompanied the magma. The stratigraphy of the Morbihan masses furnishes an example of this by giving an explanation of the difference of the intensity and extent of the *felspathisation* in neighbouring masses, sometimes separated in the field by scarcely a mile.

Thus it is proved that in the masses which consolidated at lesser depths, such as that of Grandchamp, the separation between the Silurian and the granite is sharply defined, the sediments are not felspathised, but transformed into crystalline rocks with mica and andalusite without feldspar, as is the case in Norway and in the Vosges.

In the Lanvaux-mass, on the contrary, at the contact with the granite, a persistent zone in which schists and greywackes become charged with feldspar, possibly by absorption or by injection, may be observed. All the stages of this felspathisation may be followed, and almost imperceptible passages between the felspathic

schists and the granite itself may be observed; until, in the presence of certain beds, it becomes a matter for discussion whether they are granites, mechanically crushed and deformed, or feldspathic schists. Veritable gneisses are thus produced, in the midst of which we find, here and there, more massive granites or fragments of schists representing extreme stages of alteration. The extent of the feldspathisation and the thickness of the gneissification are therefore functions of the depth of the contact observed, and permit, so to speak, of its measurement.

It becomes reasonable, therefore, to suppose that at greater depths the contacts between impregnated sediments and granite would present less and less difference; and we are thus led to believe with M. Michel Lévy that there exists a deep zone where there is complete continuity between the normal granite and the gneissic border formed under the influence of the granite at the expense of the earlier sedimentary rocks.

But whatever may be thought of this conclusion, the stratigraphical examination of the granite-masses of the Morbihan furnishes material facts which all theories must take into consideration. Stratigraphical observation negatives the view that the granite has been an intrusive plastic mass, elevating, displacing and dislocating the superincumbent sedimentary rocks at the time of its eruption. The great tectonic lines of Brittany and the general plan of structure have not been disturbed by the eruption of the granite; the long bands of colour on the geological map, the folds and faults which affect the normal sedimentary masses of the east of Brittany, continue uninterruptedly in the west, into the granitic portions of the country, without disclosing any connection between the presence of the granite and special dislocations or more complex structures which do not exist in this district. The stratigraphical order of the sedimentary blocks within the granitic areas prevents their being considered as scattered fragments floating on the surface of a granitic bath; for the sequence is normal and the included masses lie along the same lines of strike as those of the surrounding strata from which they have been derived. The sections traced across the folded and faulted sedimentary series of Brittany may be drawn continuously, in the portions replaced by the granite masses, in the same way that they may be traced in the field over those portions removed by atmospheric denudation.

The construction of geological profiles across the country does not enable us to distinguish the forms in space of the various granitic masses, but it clearly brings out the fact that the existing surface gives us sections in plan, of masses which consolidated at different depths. These sections show that the phenomena of contact-metamorphism, of injection, of assimilation and, consequently, the composition and structure of the granites them-

selves, are variable in one and the same district and round the same centre; and, further, that these variations are a function of the distance of the section in question from the upper limit reached by the magma during its ascension.

*Granites of the Côtes du Nord.*—In the Côtes du Nord there is evidence of the formation of granite at several successive periods. The first, of Lower Brioverian age, is represented by pebbles in the Brioverian conglomerates; the second is found as intrusive masses in the Brioverian rocks and also as pebbles in Cambrian strata; the third shows masses which cut the Silurian series and are of Carboniferous age. These different occurrences may best be studied in inverse order.

*The Mass of Quintin.*—This vast elliptical mass, 50 kil. in length, is composed, on its southern margin, of massive granite with biotite and on its northern margin, of foliated granite with two micas, passing into granulitic gneiss. These differences of structure are, as in the Morbihan, in direct relation to the depth of the enclosing rocks, massive granite being found in contact with the Carboniferous series and the gneissose granite with the Brioverian. Here, however, we may suppose, and there are even arguments for believing, that the differences should be attributed to the action of two successive eruptions.

This mass of granite is instructive in other ways; it not only furnishes information as to the difference both of kind and degree of metamorphism on its different faces, but also as to the unequal resistance to assimilation of the various sediments presented to it. An example of this is to be found in the neighbourhood of Plédran at the contact of the gneissose granites (gneiss granulitiques) and the Brioverian shales. These rocks, east of Plédran, present the usual characters of the St. Lô formation—argillaceous shales with intercalated beds of greywacke and a few beds of hornblendic rocks and graphitic phanites.

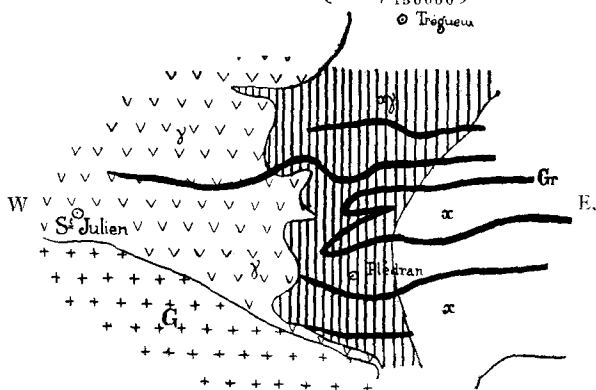
On approaching the granite mass of Quintin, from the east towards the west, the gradual alteration of the sedimentary rocks may be observed; the metamorphism of the argillaceous rocks is seen to take place more readily than that of the graphitic phanites.

The shales pass successively into spotted schists; into micaceous schists, rich in biotite, etc., with a few macliferous and sillimanitic patches; then into feldspathic schists, and finally into granulitic gneisses; the passage is very gradual between the different rocks. The gneisses contain all the constituents of the granulites, associated with the remains of the schists in the condition of continuous tissues enriched with streaks of black mica and with patches of sillimanite. The tissues give to the granulitic rock an interlaced structure, in which the wavy micaceous films separate the lenticular amygdules of massive granulite with black mica.

The beds of graphitic phtanite are far less affected by metamorphic action than are the beds in which they occur ; and they may be followed in the field, as shown upon the accompanying map (Fig. 15), which illustrates the fact that definite beds of phtanite occur successively between schists, mica-schists, and granulitic gneisses as they approach the granite ; the phtanite may be traced into a massive quartzite as the schists pass into gneiss.

Some geologists would prefer to consider these granulitic gneisses as crushed granite rather than as schists injected with granite, but the question appears to be of minor importance in view of the proved persistence of the bed of phtanite, neither

FIG. 15.—MAP SHOWING THE CONTACT OF GRANITE NEAR PLÉDRAN. (Scale, 1:50,000.)



G Granite.  $\gamma$  Granulitic Gneiss of Brioverian Age.  
 xy Micaceous Brioverian Schists. Gr Graphitic  
 Phtanite of the Brioverian.  $\alpha$  Brioverian Shales and  
 Greywackes.

disturbed nor dislocated, into the granitised mass. The granitic magma has taken the place of the schist, but not that of the quartzite.

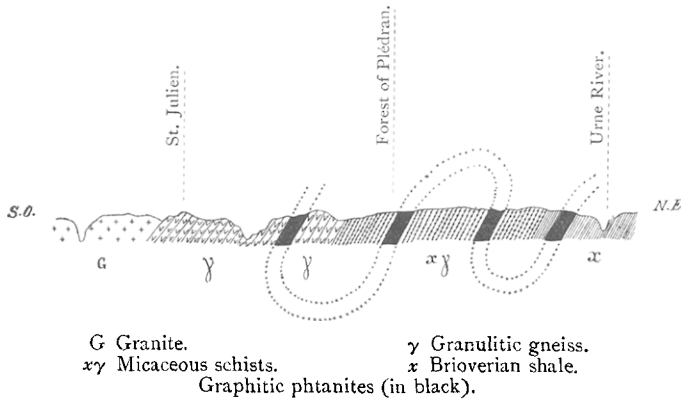
The graphitic quartzite is the actual bed from which M. Cayeux described the Radiolaria (*Cenosphaera*) obtained near Lamballe, 18 kil. distant. The age of the quartzite is as clearly established as its sedimentary origin, since it forms a well determined horizon in the Brioverian series, and is found as pebbles at the base of the Cambrian. Its great development in the Plédran district is accidental, and due to a folding, which brings the same bed to the surface several times, as shown in the section. (Fig. 16.)

2. *The granitic mass of St. Briec.*—The granite of St. Briec differs from those above described in structure, mode of occur-

rence, and age. It is more basic, containing amphibole, and occasionally passes into diorite. It is older than the others, for it occurs as pebbles at the base of the Cambrian, whilst those described above cut Silurian strata, and are of Carboniferous age.

This granite is dioritic, sometimes massive and sometimes gneissose, unequally rich in amphibole, with titaniferous iron, apatite, zoned feldspars passing from andesine to basic labradorite,

FIG. 16.—SECTION SHOWING THE FOLDING OF THE GRAPHITIC BEDS AROUND PLEDRAN, AND THEIR METAMORPHISM. (Scale, 1:50,000).



orthoclase rare, pyroxene rare, and quartz. It passes in its massive varieties from the hornblende-granite of St. Brieuc into the diorite of St. Quay. In the thin veins of the periphery of the mass it shows pegmatitic varieties, with crystals of amphibole 5 cm. in length, besides other varieties passing into microgranites.

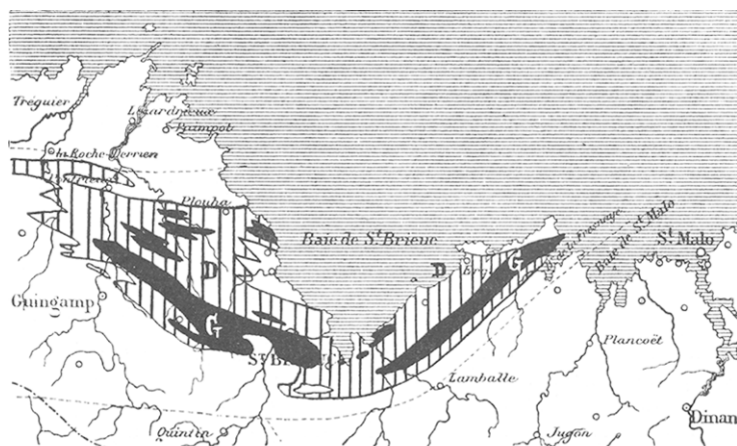
The St. Brieuc granite is only seen in contact with Brioverian rocks; it presents endomorphic and exomorphic modifications as extensive of their kind as those of the Morbihan mass. But the modifications are no longer of the same type. The Brioverian strata here are not composed of slates and greywackes as in the Morbihan (facies of the phyllades of St. Lô), but of alternating beds of clay slates, graphitic phthanites, and basic flows (more or less abundant) of porphyrites and diabases (facies of Trégorrois); it has become a complex formation composed principally of green schists with actinolite, epidote and chlorite, alternating with compact green hornstones (*schistes pyroxeniques*) and foliated gabbros resulting from the transformation of massive basic rocks, together with micaceous schists, staurolite schists, leptynites, micaceous greywackes, and felspathic conglomerates.

Its appearance under this very basic facies is limited to a bow-shaped band which corresponds, in the district we are considering, to the Bay of St. Brieuc, as shown in the map (Fig. 17).

The map also shows the distribution of the pre Cambrian hornblendic granite, and one sees that it is confined to the area occupied by the preceding basic series, which it follows closely.

It is believed that, in this coincidence, a relation of cause and effect may be observed, and that the composition—unique in Brittany—of this mass of dioritic granite, is due to the influence

FIG. 17.—SKETCH-MAP SHOWING THE DISTRIBUTION OF THE PRE-CAMBRIAN HORNBLENDIC GRANITE AND ITS TOPOGRAPHICAL RELATIONS WITH THE BASIC FACIES OF THE BRIOVERIAN STRATA. (Scale, 1:500,000.)



D Basic Facies of the Brioverian Series. G Hornblendic Granite.

of the Brioverian eruptive basic rocks, also unique, into the midst of which the granite is intruded. We drew attention in 1889, in the Puy-de-Dôme\*, to the analogy which exists between these facts and those there pointed out by M. Michel Lévy; impressed by the constant association in that district of calcareous hornstones and diabase-diorites, and by the occurrence of an aureole of hornblendic granite between the latter and the normal granite, he concluded that the various rocks resulted from the endomorphism of the granite, its composition having been considerably changed by the assimilation of calcareous beds. In Brittany, in the neighbourhood of Pontrioux and of Andel, on ascending the Trioux river, or in descending the valley of the Gouessan, one

\* *Bull. Soc. Geol. France*, t. xviii, p. 917, 1896.

may follow the passage of microlitic rocks, porphyrites and diabases, into hornblendic schists and epidiorites.

In the hornblende-schists of both valleys, on approaching the granite, grains of felspar are developed, which gradually transform the rocks into a hornblendic gneiss, a gneissose diorite, and finally into a massive dioritic granite with amphibole and biotite.

These massive crystalline rocks are well developed in the Bay of St. Briec; they present exceptionally ultra-basic types, such as norites, hornblendites, and even peridotites with hornblende, analogous with those recognised by M. Lacroix at Pallet in the Loire-Inférieure.

Numerous sections prove that the schistose hornblendic hornstones, and other associated Brioverian rocks, are disrupted by the diorite and intimately mixed with it in the form of a breccia with its angular elements in alignment; occasionally the injection occurs in slender, transverse veins, or more often following the lines of foliation, which at the same time are penetrated in all directions and in all proportions by the dioritic magma (see the survey map *Bande de Coëtmeux*).

#### IV.—GENERAL STRUCTURE OF THE DISTRICT.

The surface of Brittany consists of sedimentary and eruptive rocks of Palæozoic age; the beds are much disturbed, and their outcrops form long, narrow bands, which are seen following the strike across the whole country in a west to east direction.

These great tectonic lines were determined by an important folding movement of Carboniferous age; but their formation had been prepared beforehand during a long series of geological epochs. This is proved by the coincidence of these lines with the former basins of deposit, with the difference of facies, the transgressions of the strata, and with the alignment of the successive intrusions of the deep-seated magmatic masses.

The fundamental structure of Brittany is to be assigned to the Carboniferous period. But the ruins only now remain; the relics of the ruined structure appear to us eroded by the secular action of atmospheric denudation. All the anticlinal arches have been swept away by the irresistible action of time. The synclinal depressions alone remain for our investigation—silent witnesses of the great power of the mechanical deformation which folded, strained, and fractured the rocks of the district.

The synclinal troughs, twenty-four of which are traced on the detailed map of Brittany, no longer preserve the simple symmetrical V-shaped form; they are reduced to deep and narrow unsymmetrical depressions, into which the beds slowly descended at the time when the crust was contracting. The

beds thus buried and preserved in these depressions are, as a rule, specially broken and crushed on their borders, where the greater faults of the country are found; in the centre of the synclines the beds show a uniform dip, and are, moreover, traversed by subordinate faults, which break up the land into a series of parallel inclined "blocks" or lamellæ.

The analysis of all the earth movements, of which traces have been preserved in Brittany, shows that they are related to one and the same continuous lateral pressure. This pressure acted in the same direction during the whole of the Palæozoic period on a zone of the earth's crust which was slowly subsiding.

For REFERENCES to the LITERATURE see *Bull. Geol. Soc. France*, ser. 3, t. xiv, 1886, and *Ann. Soc. Geol. du Nord*, vol. i to xxvii, Lille.

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