Chapter 4 The petrology of the Mona Complex

Introductory

The petrological descriptions of the rocks will be arranged in the groups mentioned on p. 38, the contents of each group, sedimentary, volcanic, and the like, being described under the group-heading. But the descriptions of metamorphic state cannot often be divorced from those of original material, as in many cases the rocks are only known in that state, which is therefore diagnostic. The rocks known are: Quartzites, black quartzites, grits of several types, and conglomerates, with slates and phyllites. These give rise to quartzite-schist, grit-schists of several kinds, and a variety of mica-schists, ranging from slightly altered chlorite-sericite-schist to highly crystalline muscovite-schist, and a muscovite-schist with green biotite. With these are limestones, dolomites, and manganous-dolomites, some of which pass into highly crystalline mica-cipolini, and associated with them are graphitic phyllite and graphite-schist. There are spilitic lavas, albite-diabases, keratophyres, and felsites; with spilitic tuffs, rhyolitic tuffs, and mixed tuffs; and important ashy grits. The basic rocks give rise to a suite of chlorite-epidote and chlorite-actinolite-schists. Jaspers and jaspery phyllites occur with the spilites, and pass into hsematitic schists in places. Green hornblende-schist and glaucophane-schist are developed on a large scale. There are serpentines, gabbros, and pyroxenites, with which occur talc-schist, tremolite-schist, tremolite-marble, ophicalcite, and epidositic hornfels. There are granites of several types, with four or five types of hornfels. Finally, there are hornblende gneisses, biotite gneisses, sillimanite gneisses, forsterite limestones, and granitoid gneisses.

The Holyhead Quartzite

This rock is perhaps the most conspicuous in Anglesey, for the summit of Holyhead Mountain is composed of it. The characters that strike the eye at once are its whiteness, its uniformity, and the extraordinary massiveness of its bedding. It hardly ever shows a blue core, and even appears, indeed, to become whiter the more deeply it is quarried. Over most of the hill no bedding can be made out at all, but it is occasionally visible on the great sea-cliffs of Gigorth and Rhoscolyn, and at one or two places there are thin beds of mica-schist. The whole mass (except along the foot of the southern escarpment) is traversed by a nearly vertical foliation (Plate 16), which is as conspicuous as the bedding is obscure.

The clastic character of the rock can be seen by the naked eye on any hand specimen, and it is, for a quartzite, rather coarse, grains one-sixteenth of an inch in diameter being quite plentiful, though the great majority are smaller. The large ones are well rounded, the small ones usually sub-angular. Felspar is rare. The schistosity is determined by well-defined, though impersistent, films of white mica, along which the rock splits readily, though a cross fracture is also easy to obtain. These films are about a quarter of an inch apart, and between them the grains of quartz are often quite undeformed. The rock is, however, typically blastopsammitic, the matrix having been completely reconstructed as a granoblastic schist, with whose elements the clastic grains interlock, their original smooth outline being visible in ordinary light. Internally, their integrity is not much disturbed, and yet the edges of the foliation-micas often penetrate the quartz of a grain that is still a unit optically. Anhedral iron-ores, tourmaline, and zircon are not uncommon. Quartz-veining is abundant. Along the foot of the southern escarpment foliation disappears, and the quartzite is quite massive. This massive rock, especially the finer parts of it, is the only portion that resembles the Gwna quartzites. It is, however, blastopsammitic like the foliated variety, but the clastic grains are closely packed, and there is very little matrix. _Hence the massive structure, for in the ordinary quartzite it is the matrix alone that is really foliated. In the massive zone, south-west of Twr, the Quartzite is for a short distance pebbly, with fragments a third of an inch in length. Most of these are venous quartz, but there are some of scarlet Gwna jasper, and some from old granoblastic rocks and mica-schists.

The following analyses, by T. Blair, of Sheffield, were kindly furnished by the manager of the Holyhead Silica Works.

	I.	II.	III.
SiO_2	96.00	94.25	Less than 87.00
Al_2O_3	1.98	2.24	—
Fe_2O_3	.42	.56	—
CaO	.38	.67	—

MgO	.30	.97	—
K_2O+Na_2O	.42	(not stated)	—
Loss on ignition	.50	.65	—
	100.00	99.34	—
Spec. Grav	2.656	—	2.653

All are from the Breakwater quarries. No. I is the most siliceous variety found there, but the massive rock of the southern escarpment (E10127) [SH 220 832] must be still more siliceous. No. III is an unusually micaceous variety. No. II is the ordinary quartzite, such as (E10126) [SH 226 834]. The specific gravities are given by Mallet, and are not from the same specimens.

The South Stack Series

The South Stack Series proper

This great series of rocks, which, from its wonderful folding and metamorphism, laid bare in the lofty sea-cliffs, presents some of the most striking geological sections in Great Britain, consists essentially of grits with partings of mica-schist.

These partings were once evidently felspathic shales, so that this group and the Holyhead Quartzite are the only major subdivisions of the Mona Complex that are composed entirely of mechanical sediment. It falls into two main subdivisions, a *Llwyn* (pronounced 'Hloo-yn') Group (named from the Llwyn-y-berth promontory), that has lithological affinities to the New Harbour Beds, and a South Stack Moor (or briefly '*Stack Moor*', from the moor that extends from the South Stack sea-cliffs eastward for a mile) Group with affinities to the Quartzite. The difference is chiefly in the grits. Throughout both divisions these weather white, but in the Stack Moor part they are very massive, usually 10, and sometimes 30 feet in thickness, so that in shallow inland sections they may easily be mistaken for the Quartzite, while in the Llwyn part they are much thinner, usually about a foot, so that the general aspect here is banded or flaggy, not unlike that of the English Lias. In spite of the affinities just remarked; there is no difficulty in separating the series from the New Harbour Beds on the one hand and the Quartzite on the other. In the adjacent part of the New Harbour Beds the gritty matter is disseminated, and the whole rock is 'thin-seamed' or even laminated; but the moment we pass into the South Stack Series the grits become sharply individualised, weathering white, a foot or so in thickness, and the alternating type is quite pronounced. The massive Stack Moor. Beds, on the other hand, however white and quartzite-like they may be externally, are much more felspathic, and (unlike the Quartzite) pale blue internally, while they never fail to show bedding as soon as a deeper section is obtained. The thinner grits of the Llwyn portion, though often weathering as white as a quartzite, are also always green or blue in a fresh fracture. For so thick a succession of grits they are on the whole rather fine. The massive Stack Moor Beds have about the same texture as the Quartzite, but the Llwyn Grits are really very fine, even their larger grains, which have survived the metamorphism, being quite small. In both divisions, however, there are a few coarse beds, in which grains of as much as three-sixteenths of an inch may be found.

Throughout the deposition of the series a gradual change in the conditions of deposit was going on, from the hypopelitic New Harbour Beds, to the purely psammitic conditions of the Quartzite.

Besides quartz, felspars and white micas are frequent as original constituents, but only the massive upper beds could be called felspathic. The felspar is albite, with a good deal of albite-oligoclase, and a little microperthite. Zircon, tourmaline, rutile, and iron-ores are generally present as accessories. The coarse beds contain a good many composite fragments, most of which are fine grits, often schistose, with a foliation independent, in some cases, of that of the enclosing grit. One or two granitoid rocks have been seen. Some scarlet fragments can be identified with confidence as from the Gwna jaspers. Snell clastic grains as retain their original outlines are, in many cases, not very well rounded, but these are usually the larger ones. Blue opalescent quartz is abundant in one of the coarser grits on the South Stack. One fragment of mica-schist (E10131) [SH 217 805] contains a crystal of tourmaline. There is another of true muscovite-biotite gneiss (E10135) [SH 224 806], and good-sized plates of white mica, that are evidently from the same gneisses, are quite abundant in some beds.

Metamorphism

In spite of the beautiful preservation of their bedding, all these rocks are in reality holocrystalline schists.

The coarser grits are now blastopsammitic, but the finer grits, as well as the matrix of the coarser ones, have been completely re-constructed and are purely granoblastic. A foliation is imparted by thin straight flakes of muscovite and of a green mineral (p. 47), which, except in the more massive beds, are to be found, sparingly, all through the rock, becoming the dominant minerals along the films of parting. Their ends often penetrate the clear quartz of the clastic grains, which nevertheless retains its optical integrity. The green mineral is a biotite, the same as that of the New Harbour Schists. Its optical characters are given on p. 47. Thin plates of muscovite are intergrown with it.

The same two minerals, however, occur also in crystalline lenticular growths, elongated parallel to the general foliation, but in which the basal cleavages and planes of intergrowth are almost -at right angles to that. A name for growths of this kind in crystalline schists will be found convenient. Following the lines of Grubenmann's terminology (see footnote to p. 143), they may be called Encarsioblastic, from ■γκ■ρσιος = transverse (πλ■γιος having, in mineralogy, been used in contradistinction to ■ρθ■ς, is unsuitable, as these growths may be at an angle of 90° to the foliation). (Plate 2), Fig. 1. In these encarsioblasts biotite is usually in excess of muscovite and developed in broader plates. These delicate objects, even with the full tide, as it were, of the foliation sweeping past them, are undeformed. And, when adjoined by grains of quartz, the ends of their plates may even be seen to penetrate it, just as do the foliation-micas, though for a shorter distance. They must therefore be among the latest products of the reconstruction. Some of the finer grits contain great numbers of clear dark green spots, conspicuous even to the unaided eye, and sometimes arranged in hands, which are short encarsioblasts.

Another interesting feature is that some of the larger blastopsammitic felspars with turbid cores have peripheries of clear albite, the whole grain, twinning-planes and all, being optically undisturbed. Weathered felspar has therefore been rejuvenated, so that permeation by sodium solutions must have accompanied the dynamic metamorphism.

The fine partings, which may be as much as three or four inches thick, often show the colour-banding of the original shale, and sometimes also contain thin seams of fine white quartz-schist. The pelitic matter itself has been completely reconstructed, and is now a perfect lustrous lepidoblastic mica-schist with a pale sea-green tinge, which consists almost entirely of white mica, with a varying proportion of green biotite, and with many minute granules of epidote, zoisite, haematite, and other iron-ores. The micas may be half a millimetre in length. Encarsioblasts are an even more striking feature of these beds than of the grits, and in some case development has been carried so far that the dominant foliation has become reduced to a series of mere films between them, so as to resemble a strain-slip foliation. Specimens of such rocks (E10158) [SH 215 815] tend to be prismatic in form, and almost devoid of 'cross-fractures', being bounded by two pairs of foliation planes. The foliation of these encarsioblasts is often sharply corrugated, but their micas do not seem to have suffered from optical distortion. An unexpected feature is that the thin coarse grits are apt to lie along, sometimes partly in, these fine pelitic beds.

Lenticular seams of coarse venous quartz, which may be several inches thick, occur throughout the series; and usually contain chlorite, in irregular aggregates that may be an inch thick, and several inches long, composed of little well-formed plates that sparkle under the lens. In a few cases it is foliated, but. the quartz is not. These seams are much more frequently found in the pelitic schists than in the grits, conforming in a general way to the bedding, but transgressing it at a low angle. Thin ones may fold sharply with the beds, and may then cut the foliation at right angles, causing slight deflections of it. They are evidently the last product of the metamorphism, introduced, apparently, when the shearing stresses had nearly but not wholly spent themselves.

Chemical composition

The following analysis of a 'schist from the South Stack, near the Lighthouse', is given by Messrs. Mellard Reade and Holland in *Proc. Lpl. Geol. Soc.,* 1900, p. 472 and table. It is described as a foliated rock, with a silky texture, and folded laminations, but with no trace of slaty cleavage, composed of minute quartz, with mica in subordinate quantity and some chlorite. Evidently it is neither one of the massive grits nor one of the micaceous partings.

The description corresponds to a fine grit such as (E10599) [SH 214 806], the material containing *Planolites.*

SiO_2	76.77
TiO_2	0.74
Al_2O_3	11.15
Fe_2O_3	1.71
FeO	2.32
MnO	0.12
CaO	0.09
BaO	0.03
MgO	1.06
K_2O	2.85
Na_2O	1.05
P_2O_5	0.11
C	traces
Combined Water	2.41
	100.41

As the felspar is albite, it is evident from the percentage of potassium that the white mica must be a muscovite.

The Coeden Beds

These are regarded as a slightly differing facies of the Liwyn part of the South Stack Series. They are finely developed in the rugged tract known as The Mynydd Mechell, after which they have been called by several authors, but the word Coeden 'may be found to run more trippingly on the tongue'. Like that with which it is correlated [such as (E9313) [SH 231 821]–(E9314) [SH 217 798]], the group consists of hard, evenly-bedded, greenish-grey grits, fine-grained with few exceptions, and with partings of fissile mica-schist. The grits are from a few inches to a foot thick, the fine partings may attain two or three inches, but seldom exceed a fraction of an inch. Specimens have a flaggy 'moine-like' aspect, and the foliation planes are lustrous, though not brilliantly, the cross-fracture saccharoid. clastic quartz can usually be seen with the lens. There are also many grains of felspar, most of which is albite or albite-oligoclase. The fragments are sometimes finely rolled, but many must have been sub-angular. There is also a little clastic mica.

But they are now blastopsammitic schists, the matrix being a granoblastic but fine mosaic. Foliation is imparted to it by white mica and chlorite, but the flakes are neither as long, as broad, or as well-formed as in Holy Isle, and encarsioblasts are rare. Iron-ores are usually present. Epidote is an important constituent, its granules often being rounded porphyroblasts. Seams of pistacio-green epidosite are a conspicuous feature of the group. They may be half an inch or more in thickness, but never extend for many feet. The clastic texture still survives in them, but the matrix is crowded with granular epidote. Some are slightly transgressive, showing their secondary date. Zoisite is also present.

The fissile partings are composed almost wholly of white mica, in very thin flakes, closely felted, and with some chlorite intergrown, and granules of iron-ore. Thin seams of quartz-schist are interbanded with it. It is often full of venous quartz in sills', containing reddened felspar, some of which is albite, some apparently decomposing orthoclase.

The group has undergone more crystalline reconstruction than has the country to its north, as has been pointed out by Dr. Callaway. But less than that of the rocks of Holy Isle. Yet the survival power of the clastic grains, and the texture of the mosaic of the matrix are much the same in the two areas. Here, it is true, undulose extinction is much more often seen, which, were it a feature of the metamorphism, would indicate a lower grade. But the Coeden beds are riding upon the Carmel Head thrust-plane, which, being here at a very low angle, cannot be far beneath them anywhere; and some of the dykes by which they are traversed are deformed. Their undulose extinction may, therefore, be referred to movements of a later date.

The New Harbour Group

This is named from its fine development about the New Harbour at Holyhead. The term 'New Harbour Beds' will be used in an inclusive sense for the formation as it is found in Holy Isle, in the Western Region, and in the Northern Inters; the term Amlwch Series in a similar sense for the facies found in the Northern Region; the terms 'Green-mica-schist' and 'Amlwch Beds' for the dominant sedimentary member in each case. The group thus includes the following members:

Green-mica-schist

Amlwch Beds

Jaspery Phyllites

Bedded Jaspers

Spilitic Lavas and Basic Schists

The jaspery phyllites, jaspers, and spilites present the same characters in the Amlwch Series as in the New Harbour Beds.

The Green-mica-schists

These are flaggy or laminated schists of medium grain, with a persistent green colour, and sparkling with little flakes of mica. They are cleanly crystallised, and their green hue is clear, different in quality from the dull muddy green so characteristic of the Gwna Beds. Two elements are present. The greater part of the rock is hard and slabby, saccharoid on cross-fracture, and rather like the Moine Schists of the Scottish Highlands. The other element is a fissile schist with gleaming foliation planes, which occurs as thin partings. The hard bands, however, are seldom as much as a foot, are usually only an inch or so, in thickness, often indeed mere seams, of which eight or more may be counted in an inch. Not only so, but they are thoroughly foliated throughout their whole body. Even the most massive beds that have been seen, a yard or more in thickness, are foliated through and through. So that the granular and the fissile elements are closely bound together in this formation. The fissile beds may reach three or four inches in rare cases, but are generally not much more than a small fraction of an inch, or even mere films.

The rocks are without doubt sedimentary in origin, and their flaggy bands were grits. Where these are tolerably massive, some clastic grains are usually to be seen under the hand-lens, but they are not conspicuous. Most of them are quartz; but there is a good deal of felspar, nearly all of which is albite, with a few grains like microcline. The albite is often untwinned, and full of minute inclusions, most of which are micas. The only surviving original accessory is tourmaline, some of which has a beautiful dichroism from lark blue to rose-pink, and is sub-hedral. In a few places there are coarser grits, one of which, on the shore below the Coastguard Station at Holyhead, contains fragments a seventh of an inch in diameter, of fine white quartzite of Gwna type. One fragment of a granitoid rock was found in the massive beds at Porth-y-felin.

The rocks are typically blastopsammitic, and have undergone a high degree of alteration (Plate 2), Fig. 2. All but the larger clastic grains have disappeared, and even these have been to a considerable extent incorporated, being bounded by a succession of corrosion bays. The larger albites often have a clear margin, as in the South Stack Series. The matrix ranges from granoblastic to lepidoblastic, and in the fissile parts the grains of quartz and albite are often elongated. The secondary minerals are quartz, albite, white and green micaceous plates, epidotes and zoisite, sphene, apatite, and iron-ores. As the felspar is albite, the potassium of the analyses (p. 49) must be contained in the white mica, which is therefore muscovite.

The grass-green mineral which imparts the colour to the rock has been investigated by Dr. H. H. Thomas and the writer, from the specimen (E10151) [SH 241 829]. It is bi-axial, the axial angle 2 E, being small; and is optically negative in all cases examined. The cleavage is as in micas, and the acute bisectrix nearly perpendicular to that cleavage. It has a pronounced pleochroism: *X* pale-green to yellow, Y and *Z* deep grass-green. The refractive indices are α=1.60, γ=1.63; so that $\gamma-\alpha = \pm .03$, β being nearly = γ. The mineral is therefore a green biotite. It is abundant in the fissile seams, often intergrown with the muscovite. Some of the plates exceed .75 mm. in length.

Epidote is everywhere abundant, some seams being crowded with its granules, which attain to a diameter of .5 mm., and are porphyroblastic. Most of it is yellow and pleochroic, with high bi-refringence, but there are pale varieties with low bi-refringence, which give sometimes the characteristic polarization-blues of zoisite.

A large proportion, however, of the granules conspicuous by strong relief, are sphene. There is a good scattering of iron-ores, most of which are ilmenite, often elongated along the foliation; and occasionally apatite in some abundance. In the slide (E10151) [SH 241 829] are two grains of a remarkable mineral, which, being quite allotriomorphic, has not been determined with precision. It is biaxial, with high refringence and bi-refringence, and a pleochroism that for rays vibrating transverse to the major axes of the grains is deep yellow, for rays parallel to the major axes a beautiful rose colour. These characters agree with those of piedmontite, though the rose colour is not so deep as in the celebrated manganese-epidote of Japan. The mineral does not appear to have been recorded hitherto in British crystalline schists, and it is to be hoped that idiomorphic crystals may be found.

***Quartz-sheets*.** Venous quartz in sheets or sills, always with nests of chlorite, of precisely the same kind as those in the South Stack Series, are developed on a great scale in this group. A felspar is often intercrystallised with the quartz, so that these segregations are not mere quartz-veins, but approach in character to pegmatites. The felspar is albite, much of it untwinned. In rare cases the quartz has a rude, and the chlorite a strong foliation, so that though the latest products of the metamorphism, movement had not ceased when some at any rate of them had separated. They are present everywhere, often in such abundance as to be a conspicuous feature on the rugged bosses. There are also seams that are foliated and finely granoblastic; some parallel to the general foliation and graduating laterally into the green schist, others truncating it at a low angle. Separation of quartz must therefore have taken place during three intervals at least of the metamorphism, and it was progressively incorporated. For the granoblastic is a modification of the venous quartz, cores of which survive in it. Quartz being always in excess over chlorite, it is evident that the beds in their original condition must have been more siliceous, considered as a whole, than they are to-day.

These rocks also, therefore, are holocrystalline schists, even more thoroughly foliated than the South Stack Series. Next to the Gneisses and the Penmynydd Schists, they are the most reconstructed rocks in the Island. This character is maintained throughout Holy Isle, but a crystalline degeneration seems to set in upon the main Island, increasing eastwards. To some extent this is really the case. But the appearance is chiefly due to a platy foliation that is there developed, which is later (pp. 196–8) than the foliation-planes of Holy Isle, and on which there is a feebler development of mica, so that the planes of easy splitting are less lustrous.

***Subdivisions*.** Two subdivisions can be recognised. In the first of these the flaggy, alternating, type is pronounced; psammitic matter is dominant; clastic grains are often visible; and the coarser grits are not uncommon. The group may be called the *Soldier's Point Beds.*

The other is much more pelitic, and clastic grains are rarely seen, while the lepidoblistic seams are far more intimately interfelted with the granoblastic, so that the alternation of the two is far less conspicuous. Here, also, the sheets of venous quartz with albite are most abundant. This group may be called the Mynydd-celyn (or briefly, the Celyn-pronounced 'Kelyn') Beds. The Celyn beds lie next to the South Stack Series, the Soldier's Point beds adjoin the Skerries Group.

Chemical composition.

The following analyses have been made, some others being annexed for comparison.

	I.	II.	III	IV	V.	VI	VII	VIII
SiO_2	72.32	48.52	53.67	78.66	84.86	55.43	60.15	58.38
TiO_2	2.53	2.73	—	0.25	0.41	0.46	0.76	0.65
Al_2O_3	10.23	23.25	—	4.78	5.96	13.84	16.45	15.47
Fe_2O_3	2.31	4.17	—	1.08	1.39	4.00	4.04	4.03
FeO	2.62	5.67	—	0.30	0.84	114	2.90	2.46
MnO	0.21	0.15	—	trace	trace	trace	trace	trace

CaO	2.67	1.48	—	5.57	1.06	6.02	1.45	31.7
MgO	1.30	3.29	—	1.17	0.52	2.67	2.32	2.45
K_2O	0.80	5:94	4.41	1.32	1.16	2.67	3.60	3.25
Na_2O	3.08	0.95	2.57	0.45	016	1.80	1.01	1.31
H_2O (at 110°)	0.09	0.12	—	0.31	0.27	2.11	0.89	1.34
H_2O (above 110°)	1.67	3.81	—	1.33	1.47	3.45	3.82	3.68
CO_2, &c	—	—	—	5.19	1.16	6.29	3.07	4.27
	99.83	100.08	—	100.4	99.86	100.48	100.46	100.46
Spec. Grav.	2.763	2.746						

The specific gravities are given by Mallet, and are not from the same specimens.

I. Typical hard, gritty schist from just north-west of Bryntirion (six-inch map), Holyhead, *i.e.,* 300 yards north-west by west from the new church ('ch'. of one-inch map). No slice, but same type as (E10282) [SH 260 795]. Anal. J. O. Hughes.

II. Fissile band from same locality (E10151) [SH 241 829]. Anal. J. O. Hughes.

III. Mica-schist of intermediate character, Cromlech Farm, Rhoscolyn (E10162) [SH 264 767]. Anal. J. O. Hughes.

IV. A composite analysis of 253 sandstones; and

V. of 371 building-sandstones, from different parts of the United States.

VI. A composite analysis of 27 Mesozoic and Cainozoic Shales; and 7, of 51 Palaeozoic Shales.

VIII. The average of VI and VII 'weighted' as three to five.

These composite analyses are from Bull. U.S.G.S., quoted in Sir A. Geikie's 'Text-book of Geology', Ed. 4 (1903), pp. 165. 'CaO', here, includes BaO, and 'CO_2, &c'. includes P_2O_5, SO_3, and organic C.

The proportion of titanium in both the Holyhead rocks is remarkable, and shows what a large proportion of the minute granules of high refractive index must be sphene. But, considering the ab'undance of that mineral, and of epidote, the percentage of lime is small, and more magnesia might have been expected from the chlorite. The alkalies are high, and the reversal of proportions between them in the granular and fissile types indicates that the alkali-mineral of the one is albite, of the other, muscovite. Comparing them with the composite analyses, however, it is evident that the granular component of the group is not a normal grit, nor their fissile component a normal shale. In both types the silica (though allowance must be made for the siliceous segregations) is relatively low, the alkalies and the magnesium high, the iron (especially the ferrous iron) very high, and the titanium quite exceptional. The granular component is far more aluminous than a normal grit, and is rich in sodium, evidently contained in its albite.

Now, in the field, the persistent green tinge of these rocks undoubtedly suggests to the mind that volcanic matter must enter into their composition. Previous observers (p. 11) have noted this, and Dr. Teall, who walked over them with me near Holyhead, received the same impression. Their mineral and chemical composition leaves no doubt that such must be the case. Yet no bands that could be regarded as tuffs have been found except at the top and bottom of the group. If, however, we suppose that the basin of deposit was, throughout the whole time of their formation, within reach of showers of fine volcanic dust produced by the explosion of a basic magma, these characters receive an explanation. Can that magma be identified? We have seen that a singular character of both the psammitic and the pelitic elements is their high percentage of titanium, which is nearly the same in both in spite of all their other differences. Now there are some lavas in the group, and they are spilitic. Such lavas are apt to contain a high percentage of titania, rising to a maximum of 2.95.<ref>Dewey and Flett, *Geol. Mag.,* 1911, p. 207, and *Geol. Surv. Mem,* Lizard and Meneage, p. 185.</ref> And the spilite of the New Harbour Beds themselves (p. 55) contains 2.21 per cent. of titania, the average of that of the two components of the Green-mica-schists being 2.63. Why titaniferous particles were disseminated so much more widely than other ones may perhaps be explained in more than one way. However that may be, little doubt can remain that the volcanic element of these beds is the dust of a spilitic lava.

The Amlwch Beds

The Alternating Beds are thin-bedded schistose grits with partings of fine phyllitic mica-schist, the grits not often exceeding three or four inches in thickness. One or two inches is a common thickness, and towards Llaneilian they have become so thin that it is easy to obtain hand-specimens containing five or six grits that are from a quarter to even an eighth of an inch in thickness. All the beds are green, the phyllites pale grey-green, the grits rather darker green internally. There are two distinct types of grit, one which is rather fissile and relatively soft, the other very hard and jointed, weathering out in rectangularly-edged ribs that are sharply marked out from the phyllitic partings. These are the beds that impart such a conspicuously alternating' aspect to the series, for they weather to a light cream colour. In the fissile grits there is much more matrix. The fragments are chiefly quartz, but there is much felspar in fair condition. It is albite, sometimes untwinned, often with beautiful polysynthetic twinning. The grains tend to be sub-angular. For the most part these grits are rather fine, and usually there is a good deal of matrix. It has been completely reconstructed, and is now a fine granoblastic schist with chlorite and white mica. Epidote is usually present, and in some slides is abundant. The matrix of the fissile green grits is more full of chlorite than that of the hard bands. In these rocks also the amount of green material points to the presence of basic volcanic dust, probably derived from the spilitic lavas, as in the case of the New Harbour Beds of Holy Isle.

In a few places there are coarser grits, and at Amlwch is a true conglomerate with well-rolled pebbles up to two inches in length. Some of these are derived from Gwna quartzite, some from grits, others from granitoid rocks arid albite-quartz-felsites of the same types as those of the Skerries Conglomerates (p. 60), a few are old mica-schists. Boulders, also, as much as four inches or more in diameter (pp. 303–4), are occasionally to be seen in quite fine flaggy beds. They have probably been brought by floating vegetation, as has been suggested in somewhat similar cases that are known in coal seams and in chalk.

These pebbles are in some cases much deformed, especially the igneous, ones. Many of the clastic grains in the grits have suffered like manner, and have begun to enter into sutural relations with the matrix. The fine partings are often a little gritty, but all, except these few grains, have been completely reconstructed; and they are now fine chloritic mica-schists or phyllites. Some of the quartz veins that cut the foliation are traversed by a rude schistosity parallel to that foliation. Bands of epidosite like those in the Coeden beds are rare in this group.

Subdivisions — Here also there are two divisions. The alternating, psammitic division may be called the Lynas beds; from which can be distinguished a pelitic division that may be called the Bodelwyn Beds. Metamorphism increases in them southwards, but they never reach the crystalline condition of the Celyn beds of Holy Isle: their micas being a fine felt in which the individual flakes are small.

The following are analyses of the, grey-green phyllites.

	I.	II.	III.	IV.	V.
SiO_2	57.23	70.58	70.74	—	80.59
TiO_2	0.89	0.62	0.41	—	0.34
Al_2O_3	20.43	13.23	12.79	—	6.45
Fe_2O_3	1.33	4.23	4.76	—	4.77
FeO	5.64	1.24	1.26	—	0.73
MnO	0.05	0.35	0.38	—	0.81
CaO	1.54	—	trace	—	3.64
BaO	0.02	—	—	—	—
MgO	2.09	1.83	2.97	—	0.82
K_2O	2.39	1.92	1.90	3.61	0.24
Na_2O	3.97	3.52	2.35	2.92	0.73
H_2O (combined)	3.94	2.18	2.61	—	1.06

SO_3	0.03	—	—	—	—
P_2O_5	0.54	trace	—	—	—
	100.09	99.70	100.17	—	100.18
Spec. Grav.		2.72	2.65		

I. 'Green slate from quarry between Cemlyn and Cemmaes, a finely cleaved glossy green slate'. Anal. Mellard Reade and Holland. *Proc. Lpl. Geol. Soc.,* 1900, p. 466 and table.

II. 'Slate', 'Borth Bay', evidently Hen-borth, Mynachdy. Anal. E. Dickson. *Proc. Lpl. Geol. Soc.,* 1890.

III. 'Unaltered Slate', Porth y Gwartheg, Cemlyn. Anal. E. Dickson, *loc. cit.*

IV. Fine parting. Amlwch, the bathing creek, just where the footpath that runs north-westward from the Coastguard Station reaches the sea (E10558) [SH 437 936]. Anal. J. O. Hughes.

V. 'Greenish-grey infiltrated rock penetrating slate as a sheet, Yr-hen-borth'. The description and locality correspond with those of the bands of epidosite a little to the west of Hen-borth, Mynachdy (E10385) [SH 325 938], (see p. 299). Anal. Reade and Holland, *loc. cit.*

The Jaspery Phyllites

These are fine, fissile rocks, of a rather uniform purplish red colour, usually not very lustrous on the foliation planes. Transitional types connect them with the green ordinary phyllites, a few of which have a faint purplish tinge indicating the first approach to the purple beds. But the true jaspery phyllites are marked off quite sharply enough to be easily separable on the maps. They are composed chiefly of white mica hematite, fine quartz, and a little chlorite. The hematite is most of it thin scaly eisenglimmer. Some of the quartz and mica seem to be clastic, but the grains are very small. Rocks with the full red colour are known in Holy Isle only at one place, but in many places the Green-mica-schists contain thin beds that have a tinge of purple, and can be separated roughly on the maps. They are as lustrous as the fissile portions of the mica-schist, and differ only in the presence of abundant scales of eisenglimmer, which are interfelted with the mica, larger and better formed than in the north, but in less quantity, It is not unlikely that, in these highly crystalline schists, the red colour has been partly discharged by reduction of the ferric oxide (cf p. 88).

The Bedded Jaspers

Intimately related to the jaspery phyllites, these rocks cannot be separated from them on the maps; usually occurring as bands in them that are less than an inch in thickness, the bedding being well preserved, and the jaspers finely banded. They are not fissile, but are hard, compact, and brittle, with a cross-jointing like that often seen in bedded cherts. Their colour differs from that of the phyllites in being brick-red rather than purple; but they never show the bright scarlet of the nodular jaspers of the Gwna Beds. They are composed (Plate 2), Fig. 3 almost entirely of quartz and haematite, with a very little mica. The haematite is in great quantity and gives a deep red colour to a thin section; it is not in scales, but in fine dust, which is aggregated into clots, leaving other parts a paler tinge. The quartz is in a mosaic so fine as to suggest that it has crystallised from colloidal silica. In a few of the slides are much larger elements, some of which are felspar, evidently clastic and also abundant granular epidote. These are from beds that rest upon a spilitic lava,. and might easily have received some volcanic dust. Some slides were submitted to Dr. Flett, who remarks: These cherts are very like the radiolarian cherts of Cornwall and Devon where they have been flattened by pressure. I do not think there is much room for doubt that they were originally radiolarian, but no radiolarian shells can now be detected in them'. Possibly some lenticular spots now filled with quartz and white mica may be deformed radiolarian casts. The rocks are full of complex veins, a few of which contain a carbonate.

In No. III. of the following analyses it was found impossible to exclude a proportion of the jaspery phyllite, owing to the rapidity of alternation. If it be compared with that of a pure jaspery phyllite (p. 89), no doubt will remain that the silica percentage of the pure jasper must be very high.

	I.	II.	III.

SiO_2	55.34	61.65	67.07
TiO_2	1.94	0.70	0.69
Al_2O_3	20.87	16.82	14.79
Fe_2O_3	7.07	6.61	6.33
FeO	1.19	1.39	0.81
MnO	0.36	1.07	0.26
CaO	0.78	0.15	1.14
BaO	0.07	0.03	not det.
MgO	1.58	2.02	2.23
K_2O	4.76	2.90	1.85
Na_2O	2.80	3.36	3.51
H_2O	—	—	0.07
H_2O (combined)	3.39	3.15	1.78
P_2O_5	0.13	0.08	not det.
SO_3	trace	not fd.	not det.
CO_2	—	—	none
	100.28	99.93	100.53

I. Purple-grey 'slate'. Hen-borth, Mynachdy. Anal. Mellard Reade and Holland. *Proc. Lpl. Geol. Soc.* 1900, p. 469 and table.

II. Purple-grey 'slate' ('crinkled'). Llanrhwydrys. Anal. Mellard Reade and Holland, *loc. cit.,* p. 467 and table.

III. Jasper. Amlwch. South side of creek, 80 yards north of where the path, running north-westward from the Coastguard Station, reaches the cliff (E10535) [SH 437 936]. Anal. J. O. Hughes.

The Spilitic Lavas

are massive, heavy rocks, normally of a pale sea-green colour, but mottled and shot throughout with the pistacio-green of epidote, some parts being thoroughly epidotised. They have not the dull fracture of the Gwna spilites<ref>The description of the unaltered Gwna spilites (pp. 71–74) should be read first.</ref>, but look saccharoid under the lens. In many parts they are full of sometimes white but usually yellow spots which range from an eighth to half an inch in diameter. The pillowy structure is well developed, for they are built up of ellipsoidal masses that range from six inches to two feet in length, and that push into each other (Figure 1) in the manner that gives such a plastic appearance to lavas of this kind. The yellow spots have often a rudely concentric arrangement that conforms to the curves of the pillow's outline, but may be as plentiful in the core as at the margins. Between the pillows are fissile skins of darker colour, in which the spots are also present. Carbonates are often abundant, white, saccharoid, and shot with epidote.

The rocks have been composed of felspar and ferro-magnesian minerals, iron-ores being usually present in but small quantity. Some porphyritic pseudomorphs have the form of olivine. The pyroxene has been completely converted into fine pale actinolitic hornblende, with a varying amount of chlorite. In some there is a little quartz, but epidote is generally present, often in great abundance, and beautifully crystallised in large grains with strong pleochroism. The spots are now entirely composed of it: they are often hollow spheres enclosing cores of the general body of the rock. This body consists of lath-felspars, with which are intergrown the needles of actinolite. Some of the felspars are of fair size (these are usually sericitised), but the great majority, which give nearly straight extinctions, are slender and delicate almost to fibrosity. In the best-preserved specimens they are arranged, throughout, in brushes and subradiate groups, so that the structure is thoroughly variolitic. The needles of actinolite share the same arrangement, so that it is to be supposed that the original pyroxene shared the variolitic disposition which is, as it were, first indicated in the Gwna spilites. Some fine varieties appear to have been glassy, the glass being now chloritised. The rocks are true variolitic spilites like those of the Gwna Beds.

Nor need any doubt be entertained of their having been true lavas. Their associates are too much reconstructed for pyroclastic structure to be recognised: but close to the epidotic variolite of the Cliperau shore some green chlorite-epidote schists, which nevertheless contain much quartz, are interbanded with the green-mica-schists, and can hardly represent anything but fine tuffs. A thin chlorite-epidote-albite schist that occurs just at the junction. of the New Harbour Beds and the South Stack Series in Holv Isle is almost certainly a tuff, for it graduates into the sediments above and below. Its chlorite seems to be after hornblende. And we have already seen that the peculiar composition of the New Harbour and the Amlwch Beds indicates that explosions of spilitic dust were taking place from time to time. These variolitic spilites must therefore be regarded as contemporaneous outflows.

The following analysis shows that, while the rock has in a general way the composition of a spilite, it has been modified by epidotisation,-as well as having been probably more basic originally.

	I.	II.
SiO_2	39.20	42.26
TiO_2	2.21	—
Al_2O_3	18.80	—
Fe_2O_3	8.61	—
FeO	4.99	—
MnO	none	—
CaO	9.69	—
MgO	10.03	—
K_2O	016	—
Na_2O	1.88	—
H_2O	0.10	—
H_2O (combined)	4.52	—
CO_2	none	—
	100.19	—

I. Variolitic spilite, Amlwch, 100 yards north of the path's end on the cliff, north-west of the Coastguard Station (E10529) [SH 437 936]. Anal. J. O. Hughes.

II. Chlorite-epidote schist, probably a variolitic tuff, 100 yards north of the cottage on the east side of Borth-wen, Rhoscolyn, Holy Isle (E10165) [SH 275 751]. Anal. J. O. Hughes.

Metamorphism — Under the influence of the great shearing stresses of the Complex the tough ellipsoids of the lavas lend themselves readily to the production of large lenticular augen, about which winds the less obdurate material of the skins', now converted into a chloritic and actinolitic schist; and by further deformation the lenticular cores themselves become attenuated, and finally foliated. But even in the most advanced stages reached some trace of the pillowy structure can generally be detected.

If we now compare the lavas of this horizon with those of the Gwna Beds it would seem that they differed but little in their original condition. Both are spilites with a marked tendency to variolitic structure. The differences are in their dynamic metamorphism. No hornblende has been found in any undeformed Gwna spilite. It does not appear at all, nor does epidote in quantity, until foliation has developed. But in these rocks not merely epidote but actinolite appears in abundance without any breaking down of the delicate variolitic disposition of the felspars. And where foliation is developed there is no concurrent advance in the development of hornblende; the rock does not become a hornblende-schist. If we consider the state of the associated sediments we find that those of the Gwna Beds have suffered severe cataclastic deformation, while those of the New Harbour Beds have been rapidly folded and have acquired a much more crystalline foliation. There can be little doubt that the different condition of the two groups of spilite is in some way connected, first with their positions on the maximum primary folds, and next with the types of stress that were set up in the major secondary folds of the Mona Complex.

The Skerries Group

The formation included in this group are the Skerries Grits, the Church Bay Tuffs, and the Tyfry Beds.

The Church Bay Tuffs

Its generally unstratified character is the salient feature of this formation, and one that is unusual in deposits that are so fine of grain. At Clegyr-mawr alone can bedding be seen through a thickness of 180 feet, and even this disappears rapidly along the strike. Elsewhere, a thin bed or two coarser than the rest, may be quite sharply marked out, but none of these can be followed for more than about 50 yards; and a banding that is occasionally visible in the fine material dies away in a few feet. Where there is no deformation, the only structure visible is a plexus of irregular joints, and its aspect in the long lines of sea-cliff is that of a massive igneous rock. The typical material is a dull greenish-grey porcellanite, weathering to a cream tint, and almost invariably traversed by a multitude of thin, dark green, anastomosing veinlets, which impart a crackled ' appearance to the outer crust. On a fresh fracture, minute clastic grains are just perceptible under the hand lens. In thin section, the porcellanous matrix, which is turbid at first sight, resolves itself under a higher power into finely granular epidote and minute clots of sericite, but iron-ores are scanty. Plentifully strewn throughout it are small angular fragments, which often, indeed, have re-entering angles. A few are of quartz, but the great majority are of felspar, now almost entirely sericitised. The sericite, however, is often differently disposed in different lamellae, so that the twin-lamellation is itself pseudomorphed. The felspar was therefore triclinic. In a few cases it is fresh enough to show a positive optical figure, and extinction angles near to those of albite. In a coarse tuff at Porthmadog it is without doubt albite. The veinlets are partly of chlorite, partly of a honey-coloured pleochroic delessite.

The coarser bands resemble grits externally, but are essentially of the same nature as the porcellanite, their matrix being identical with that. The composite fragments may sometimes be seen to be of spilitic type, but there are also irregular chloritic bodies like lapilli of a basic glass. Fragments of a reddish felsite are also to be seen. In a few places there are thin, even, bands of purple phyllite and bedded jasper that resemble in every respect the similar beds in the New Harbour Group, some of them being composed of crypto-crystalline silica full of hmmatite dust and containing very minute clastic quartz and mica.

The green porcellanites are not often as homogeneous as at Clegyr-mawr: they commonly have a confusedly mottled aspect, and are full of yellowish matter. At a little cove south of Porth Trwyn a green gritty porcellanite is crowded with clots of pale, compact, epidosite, one-eighth of an inch or less in length, lying in beautifully parallel bands. But often a number of such clots will run together, so as to form a ragged-edged bed. This clot bed' is two to three feet thick, and its bedding is parallel to that of the adjacent rock. In other places, the same compact epidosite forms even-sided bands, which are sometimes very fine, but they are apt to be broken up into isolated fragments, and that in rock that shows no sign of deformation.

At Castell, Trefadog, is a sheared volcanic breccia with fragments of acid lavas, while north of Church Bay, fragments of keratophyre and mica-schist occur in a grit, and a massive gritty epidosite contains many pebbles about half an inch, and some of them two inches, in length, of acid igneous rocks, quartzites, and jaspers. They are of great stratigraphical importance, and are discussed on pp. 60.

A specimen of the typical porcellanite was analysed by Mr. J. O. Hughes.

SiO_2	59.62
Al_2O_3	19.59
Fe_2O_3	2.66
FeO	3.59
CaO	2.82
MgO	2.05
K_2O	3.56
Na_2O	3.51
H_2O (at 110°)	0.23
H_2O (above 110°)	2.52
	100.15

TiO_2 with Al_2O_3, MnO with FeO

(E9315) [SH 300 901], from one of the bosses on the high summit, 340 yards southwest of Clegyr-mawr, Llanrhyddlad.

It is therefore evident that the rock is a fine tuff of intermediate composition. Not only, however, are no lavas of andesitic type known in the Mona Complex, but it is difficult to suppose that it can have been produced simply by the explosion of such a magma. The proportions of most of the constituents, especially of its alkalies, are such as may often be found in andesitic lavas, but the calcium it contains is nearer to that of the dacites, for which it does not yield sufficient silica. The nature of the composite fragments of the coarser beds explains the anomaly, showing that the porcellanite must be a spilitic tuff with an admixture of rhyolitic debris.

Metamorphism

Deformation. There is perhaps a greater mass of undeformed material in this formation than in any other member of the Complex, which is probably due to its remarkable homogeneity, hardly any native planes being provided along which it might begin to give way. But eastward and southward it breaks down, and the process may be studied along the coast. Mylonisation sets in, confined at first to definite slips, but soon extending over zones of several inches. These become frequent, and then the whole rock acquires a rude fissility, along which the epidosite clots, and the veinlets, are drawn out into light and dark green lenticular streaks. In the midst of the massive porcellanitic tuff of Church Bay the process does not often get to this stage; but at one place a schist with a good long lenticular structure and a dull sheen has been produced for a few yards, which could not be distinguished from much of the material of the Gwna Beds. Near the junction with those beds, however, such material is found in abundance.

Silicification. The tuffs have been sporadically silicified, the final product being a fine white quartz-rock that graduates into the normal dull-green material. This, resisting the deforming stresses, has been cut up and sheared out into augen. The resulting rock simulates closely the Autoclastic Mélange of the Gwna Beds (pp. 65, 66), but its augen, instead of being blastopsammitic, are finely granoblastic. It is clear that the silicification is older than the great movements of the Mona Complex, and it may therefore be ascribed to a geyseritic episode that followed closely upon the eruptions of the tuffs themselves.

The Trwyn Bychan rocks of the north have (except that they are not, perhaps, quite so compact as a whole) the same peculiarities of composition and structure as those of Church Bay, and their extraordinary massiveness is finely displayed on cliffs more than 100 feet in height. In some places their epidosite clots appear to be genuine lapilli. But they have been far more deformed. Few parts have escaped, and considerable tracts have been transformed into a dull but fissile schist.

The Skerries Grits

The Skerries Grits are the 'Llanfechell' Grits of Dr. Callaway, but, as in the case of a similar group-name, that word scarcely runs 'trippingly' even off a native tongue; and as all the most interesting and important characters of the rocks are far more strikingly developed on The Skerries than at any other place, that name seems more appropriate as well as more euphonious. They are hard 'greywackes', generally rather coarse, and often pebbly; greenish grey inland, but green with subordinate grey mottling on The Skerries. The most remarkable thing about them is their unusual massiveness. On most of the sections no bedding whatever can be seen; and except at base and top it is rare throughout. They consist of quartz, felspar, and composite fragments, with abundant secondary epidote, chlorite, and sericite, and some iron-ores, most of which appear to be ihnenite. The felspars are chiefly albite, with some albite-oligoclase and micropegmatite. But the clastic grains are not closely crowded as in ordinary grits; they are visibly isolated by the matrix. This, which is of a low pistacio-green colour, plays an important part, and is identical in appearance with the green clots and mottlings of the Church Bay Tuffs. It looks turbid under a low power, but with a 4-inch objective is resolved into minute granules and prisms of epidote, clots and specks of sericite, and abundant chlorite.

This matrix is therefore the same as the fine epidosite of the Church Bay Tuffs, and as the composite fragments are for the most part volcanic, it is evident that much of the rock is of pyroclastic origin. At the Bull Bay section the proportion of matrix increases rapidly northwards; it then comes on in bands, and these in their turn increase until there is a complete passage by alternation into pure Church Bay Tuff. Further, we have called them 'grits', but there is reason to suspect that even their quartz is but partly epiclastic. Many of its grains have not the rounded or irregularly sub-angular outlines of ordinary sand; they tend to be quadrangular or triangular, sometimes with bays and re-entering angles. These are forms typical of the phenocrysts of the quartz-felsites. On the East Mouse, grains like them can be seen (p. 318) with still a little matrix adhering, and it is therefore likely that these detached grains are direct products of the explosion of an acid lava. The Skerries Grits, then, are far from being normal sedimentary rocks: the pyroclastic element in them preponderates, and, doubtless, to this is due their extraordinary massiveness.

The Conglomerates

Composite fragments are more plentiful as well as much larger than in any other member of the Mona Complex, and they are of great importance. Small ones, visible in thin section only, are extremely abundant, often exceeding in quantity the grains of quartz or felspar; and hand specimens usually show a good number that are about an eighth of an inch in diameter; but larger ones are rare upon the mainland, a few only having been found of half an inch or so in length. They are larger on the islets, there being a good many on the East Mouse that are an inch or two, and some even six inches across.

But by far the finest development is on The Skerries. There, and there alone, are true conglomerates in the Mona Complex. Bands occur at intervals all over the little archipelago, the pebbles being usually three or four inches across. But on Ynys Arw the conglomerate may be called a boulder-bed, being full of great oval blocks, most of which are six inches, many of them a foot, and some nearly two feet in diameter. They are well rounded, and being light in tint, stand out in strong contrast to the dark green matrix, so that the beds are very striking in appearance. But so tough and resistant is the matrix that the boulders do not always weather out, some even weathering into cavities. The grits contain many short bands, an inch or so in thickness, of a fine epidositic mudstone, with minute clastic quartz, which is of the same nature as the matrix. These bands may be finely bedded, but in the boulder-beds are broken up into long strips, and these into fragments, many of which are well rounded, so that contemporaneous erosion was at work.

All but a few of the larger pebbles in the Skerries Conglomerates are of acid igneous rocks, with a textural range from quartz-rhyolite to granite, and are very fresh and well preserved. The finest are compact, of a clear bluish purple tinge, and consist of a cryptocrystalline matrix that may once have been vitreous, in which are phenocrysts of quartz, often corroded, and felspar. At the other extremity of the suite are granites (Plate 2), Fig. 4 with a good deal of micropegmatite, but no porphyritic crystals. The majority link these extremes. They contain the same phenocrysts as the felsites, but the matrix, no longer cryptocrystalline, comprises two or three varieties of crystalline mosaic, most of which is relatively large of grain, and sometimes is beautifully micro-pegmatitic (Plate 2), Fig. 5. In some of the pebbles the texture varies rapidly, even within a single slide. Good-sized grains of pleochroic epidote, often in clusters, are frequently present. The felspar is a sodium variety near to albite, with which the micro-pegmatite is often in optical continuity, and it is evident that all are products of one and the same acid sodium-magma. None of them are 'foliated'.<ref>On account of the great importance of these boulders, the slides were submitted to Dr. Teall.</ref> The rocks from which these interesting pebbles are derived are never seen in situ.

Throughout the Skerries Grits, whether on the other islets or the mainland of Anglesey, the same acid igneous rocks contribute the majority of the larger pebbles, and they play the same role in the pebbly portions of the Church Bay Tuffs, as well as in the pebbly beds of the Amlwch alternating series, which are close to the junction of the groups, near the East Mouse. On the Middle Mouse is a variety composed entirely of micropegmatite with a few phenocrysts of albite. Not infrequent, but never in large fragments, are spilitic lavas of Gwna type.

Less in number, but of great stratigraphical importance, are pebbles of hard fine green grits, fine purple grits and hard purple mudstones, white quartzite, scarlet jasper, and schistose grit. Those of white quartzite (one of which was two inches in diameter) and of jasper were first found upon The Skerries. The jasper has all the characters of that which is known only in the spilitic lavas and limestones of the Gwna Beds, and the quartzite is not of Holyhead but of thorough Gwna type. The green grits are also very common in (though not confined to) that group. Many schistose fragments occur throughout the Skerries Grits, but in most cases their foliation is parallel to (though stronger than) that of the matrix of the grit, and might, perhaps, have been induced *in situ.* Some, however, can be found whose foliation is undoubtedly their own, for it is oblique, sometimes at a high angle, to thab of the enclosing rock. The largest of these that has been collected and preserved is shown in (Figure 2). It is a markedly schistose, but not much reconstructed, grit. Small fragments of holo-crystalline schists, with well-formed foliated micas have also been found (in the same relation) in microscopic slides (E10384) [SH 306 929].

It is certain, therefore, that a foliated complex exists within the region, whose metamorphism is older than that of the Mona Complex.

A few of the pebbles, in their turn, contain little fragments of yet older rocks. A purple ashy grit pebble from the Middle Mouse encloses pieces of the spilitic lavas: Those of quartzite from the Skerries Conglomerates contain fragments of tourmaline and of mica granulites. The formation from which these have been derived must be of extreme antiquity.<ref>As The Skerries are difficult of access, it may be well to mention that the same pebbles are well seen on the East Mouse, though not so numerous or so large, and usually deformed (p. 318). The East Mouse can be reached easily by a boat from Amlwch Port.</ref>

Deformation and foliation The Skerries Grits have been unequally deformed. In some parts the pebbles are smooth, oval, and uninjured internally even when quite small, and the secondary products have no definite orientation. Usually, however, the chlorite of the matrix is well foliated, and the sericitised fragments are drawn out into lenticular augen. The power of the deforming forces may be gauged by the fact that along certain zones that cross The Skerries large pebbles of rhyolite and granite are drawn out into thin lenticular strips (Figure 3). Some degree of reconstruction always accompanies the deformation. The matrix is full of well-formed secondary mica, and the sericitised felspathic fragments have become streaks of sericitic schist. Minute needles of actinolite have appeared among the foliated chlorite, and they, as well as the edges of the micas, penetrate the clear quartz, and also felspar, of many of the clastic grains. In fact the less resistant portions of the rock have passed into the state of a chloritic mica-schist.

The Tyfry<ref>Pronounced 'Tyvry'.</ref> Beds

In the eastern parts of the Middle Region, and along the Malldraeth, where the metamorphism is of a low order, many strips of ashy grit and phyllite have been separated from the surrounding Gwna Beds. Most of them are green, but some are purplish. The contents of the ashy grits link them to the Church Bay Tuffs and Skerries Grits, with which they have accordingly been coloured. They are composed essentially of albite and quartz, with some large flakes of clastic mica, often much chloritic matter in the matrix, and iron-ores. Albite is usually in excess of quartz, and where the rocks are not much deformed the broken albites are sub-angular, often angular, sometimes with re-entering angles. Some are lath-shaped, but most are tolerably broad, and with polysynthetic twinning. The quartz is angular, sometimes tending to be square, as in the Skerries Grits.

Composite fragments are also plentiful. The most abundant are spilitic lavas, albite trachytes, and keratophyres, some of the trachytes containing porphyritic albites with the same broad habit as the isolated broken crystals. Fragments of a quartz-felsite are also present. Many of the spilites are. deeply hæmatised, and an albite grit on Llanddwyn, associated with jaspery phyllite, is luematised throughout. About Nantnewydd, Llangefni, and especially at Trefdraeth Church, are beds in which the matrix is a pale green epidosite of the same kind as that of the Church Bay Tuffs and Skerries Grits, and some of the finer bands are largely epidositic dust. These are true tuffs, and some of the ashy grits of Tyfry and other places are but slightly mixed with epiclastic sediment. Their volcanic materials were evidently drawn from the same sources as those of the pyroclastic rocks of the north and west, and they are therefore best placed with the Skerries Group. But their spilitic fragments, occasionally haamatised, and the hmmatisa-tion of some of the beds themselves, link them closely with the Gwna spilites, which are, in their vicinity, developed on a large scale.

Epiclastic fragments Besides these pyroclastic fragments the grits contain some epiclastic ones of great interest. These are of a true granoblastic mica-schist (Plate 2), Fig. 6, composed of a quartz-mosaic with a little sodium-felspar, white mica, and a chlorite that may be after biotite. The rock is very clean and holocrystalline, the mica well developed, and the foliation strong and even. It might be matched among the adjacent rocks of the Penmynydd Zone, but for two characters. These are that it is poor in epidote, and that it contains tourmaline; whereas the Penmynydd Mica-schists are very rich in epidote, and tourmaline is an extremely rare mineral in them. The only true tourmalinic member of the Complex, the hornfels (pp. 93–99) is nothing like so rich; and, from its field relations, cannot have been the source either. In every one of these fragments that has been seen (save one or two that are very small), tourmaline is present, sometimes lying across the foliation planes (E9839) [SH 517 767], (E10009) [SH 435 743], (E10117) [SH 388 632]–(E10118) [SH 388 632]. One pebble, a millimetre in length (E10074) [SH 405 719], contains no less than nine crystals of it; so that the rock is really a tourmaline-mica-schist. There can be no doubt that it belongs to some very ancient series, whose foliation is older than that of the Mona Complex.

Deformation At Tyfry the coarser grits are, for a short distance, free from cleavage, but this is exceptional. In all the other strips that are shown upon the map they are schistose, though usually less so than the surrounding Gwna Beds. About a mile beyond the Malldraeth Marsh, however, they are to be recognised only by their larger fragments, the finer parts having passed into a schist indistinguishable from the Gwna Green-schist. There is little doubt, indeed, that they are separable only in tracts of minimum deformation, and that their boundaries, as drawn, are not stratigraphical but arbitrary. It is impossible to distinguish the finer grits and phyllites with which they are associated (and which have been coloured with them on the maps) from those of the Gwna Beds themselves. No unconformity whatever can be found, and it must be admitted that considerable tracts of them have probably been included with the general schistose mélange which has been termed the Gwna Green-schist.

The Gwna Group

This group, which is found at intervals all over the Island, is here named after the vale of the little River Gwna, near Bodorgan Station, that being the only district in which every subdivision of the group is to be found.

The subdivisions in question are:

Alternating Green Grit and Phyllite (usually as Mélange)

Spilitic Lavas and Tuffs

Albite Diabases

Keratophyres

Quartzite (and black quartzite)

Limestone

Graphitic Phyllite

Jasper

Jaspery Phyllite

The diabases and keratophyres are closely associated with the spilitic lavas and tuffs, and constitute a single volcanic suite. The formation has a wider distribution than any other in the Island, being found at intervals all the way from Carmel Head to Garth Ferry. Except where it is involved in the Penmynydd Zone of metamorphism (a special phase which will be considered in connexion with that zone), this group has undergone less mineral reconstruction than the rest of the Complex; but it has been excessively broken up, so that bedding can seldom be traced for more than a few yards. The rocks that will here be termed Alternating Beds, Mélange, and Green-schist are undoubtedly phases of one and the same formation in different states of destruction and reconstruction: but the two last occupy so much more space than the first that they may be regarded, for Anglesey, as the normal states of that formation. On account of their great importance they will be allotted separate headings in this chapter. They have a characteristic aspect, and are not difficult to recognise, even without the aid of the other members of the Gwna Group.

Alternating Grit and Phyllite

Passage Beds.The original bedding is hardly ever seen for more than a few yards at a time, except in the zones of minimum deformation that skirt the Malldraeth Marsh. Here we find alternations of banded green phyllites and rather fine green grits, with purplish beds that graduate into the jaspery phyllites. They contain minute clastic micas, and the grits have a good deal of angular broken felspar which when determinable, is found to be allied to albite. The phyllites alternate near Llangefni with the fine epidosites, and the grits graduate by increase in the size of their fragments into the Tyfry Ashy Grits (with which, for convenience sake, both have been coloured on the maps); but both graduate, in the other direction, into the general mass of the Gwna sediments. The group must therefore be looked upon as a zone of passage from the Gwna Beds proper into the pyroclastic Skerries Group, and is decidedly more felspathic than the normal Gwna sediment. These passage beds, though traversed by more or less cleavage,, retain their bedding well, and it is fine and even. Minute filmy sericite has often developed along the cleavage, and some of the phyllites are excessively chloritic.

Alternating Beds

A picture of the normal Gwna sediment can be obtained only by consideration of such original characters as can still be made out in the mélange and green-schist. The materials were, speaking generally, grit and shale, the latter, however, having been reconstructed everywhere. Now, from an inspection of the strips and fragments of grit that crowd the mélange, it will be seen that the beds that were broken up to make them could not have been thick or massive (the few massive ones are ashy, and probably nips of the Tyfry Beds). A foot or two was probably the limit, and the average thickness not more than a. few inches, much the same being, apparently, the case with the shales; the series was, therefore, one of rapid alternation.

The grits are grey on parts of the northern coast, but everywhere else are greenish, with much chlorite in the matrix. Some are hæmatised. But nearly all of them are siliceous enough to weather white and quartzite-like. Not only are they much less felspathic than the Tyfry Beds, felspar (though always present) being often a mere accessory, but fragments of spilitic and other volcanic rocks are only locally abundant. Their felspar is of the usual sodium types, often albite, with some oligoclase, but orthoclase is also present. Rutile, tourmaline, and zircon are not uncommon, but garnet very rare. Some scarlet fragments are present, but whether these be jasper is not yet certain. The quartz is often of plutonic type, and there are fragments of sodium-granite, micropegmatite, albite-quartz-felsite, hypabyssal albite-rocks like those of The Skerries, keratophyre, and spilite, with some of schistose grit, quartz-schist, and mica-schist. Their texture varies usually between fine and medium, coarse grits with grains one-eighth of an inch across being rather rare. The form of their grains is that of true sediments, for though many are sub-angular, many also are well rounded. Besides the grits that are still visibly clastic, a fine siliceous sediment is an important member of the series, especially in parts of the Aethwy Region. It is a very fine hard granular material, sea-green with chlorite, but weathering white, and on weathered faces remains of clastic texture may sometimes be detected. A felspar of low refractive index is present as well as quartz, but the rock must have been an unusually fine siliceous sand. It occurs in seams that seldom reach a quarter of an inch in thickness, with partings of fissile matter, once a shale, so that the fine-bedded, alternating type of sedimentation is pronounced. These fine siliceous beds appear to have preserved their bedding ky reason of their amenability to folding, but they are almost the only ones that have preserved it.

Autoclastic Phyllite-and-Grit Mélange

This is really a gigantic autoclast, extending over many miles of country in several districts, as does the 'crush-conglomerate' of the Isle of Man, but on a still greater scale. It consists essentially of lenticular strips and lumps of grit (Figure 4) and (Figure 5) floating in a schistose matrix that sweeps curving round them (Plate 7), (Plate 23).

Rounded fragments are rare, but in the Cemaes district the mélange is more of a pseudo-conglomerate than elsewhere, having less parallel structure, both in me forms of the lumps and the nature of the matrix. Almost everywhere the lumps are phacoidal, their boundary curves meeting at sharp angles in the direction of the strike. The matrix is now a fine greenish or pale straw-coloured schist, composed of minutely flaky sericite (see p. 67) in curving sheets and seams, always with a considerable quantity of chlorite and some finely granular quartz. In the matrix of the northern breccias these minerals are but feebly developed, and the colour may be a dull grey. The matrix not only sweeps round the phacoids, but often invades them, so that they are traversed by films of it, along which they tend to part. And where the larger augen are not close together, it is full of smaller and smaller augen, as well as detached clastic grains that have been torn from them. In the cores of the augen the clastic grains retain often their original rounded outlines quite uninjured, but along the margins and the fissile films they are deformed and flattened. This may take place without 'crushing', but it is possible that matter has been stolen from the sides of the grain, thus thinning it. Undulose extinction is general, but far from universal. The matrix of the grit has become a mosaic, with which almost all the grains, felspar as well as quartz, interlock, especially at their 'ends', in the direction of the strike; so that the old clastic outlines are better seen in ordinary light than between the nicols. Many of the grains have broken up, optically, into a mosaic. In the unsheared areas there is a tendency to marginal enlargement of the grain at the expense of the matrix— In the shear-zones the mosaic of the grain becomes gradually incorporated with that of the matrix, into which it merges and finally disappears. The crystalline elements of such mosaic tend to be fusiform and nemablastic, especially towards the ends of the augen. These grit-augen are often excessively quartz-veined, especially in the Aethwy Region. There is usually a system parallel to the minor axis, doubtless a 'stretching' system, but more and more come in, sometimes to such an extent that in the meshes of their intricate net-work the original structure of the grit can hardly be made out.<ref>This mélange has been treated here because it is the usual condition of the alternating Grit-and-Phyllite member of the Gwna Group, which could hardly be described without reference to it. But it must not be forgotten that the Gwna Group as a whole is usually in the condition of an Autoclastic General Mélange in which *all* the members of the group are involved (Plate 22) and even sometimes the Tyfry Beds as well. (See Chapter 7.) But in that mélange it is generally possible to separate the several members on the map, whereas the mélange just described has to be treated as a unit even on the six-inch and .0004 maps. The latter, moreover, broken as it is, functions as a stratigraphical horizon within the group.</ref>

The Gwna Green-Schist

This term is proposed as a brief convenient working designation for a widespread type to which, though undoubtedly a petrological unit, it is not easy to give a concise name based either upon its structures or its mineral composition. That it is confined, so far as is known, to the Gwna Beds, appears to be due to an accident of the folding, by reason of which a particular stratigraphical horizon has been brought on to a particular tectonic horizon over the greater part of Anglesey (see Chapters 7, 8).

The type is more easy to recognise than to describe. It is a pale sea-green schist, whose fissile seams tend to weather to a straw-colour; and usually dull upon the foliation planes, because of the small size of its foliating minerals. The hard parts are really much more siliceous than would be expected from their green colour, and often weather nearly white. Its aspect in the field is more irregular than that of any other member of the Complex, for it is not at all platy or evenly laminated<ref>Where a platy type does appear, it is really a survivor of the fine siliceous beds described on p. 65.</ref>; and hand-specimens have an undulating, almost lumpy, surface, apt also to be scored with fine striae, due to nemablastic foliation. This aspect is due to its being built up of lenticular overlapping sheets, often rather short and thick, of hard siliceous matter (too irregular to be called augen) with winding fissile seams between them, the whole being usually corrugated, sometimes cross-corrugated also. The essential constituents are quartz, chlorite, and a white mica, usually 'sericitic ' but sometimes in larger, though never well-formed flakes.<ref>Where, however, as in the Aethwy and Middle Regions, the rocks approach the Penmynydd Zone of metamorphism, the micas rapidly increase in size, and the grade of crystallisation rises generally.</ref> An alkali felspar, which where determinable is albite, seems always present, but not abundantly. There is usually a little haematite, and opaque iron-ores. The proportion of mica to chlorite is very variable; sometimes one is in excess, sometimes the other. The chlorite is apt to be in irregular sheets and clots as well as in minute flakes, but never in well-defined crystals; and there is generally less of it than would have been expected from the colour of the rock. A carbonate is not uncommon. Tourmaline, garnet, apatite, and zircon, have been observed, but heavy minerals are rather rare. In the more altered portions, a pale actinolite seems to be developed among the chlorite in minute needles, but its presence is obscured by that of the all-pervading sericite.

The irregular aspect of the rock is determined not merely by its megascopic but by its microscopic structures' (Plate 9), Fig. 2. The hard parts are composed of a colourless mosaic (most of which is quartz, with a little alkali felspar), shot through and through with minute flakes of chlorite and sericite. But the texture varies from crypto- to macro-crystalline, and the variations are frequent, often so sudden that the finest may adjoin the coarsest. In much of the mosaic the elements are isodiametric, but almost as often they are fusiform, interlocking, however, diablastically, just as the isodiametric elements do. It is this nemablastic mosaic (called by Blake 'elemental orientation') which imparts to the type its linear foliation, so pronounced in the Aethwy Region. It may adjoin the ordinary mosaic, parted perhaps by a sericitic film; and may contain fusiform grains of alkali felspar as well as of quartz. The fissile seams are almost wholly sericite and chlorite. They divide the hard mosaic into lenticular plates, often stout and short; but these tracts are apt to be very jagged and irregular. Undulose extinction is general, and often pervades all the elements of a mosaic, especially the nemablastic portions, producing a confused effect called by Blake 'micro-spectral polarisation'.

Several varieties may be noted. One is a purple schist or phyllite, which, however, is not the jaspery phyllite, for it contains albite, and differs from the green-schist merely by its richness in haematite. Another is a quartz-schist, nearly white (Plate 8), which again is but a variety of the green-schist so rich in silica that felspar, chlorite, and mica sink to mere accessories. Such felspar as has been detected is albite. The mosaic is fusiform, but so strong is the nemablastic foliation that the tracts of this, about which wind the sericitic films, are themselves fusiform, being several inches in length and about half-an-inch thick, with stout lenticular cross sections. On its pitch escarpments this type of schist resembles nothing so much as a bundle of hard white or cream-coloured pencils, showing all down their subtranslucent sides the fine-drawn threads of their internal nemablastic foliation. Lying among these nemablastic pencils are long lenticular seams of venous quartz (Figure 6) and (Plate 8), which on the escarpments are seen to behave as convoluted sills, conforming in. a general way to the corrugations of the nemablastic seams, but frequently transgressing them at' low angles, as well as anastomosing, swelling, and thinning in a most capricious manner. They in their turn are slightly nemablastic. Undeformed augen of venous quartz abound, some containing large twinned albites.

The Gwna Green-schists are traversed by vast numbers of quartz-veins at all angles, most of which are only a small fraction of an inch, but many also an inch or two in thickness. One series has separated along small cross-wrenches, imparting to the rock a look as if tied up by little cords at intervals; and some of the veins that cut across the dominant nemablastic foliation are themselves traversed by a similar one that is in line with it, softening the sharpness of their outlines and making them seem to melt off a little into the adjacent rock. Movement therefore was taking place at intervals, between which the rock was sufficiently brittle to be fissured. Yet the later movement was on the borderline of the molar and the molecular, for the veins are seldom shifted by it. In fact, the amount of segregated quartz in the Gwna Green-schist, especially in the Aethwy Region, is enormous, amounting sometimes to local metasomatism, though there is no reason to suppose that the silica was introduced from without. It is a product of the metamorphism, separating at several different episodes, and the presence of large albites in it shows that the temperature was still high.

Origin of the Type — The material of the Gwna Green-schist is without doubt of epiclastic origin. In almost all microscopic slides (unless taken from zones of exceptional alteration) a few clastic grains are to be found, and many schists that show no signs of such externally are crowded with small ones, many of which, however, have undergone partial absorption. Its nemablastic mosaic is identical with that into which the grits pass locally by deformation. Moreover, the Green-schist, when considered on the large scale, is found to pass gradually into the Autoclastic Mélange. If we cross the Gwna Beds of either the Middle or the Aethwy Regions in an easterly direction we find first, as we leave the Penmynydd type, a green-schist' with well-developed micas; then a normal green-schist, still completely reconstructed; then (the rock remaining the same in every other respect) isolated clastic grains appear; then small knots of them; then well-defined lenticles; until, as these increase in number, the type changes to that of the Autoclastic Mélange, whose lepidoblastic matrix differs from that of the schist merely in being rather less well-crystallised.

Put conversely, there is a progressive metamorphism from the Alternating group, through the Autoclastic Mélange, into the Green-schist. In the earlier stages we have disruption and deformation with subordinate mineral reconstruction; in the later, mineral change is obliterating the effects of deformation. There can be no doubt that the Green-schist is a curiously altered condition of a rapidly alternating grit and shale series, that its lepidoblastic schists represent the shales, and that the hard portions are the grits, now in the condition of siliceous mosaic, some nema-, some granoblastic. But the bedding has totally disappeared, and the schist, in spite of the low grade of anamorphism, often retains no traces of its origin.

The following analyses have been made of Gwna Green-schists and of a grit from the Autoclastic Mélange.

	I	II	III	IV	V

SiO_2	72.76	74.19	62.38		63.65	5315
TiO_2	0.45	not est.	0.46		0.60	0.55
Al_2O_3	12.49	14.52	15.35		17.10	23.15
Fe_2O_3	1.07	0.75	1.75		1.17	1.11
FeO	3.69	2.04	4.77		5.12	5.95
MnO	0.41	not est.	0.20		0.37	0.07
CaO	0.43	0.08	2.36		0.28	0.29
BaO	0.03	not est.	0.02		0.03	0.04
MgO	1.57	1.09	2.80		2.42	3.08
K_2O	2.11	1.21	0.21		3.63	5.22
Na_2O	2.10	4.74	3.64		1.81	P84
CO_2	0.34	none	1.70		none	none
SO_3	0.06	not est.	0.04		0.02	0.03
P_2O_5	none	not est.	014		011	017
H_2O at 110°	—	0.15	—		—	—
H_2O (combined)	2.79	1.13	3.76		3.78	4.69
	100.30	99.90	99.58		100.09	99.94
Spec. Grav.	2.735		2.768		2.748	2.784

Nos. I, III, IV, V; were kindly made by Mr. Edmund Dickson, in the year 1900, in aid of the present work. He remarks that a little carbon is present, and that S03 belongs to sulphates soluble in hot dilute HCl. It is probably from the oxidation of pyrite.

I. Pale green grit, lenticular mass in Autoclastic Mélange. Same type but not collected at same time as (E9825) [SH 559 764]. At forking of road between Tai-lawr and Llansadwrn Church (Pencraig of six-inch map). Quarry on south side of road.

II. Hard siliceous part of Gwna Green-schist. Roadside, at a farm (Ysgubor-fawr of six-inch map), 442 yards north-east of Soar Smithy, north of Bodorgan Station (E10426) [SH 388 724]. Anal. J. O. Hughes.

III. Typical Gwna Green-schist. Roadside, 760 yards north-east of Garth Ferry Inn (at B.M. 77.0 on six-inch map) (E9911) [SH 586 745].

IV. Typical Gwna Green-schist. Same locality at Llansadwrn as No. I, but from quarry on north side of road (E9934) [SH 559 764],(E9935) [SH 375 781], (E9936) [SH 375 781], (E9937) [SH 326 719]

V. Gwna Green-schist. Locality record lost, but from near Llansadwrn.

Comparison with the composite analyses given on p. 49 shows that these rocks are not normal grits and shales. Iron is high throughout, and the relative proportions of Fe_2O_3 and FeO are the reverse of those in ordinary sediments. In I and II the alkalies are high, as well as the aluminium, and sodium tends to be higher than potassium, due respectively to muddiness of the grits and to the presence of albite. In III, IV, V the silica, too high for a shale, is due to the intimate interfelting of thin seams of grit, which could not be eliminated in collecting. The relations of sodium to potassium are variable, and there seems less albite in (E9911) [SH 586 745] than the sodium would lead one to expect. No. V is nearer to an aluminous shale than the rest are. The variability of CaO and CO_2 is due to a capriciousness in the distribution of calcite.

As in the case of the Green-mica-schists of the New Harbour Group (see p. 50) the persistent green colour of these rocks conveys an impression (shared, again, by Dr. Teall when traversing them in 1911) that they contain an admixture of volcanic dust, and this is borne out by the analyses. They are rich in iron, their alkalies are high, and their magnesium somewhat (though less than would be expected) above that of normal sediments. In the Gwna Series, as in the New Harbour Group, there are spilitic lavas; and in this case tuffs are also known. It is reasonable to suppose that fine dust of their explosions was carried in small quantities (probably from some distance away) over the basin of deposit throughout the period represented by the Alternating group, and that this accounts for the composition and colour of the rocks. Moreover, the green colour is most pronounced in the Aethwy and Middle Regions, and those are the regions where the spilitic lavas and their tuffs are developed on the greatest scale. On the northern coast the colour is feeble and often absent altogether, and there, accordingly, the development of the volcanic rocks is feeble also. A noteworthy difference between the New Harbour Beds and the Gwna Green-schist is that the former contain an unusual proportion of titanium, the latter very little. This, again, reflects the composition of the lavas; for those of the New Harbour Group are rich, those of the Gwna Beds (whether in their original or schistose condition, see pp. 74, 78) poor in that element.

The Spilitic Lavas

The Spilitic Lavas, where unmodified, are massive, and thoroughly igneous-looking, but too fine in grain for their texture to be visible by the unaided eye. Under the band-lens, on polished or wet surfaces, a mesh-work of little crystals can be seen, with, sometimes, a few felspar phenocrysts. The normal colour is a pale grey-green, but reddish mottling is rather common, and this may extend itself until the whole rock is of a uniform low purplish tint. Far more striking is their aspect in the field, for, where undeformed, they always display the characteristic ellipsoidal or pillowy structure, sometimes in great perfection. On Llanddwyn Island and among the dunes of Newborough, boss after boss is built up entirely of these curious pillowy bodies, often with small interspaces (which are usually filled with jasper, but sometimes with limestone), often pressing one another's sides into gentle re-entering curves that impart a strangely vivid sense of softness, and suggest the rolling over and over each other of pasty masses, kept from adhering by immersion in such a medium as the water of the sea. Under the incessant sandblast, they are not obscured by soil or vegetation; are not blurred even by a weathered crust; are as fresh and clean at the surface as they are within; and look almost as if their motion had been arrested but yesterday (Plate 3), (Plate 4). Two types of pillow can be distinguished: large ones, a yard or more in length and ellipsoidal, and smaller ones that are seldom a foot in diameter and tend to be globular. No differences of importance have been seen between the inner and outer parts of the pillows, but there is often a slight concentric banding, and a much darker skin, rudely banded or even fissile, its banding sometimes broken up into a fluxion-breccia. Steam-cavities are small, rare, and of the spherical form usual in spilites, but at Cerrigceinwen there is a rock so vesicular as to be in parts almost a pumice. The vesicles appear to be as numerous in the dark skins as in the pale hard cores of the ellipsoids. Little spherulites, about 1 millimetre in diameter, are to be seen in places, especially in the dark skins. They are usually in bands, but sometimes these bands are concentric shells, parallel to the surfaces of the smaller pillows' and conforming even to their in-pushed curves. As a rule, the spherulites occur towards the margins of the pillows, but there may be shell within shell, even to the core.

What may perhaps be called the normal spilite (Plate 5), Fig. 1 (E9895) [SH 396 645]<ref>Nearly all the slides and specimens of the Gwna spilites, tuffs, diabases, and keratophyres, as well as of the spilites of p. 54, were kindly examined by Dr. Flett.</ref> is composed of lath-felspars and a very pale brown augite such as is usually found in rocks of this kind. There are often a few felspar phenocrysts, occasionally opalescent and usually small, though varieties exist that are porphyritic to the unaided eye, whose phenocrysts are apt to be in groups. Specks of iron-ores and sphene are frequent. Olivine has not been found in any of the writer's slides, but good, pseudomorphs after it occur in some from Newborough, kindly lent by Prof. Grenville Cole, and have been figured in his paper. The augite is often in elongated grains, not eumorphic, but apt to be moulded over the ends of the felspars, so that the structure may be described as sub-:ophitic. In another type no pyroxenes can have been present, the rock being composed almost entirely of slender laths of felspar. In both kinds the felspar of the body, wherever it can be determined, is albite, or some allied sodium variety. The larger phenocrysts are albite, often with a turbid core. Glassy varieties (E11222) [SH 518 785]–(E11223) [SH 518 785] are found, always much chloritised, but still isotropic in some cases, and even retaining traces of the perlitic structure of the tachylite. One of these. (Plate 5), Fig. 3 was described by Prof. Grenville Cole for the present writer (*Quart. Journ. Geol. Soc.,* 1902, pp. 430–31) as having been first brecciated during viscid flow, so that a certain blending took place between the firmer glass-fragments and the new material from the matrix that gathered round them. Banding, often very delicate, resulted from the movement of the mingled mass; after which came a second brecciation, affecting both the fragments and the consolidated parts of the banded matrix.

A marked feature of the Gwna spilites (and indeed all the spilites of the Mona Complex) is the frequency with which they display variolitic structure, sometimes in great perfection. It may be remarked that the best variolitic developments have not, so far, been found to be coincident with the strongest developments of the pillowy structure. In some of the augitic rocks no variolitic arrangement is discernible. In others, the little felspars begin to form the rudiments of sub-radiate groups and brushes, and sometimes the augite rods also are grouped in the same way, so that we have the beginnings of a variolitic structure. This can be traced in other slides through further stages, until the rock would certainly be called a variolite. The highest developments are reached, however, in the anaugitic rocks, in some of which the whole body is a plexus of radiate groups and brushes of delicate lath-felspars, as in the beautiful variolite (E9843) [SH 520 775] of (Plate 5), Fig. 2.

The spherulites with definite boundaries, already described as visible to the unaided eye (E9956) [SH 398 650], are usually found in the glassy rocks. They are sharply separated from the chloritised body, and are composed of radiating lath-felspars, closely set, and of extreme delicacy, giving sometimes a good dark cross in polarised light. Partly developed radial groups of microliths may also be found in the glass, which, in (E11222) [SH 518 785] (Plate 5), Fig. 3, are arranged in bands parallel to the periphery of the ellipsoid. In the dark skins that enwrap some of the pillows, very perfect spherulites, both simple and compound, occur, but they are composed of quartz, and set in granular epidote, all igneous texture having disappeared.

The Gwna spilites display in a high degree the decomposition now known to be characteristic of such rocks. Fresh augite has been found in a few slides only, and the felspar is generally riddled with cavities now filled with chlorite, epidote, sericite, calcite, and quartz. The glasses have been converted into chlorite, epidote, quartz, and iron-ores. Often the decomposition is complete, and the felspars are mere pseudomorphs. The steam-cavities are filled with the same secondary minerals. Hzematisation, unusual in other British districts, is very frequent in the Gwna spilites, and is the source of the purple nolouration already noted. When haematite is abundant chlorite is rare, and sometimes every mineral of a lava has been replaced by haematite except the felspar, which then, whether fresh or sericitised, is clearly outlined by it, as in (E9843) [SH 520 775], (Plate 5), Fig. 2. Although the felspar, where fresh, is albite or one of its allies, yet the frequency of complete decomposition shows that albitisation is far from general, and Dr. Flett considers that it has gone on to a considerably less extent than in Devon and Cornwall. That the process, where it occurred, was the same is shown by the occurrence of felspars with fresh margins and decomposed cores.

Finally, it can be shown in many cases that the decomposition, the hmmatisation, and the albitisation all took place before the shearing, and therefore before the great movements of the Mona Complex. There are spilites in which all the felspars have the cores decayed and the margins clear and fresh. Where such have been a little sheared many of the felspars are broken and slightly shifted along the planes of movement, sometimes a single crystal by two or three such planes. The fractures are unhealed, and the shifted fragments correspond exactly, margins to margins, cores to cores, each zone being in the same condition in each fragment.

The following analyses will show the relations of these rocks to the spilites of other parts of Britain.

	I	II	III	IV	V	VI
SiO_2	47.45	50.05	51.31	46.4	48.58	47.56
TiO_2	with Al_2O_3	trace	1.92	0.24	1.77	2.40
Al_2O_3	17.54	17.34	12.67	20.4	14.58	14.27
Fe_2O_3	2.04	3.18	0.54	6.9	1.89	1.63
FeO	7.44	7.92	7.99		7.65	6.80
MnO	not det.	—	0.45	—	0.46	0.30
(Co, Ni)O	not det.	—	? trace	—	0.03	0.08
CaO	10.96	9.06	8.17	7.7	9.80	10.95
MgO	6.72	—	2.19	3.5	6.36	4.90
K_2O	trace	—	0.54	0.54	0.43	0.27
Na_2O	3.93	4.43	5.21	6.93	4.02	4.61
H_2O at 110°	0.23	—	0.04	1.1	0.68	0.42
H_2O (above 110°)	2.67	—	2.31		2.93	2.65
CO_2	0.55	—	6.15	5.8	1.00	2.95

P_2O_5	not det.	—	1.37	—	0.45	046
	99.53	—	100.86	99.51	100.63	100.25

I. Boss south-west of Bryn Llwd, Newborough Dunes (E9895) [SH 396 645]. Anal. J. O. Hughes.

II. From close to the same spot. Anal. C. T. Gimingham (for which I am indebted to the kindness of Sir William Ramsay) in 1903 (E9895) [SH 396 645].

III. Tayvallich Peninsula, Argyllshire. Anal. E. G. Radley. Geology of Knapdale, Jura, and North Kintyre' (*Mem. Geol. Surv.*), p. 87.

IV. New Cumnock, Ayrshire. Anal. J. J. H. Teall. 'The Silurian Rocks of Britain, vol. I, Scotland' (*Mem. Geol. Surv.*), p. 85.

V. Mullion Island, Cornwall. Anal. W. Pollard. 'Geology of the Lizard and Meneage' (*Mem. Geol. Surv.*), p. 185.

VI. Tregiddon, Cornwall. Anal. E. G. Radley. *Loc. cit.*

Nos. I and II are from the large pillows, shown in (Plate 3). The rock contains fresh augite, and is hardly variolitic. No. III may very likely be of Pre-Cambrian age. Nos. IV, V, VI, are Ordovician. It will be seen that the Gwna lavas have the characteristic composition of the spilites, being basic alkaline rocks rich in sodium. They differ chiefly in the lack of carbonates (though carbonated specimens could have been selected); and of titanium, in which last they differ also from the other spilites of the Mona Complex.

Compared with those from other British districts, they are on the whole finer, perhaps more often glassy, and olivine is not quite as rare as usual. The tendency to variolitic structure is more pronounced than elsewhere. Though they have undergone the characteristic early decomposition, they have been less extensively albitised, but more often hmmatised, than the other spilites of Britain.

Azinite — The spilitic lavas are traversed at the north end of Llanddwyn by a six-inch vein of a heavy mineral (E11389) [SH 391 633] with good cleavage, about the hardness of orthoclase, and of a low plum-violet colour. Dr. H. H. Thomas examined it. It is biaxial with a tolerably wide axial angle, optically negative, and with a mean refractive index about 1.68–9; fuses before the blowpipe to a green glass, and gives the flame reaction for boron. It is therefore axinite. Axinite has not hitherto been recorded in Wales, nor, apparently, in Britain outside Devon and Cornwall. Its occurrence here is therefore of considerable interest. In the Pyrenees and elsewhere it has been found in association with diabasic rocks, but whether spilitic is not yet known.

The Tuffs

These are usually green, but sometimes haematised. Most of them are of medium grain, but some are agglomerates with fragments of jasper and blocks of the lavas that may be several inches in diameter. Some of these are isolated ellipsoids, as if detached by explosion during flowage under water. The tuffs are distinctly bedded and, at the north end of Llanddwyn, some bands of pillowy lava from one to two feet thick appear to be interbedded with them. They consist of a completely chloritised or haematised base in which are (sometimes with a few round grains of quartz) jagged and torn lapilli, sometimes vesicular, of highly felspathic lavas, identical in character with the adjacent spilites, some of them even delicately variolitic. They are true spilite-tuffs, and are of no small interest; for, if any doubt on the point could be entertained, they show that the spilites themselves must be regarded as contemporaneous outflows. Some are full of fragments of the banded glass already described, and are thus allied to the 'palagonite tuffs'.

The Albite-Diabases

Being externally dull 'greenstones' of medium grain, these present nothing special in their external appearance. They are composed of albite, pale brown augite, iron-ores now generally leucoxenised, and sometimes a few pseudomorphs that may be after olivine. Fresh augite is rather more frequent than in the lavas. Nearly all the determinable felspar is albite, in laths that penetrate the augite ophitically, but porphyritic varieties are occasionally, though very rarely, seen. Sometimes it is decomposed throughout; but there are many zonal felspars whose cores (Plate 5), Fig. 4 have been completely sericitised, while the margins are now clear albite, and in a few cases a core at least as basic as andesine (and probably more so) still survives. For the most part they appear to be sills among the spilitic lavas.

Hornblende-diabase — There is a sill on Llanddwyn composed of large plates of green hornblende and albite, some of which only is in ophitic relation, and large grains of leucoxene. With this may be considered the large epidiorites of Bodowen Warren, heavy green rocks with lustre-mottled fibrous pale hornblendes a third of an inch in length, and full of yellow epidote. Their felspar is albite, but is often almost entirely replaced by pleochroic epidote in large hypidiomorphic crystals, which here and there penetrate the plates of hornblende ophitically; and there are some iron-ores, partly leucoxenised. The hornblende is in well-formed plates, but contains good-sized cores of a nearly colourless augite, and is therefore, secondary. But it is older than part of the movements, for the product of its deformation is not a hornblendic but merely a chloritic schist. The adjacent Gwna grits and phyllite have been baked and at Bone Twni cove converted into a true adinole, composed chiefly of albite, with iron-ores.

Keratophyre

Where recognised *in situ,* this is a fine, dull-green, speckled rock. Small phenocryts of either albite or orthoclase, fairly preserved, are 'scattered freely in a fine matrix which is now green with chlorite. This has been composed essentially of minute rods of felspar, and there are grains of magnetite, but no recognisable pseudomorphs after ferro-magnesian minerals. The contents of conglomerates (pp. 62, 251) reveal that keratophyres must have been abundant.

Basic Schists

Catamorphic Schists — The tracts of undeformed spilite are never wide, and along their margins the lavas break down rapidly, so that even their pillowy structure may become inconspicuous in 100 yards across the strike. The soft skins' give way first, then the outer portions of the pillows, which break up along the concentric shells, the fragments shearing into phacoids, and the hard cores into larger phacoids, about which dark green schistose matter winds. This gradually increases at their expense, until all is converted into a dull green schist in which lenticular structure may hardly be discernible, as may be seen very clearly along the -western side of Llanddwyn. Internally the process begins by appearance of planes which break the felspar laths that lie across them. More of these appear until they are quite close together, by which time the ferro-magnesian minerals have been converted into a sheet of schistose chlorite, with grains of calcite and epidote. Such a rock, while showing no sign of igneous structure to the unaided eye, will still be full of broken felspars, and may be called a spilite-schist. The felspars then break further down into a micro-breccia, and igneous texture disappears. Finally the felspar breaks down chemically also, into kaolinous and epidotic dust with streaks of sericite, interfelted with the long-since schistose chlorite. Such are the chlorite-schists of Llanddwyn and other zones along the margins of the spilites; dull-green, with parallel structure, but no banding, rough upon the foliation-planes, unelastic, and shattering under the hammer. Where the spilites had been hmmatised, the resulting schists are purple, and may easily be confused with the purple phyllites that are often their associates. Rocks of this kind are built up of minerals that may arise as products of mere decomposition (though probably not of mere weathering); and are to be regarded as degradation-schists, their foliation not being anamorphic.

Anamorphic Schists — In the Middle Region, however, from Llyn Coron to the Cefni, there is a great zone of basic schist (p, 352), derived from spilitic-lavas (which will be called, from the crags of Cerig-engan, the Engan spilite), that is very different in aspect. It is compact, heavy, dark green, with a fine parallel foliation, smooth upon the planes, and with a faint lustre, sometimes even a banding due to thin epidotic seams, while wriggling epidotic veins cut the foliation, and is tough and elastic, not shattering under the hammer. This rock is a dense felt of chlorite, full of granules of pleochroic epidote, with some iron-ores (often octahedral), a varying amount of quartz, and minute grains that seem to be an alkali felspar. These are still the minerals of the degradation-schists, though they are far better crystallised and interfelted. With a higher power, however, the chlorite is found to be full of minute short needles of a pale green hornblende. The physical properties of the rock are therefore due, not merely to a better foliation, but to the presence of the hornblende. The rock is a true granoblastic anamorphic-schist, though of a relatively low order.

In the Aethwy Region there are also large tracts of basic schist that are just as certainly derived from these same lavas. Heavy, dark-green, while on the whole fine in grain, they are still better foliated than those of the Middle Region. A platy character is general, there is greater fissility, the foliation begins to show small corrugations in a hand specimen, and in the field is seen to be powerfully folded, while the divisional planes, especially towards the western margin where they approach the Penmynydd Zone, acquire a low but a decided lustre. Their mineral components are the same as in the group just described, but the crystal individuals are clearer and larger. Most noteworthy is the amount and the condition of the hornblende, a sure measure of advancing metamorphism. Minute in the Middle Region, this is now easily visible with a one-inch objective. The chlorite is shot through and through with it, flashing up, when the nicols are crossed, in countless needles, which in some cases approach 0.5 mm. in length. Perhaps chlorite even then preponderates, but the rock has become an actinolitic epidote-chlorite-schist. Thin pale seams are always present, and swell out locally to an inch or two. Some of these (Plate 9), Fig. 3 are composed of quartz and albite, others of albite only. Both minerals are quite granoblastic, interlock intimately, and both are penetrated by the actinolite. The albite may be untwinned, often shows two good cleavages, and is as clear as the quartz. It is therefore- a ternary felspar, having first crystallised from igneous fusion, then undergone albitisation, and finally total re-crystallisation during dynamic metamorphism. There can be little doubt that parts of these large tracts of basic schist are derived from spilitic tuffs and albite diabases, but such have been recognised, so far, at a few places only.

The following analyses of typical basic schists from the Middle and the Aethwy Region respectively show that their composition is essentially the same as that of the spilites, for the differences from any one spilite are no greater than those of the spilites from each other. There are two exceptions: the curious reversal of the proportions of calcium and magnesium in No. II (may this. be a slip of the pen in transcribing No. II?) and its ferric iron, for a consideration of which see p. 88.

	I	II	III
SiO_2	45.94	45.86	47.89
TiO_2	trace	0.97	—
Al_2O_3	17.39	15.83	—
Fe_2O_3	4.68	2.84	—
FeO	7.49	7.96	—
MnO	trace	0.32	—
CaO	11.05	5.64	—
BaO	not det.	0.02	—
MgO	8.29	10.76	—
K_2O	0.14	0.17	—
Na_2O	2.86	3.49	—
H_2O at 100°	0.24	—	—
H_2O (above 100°)	2.22	5.14*	—
CO_2	none	0.64	—
SO_3	not est.	0.17	—
	100.30	99.81	—

I. Chlorite-epidote-actinolite-schist (E10019) [SH 388 722] ('Engan spilite'). 220 yards east-north-east of Capel Soar Smithy. Anal. J. O. Hughes.

II. Actinolitic epidote-chlorite-schist (E9913) [SH 587 745]. Roadside, 850 yards north-east of Garth Ferry Inn. Anal. Edmund Dickson, F.G.S. *'Combined water'.

III. Similar schist, but with a little glaucophane (E10208) [SH 553 716]. Shore, 210 yards east-south-east of the church on the islet, Llandysilio. Anal. E. Greenly.

The Quartzites

These rocks are very massive and uniform, bedding being discernible at a few places only, most of which are on the northern coast; and on the whole are fine in texture, though clastic grains are usually to be seen under the hand-lens, and often by the unaided eye. Internally there may be a tinge of blue or green; and they are apt to oxidise to a light brown within a few inches of the surface, but all weather white externally. They are almost wholly composed of quartz, felspar being no more than an accessory, and sometimes absent. All the determinable grains are albite. Zircon, tourmaline, and rutile are generally present, and in some slides quite a number of the two first are to be seen, the zircon being sometimes in beautiful doubly-terminated crystals. A few of them are to be found enclosed in the grains of quartz, in which are also minute 'hairs' like rutile, and moving bubbles, all of which are characters of the quartz of granitoid or gneissoid rocks. Fragments of fine mosaic rocks are not uncommon, a few of which are granoblastic mica-granulites, and one or two of these are foliated and are true mica-schist (E10196) [SH 457 758]. Here and there is a bit of spilitic lava, and one small grain has been found that resembles the Gwna jasper. The quartz is well rounded on the whole, and closely packed, leaving little room for matrix, which in some cases appears to be entirely siliceous, but usually contains a little mica that is probably a product of original felspathic mud. The green varieties may have contained a sprinkling of spilitic dust. The following analysis was kindly communicated by the manager of the Porth Wen Silica Works. The rock is from the large boss of Graig Wen, close to the northern coast, which has long been quarried, and is a typical Gwna quartzite.

SiO_2	96.40
TiO_2	0.05
Al_2O_3	0.84
Fe_2O_3	0.31
CaO	1.22
MgO	0.21
K_2O	0.16
Na_2O	0.04
Loss at 109°	—
Loss over 109°	0.34
CO_2	Nil.
P_2O_5 and SO_3	Nil.
	99.57

Dried at 109°. Anal. J. W. Mellor, D.Sc., Director of the County Pottery

Laboratory, Stoke-on-Trent, March, 1909. aterial composite, from a number of blocks then at the Basin Wharf, Stoke-on-Trent.

The amount of lime is remarkable, for it cannot have been calcite, and in two slides (E10953) [SH 398 948]–(E10954) [SH 399 947] of the rock no lime-silicate is to be seen, unless the mica be a margarita, and even then the lime would be too high. In any case, it will be seen that this rock is more siliceous than any part of the Holyhead Quartzite, and Dr. Matley was informed (*Quart. Journ.,* 1899, p. 670) that the same rock had yielded 99.60 per cent. SiO_2.

Metamorphism

An old secondary enlargement of the grains, anterior to the regional metamorphism, and resembling that found in ordinary quartzites of non-metamorphic regions, can here and there be detected; but it has been obliterated for the most part, and the union of the grains with the elements of the matrix, which is very common, and has in great measure destroyed their epiclastic relations, is due to incipient granoblastism. The matrix has become finely granoblastic, and its micas are often foliated, sometimes enwrapping the clastic quartz, but more often penetrating it after the manner of a true schist. Along planes of deformation the clastic grains begin to break down into a mosaic like the matrix, which grows at their expense. Undulose extinction is common along the northern coast, where the rocks are less reconstructed.

The Quartzite of Mynydd Bodafon has peculiarities of its own. Where unfoliated, this is full of unoriented mica like that of the adjacent hornfels, it has a 'glassy' fracture, and there is reason to think that it has been thermally affected by the granite. It is rich in zircon, one perfect crystal of which (Figure 7) has been broken and shifted, but not along any visible plane of rupture (E10710) [SH 473 840]. Between the shifted parts a little of the ordinary mosaic of the rock has forced its way, showing that the zircons are not products of the regional metamorphism, but (though perhaps thermally enlarged and perfected) are old clastic elements. Clastic quartz is not often to be seen in this rock, and was probably obliterated in part by thermal influence before the close of the regional metamorphism. The Bodafon Quartzite is of a delicate rose colour, by which fragments can be distinguished at once from every other quartzite in the Island. This is due to minute scales of haematite, which tend to be grouped in little aggregates, and as, in the foliated portions of the rock, these are elongated along that structure, it has the aspect of a true metamorphic mineral. The foliation however, is cut sharply by late planes of movement, along which are thin veins of quartz, and the haematite scales and aggregates follow these quite as much as they do the foliation; so that the mineral is later than all the metamorphism, and has no connexion with the old haematisation of the spilitic lavas. Some 'of its aggregates have rectangular outlines, as if about to build up larger idiomorphic crystals. Many small red clots are also seen, and the faces of the veinlets have a coating that soils the fingers, and when teased out in water is found to be composed of minute blood-red scales. It is evident that the staining (which extends into the adjacent schists) is quite a late product; and it may with confidence be ascribed to percolation from the Old Red Sandstone, which rests immediately upon this quartzite.

Black Quartzite

Only one or two thin beds of small extent are known, all on the northern coast; but much more of it must exist about the middle of the Island, for pebbles abound in the Arenig conglomerates of Bod-Deiniol, which indeed led the writer to search for it *in situ.* The rock is a true quartzite with conchoidal fracture due to the usual cement of secondary quartz, but is dark almost to blackness. There is russet oxidation on the joints, and a little in the matrix. Two colouring matters are present: one which transmits a faint brown light when cut thin, another which is opaque even in the most minute specks. The first occurs as films in the matrix, the second as little clots and granules that penetrate the clastic grains of quartz along their cracks and along the bands of inclusions that pass from grain to grain. Mr. J. O. Hughes has investigated the colouring-matter in (E10508) [SH 373 945]. He first found that the rock became almost white on being strongly heated. Then, decomposing six grammes of its powder by means of HF and a little H_2SO_4, he obtained a residue, which was black. This was filtered, washed, dried at 130°C, and weighed. On strong ignition the blackness disappeared completely, and there was a loss of weight equivalent to 0.35 per cent. of the rock. He does not wish this to be taken as an accurate estimate. But it is evident that the opaque particles, which are the principal colouring matter, consist of carbon. The others are probably a dense hydro-carbon.

Limestones

Amid many variations, two principal types can be distinguished: the Simple or 'Cemaes' type, and the Complex or 'Llanddwyn' type.

The Simple Type

The Simple type is, normally, a very massive blue-grey rock, rather fine in grain and uniform in aspect, and is composed of a mosaic of clean calcite. Small round grains of quartz, though very rare at Cemaes, are found in other places. From their form and distribution they are evidently clastic, but in the present condition of the rock interlock with the adjacent calcite. Films of carbon are generally present. Fine parallel bedding can sometimes be seen on the margins of the massive rock. Oolitic structure is not uncommon, and is highly developed at Cemaes Bay, where the rock is, locally, a true pisolite, for a good many of the grains are as much as a quarter of an inch in length. The larger ones are usually flattened, but there is no sign of this being due to deformation, and flattening is also common in the 'Pea-grit' of Cheltenham. Some have good concentric structure, otners are mere shells, the mosaic being finer in the oolitic rings than in the matrix. Many of the grains are compound (Figure 8), being composed of irregular groups of smaller grains enclosed within a large one. Two or three are quite common, and 13 were counted inside one large grain. They do not give a black cross. Some varieties are mottled, and the rock is generally much veined, not only with carbonates but also with quartz, by which fragments of it can be distinguished at once from those of the Carboniferous Limestone. It has been locally doloinitised, often in well-defined bands, and in some places dolomitised throughout, but without losing its general texture and aspect. The following analyses have been made:

	I.	II.
$CaCO_3$	96.560	53.11
$MgCO_3$	0.776	42.61
$Ca_3(PO_4)_2$	0.091	not est.
SiO_2	1.650	3.70
TiO2	—	not det.
Al_2O_3	0.040	0.44
Fe2O_3	0.076	
FeO	0.182	not est.
MnO	trace	not est.
K_2O	0.069	none
Na_2O	0.016	none
H_2O ('Combined')	2.270	not est.
C	0.228	not est.
	101.958	100.10
Percentage $CaCO_3$		53.11
$MgCO_3$		42.61

I. Fine limestone from Cemaes. Anal. Holland and Dickson. *Proc. Lpl. Geol. Soc.* 1890 *Cf.* (E10518) [SH 368 937].

II. Grey limestone. Pedair-groeslon kiln, 15/8 mile north of Menai Suspension Bridge (E10801) [SH 551 740]. Anal. J. O. Hughes.

The exact locality of No. I. is not given, but there can be little doubt that it came from the large quarry west-north-west of Gadlys (Penrhyn-mawr of the six-inch map) (E10518) [SH 368 937].

It is not easy to see with what element in such a rock so much water could be combined, and the high total suggests that the powder must have absorbed moisture between weighing and ignition; also possibly CO_2 absorbed by free lime in the $CaCl_2$ used. Mr. J. O. Hughes tells me that he treats his own $CaCl_2$ with a stream of CO_2 before using it. In No. II., Residues insol. in 'HCl' have here been placed under 'SiO_2', as it can be seen from thin section that there is no such material but quartz, in veins. The body of that rock is therefore a nearly pure dolomite. In the Cemaes rock there is so little granular quartz that the SiO_2 may safely be taken to be that of the veins. If, therefore, we eliminate this, as well as —say—two per cent. for moisture, it will be seen to be a nearly pure calcite-limestone.

The Llanddwyn Type

This class, well-developed on Llanddwyn, includes really several sub-types, differing considerably from one another. They vary, also, with great rapidity, the character of the rock changing often in the space of a yard or two, so that no adequate picture of the class can be conveyed in words. Three sub-types may be distinguished, namely, rose-coloured, green, and breccia-limestones. Nearly all of them are massive.

The first sub-type is the one that is most characteristic of the class. It has a delicate rose-colour, is of medium grain though saccharoid on fracture, and tends to be rather hard. All the rose limestones are magnesian, and the typical one analysed is a thorough dolomite.

Residues insol. in HCl	5.84
Al_2O_3 +Fe_2O_3	2.72
MnO	trace
CaO	29.93
MgO	18.76
CO_2	42.84
	100.09
Percentage $CaCO_3$	53.44
$MgCO_3$	39.19

Llanddwyn Island, south of Lifeboat Station (on six-inch map, at west end of Pilots' Cove Breakwater) (E10100) [SH 387 624]. Anal. W. Roberts, B.Sc. In a specimen from the same place Mr. J. O. Hughes found .016 $MnCO_3$.

The iron resides chiefly in thin brown skins between some of the elements of the mosaic, but the rose-colour is diffused throughout the grains, and so the carbonate of these rocks may be regarded as a dolomite with a slight isomorphous admixture of rhodochrosite. The tint of the rose limestones, indeed, is precisely that which is found in so many of the manganous salts; and it is known that surprisingly small quantities of manganese are sufficient to diffuse that tint throughout a crystal. Quartz in allotriomorphic grains and veinlets is always present; and there are small aggregates of a white mica, flakes of which are also to be found enclosed in the grains both of quartz and dolomite. Sometimes there is a good deal of granoblastic albite.

The green types are really varieties of the rose limestones that are mottled with aggregates of chlorite, usually also with iron-ores. These are the most variable rocks of all, composition, and still more, texture,. often changing within the limits of a hand specimen, while a few of them are banded. Others have a rudely spherulitic structure, their chlorite aggregates being set in a frame-like ring of carbonate. In the coarser parts of the mosaic the carbonates are idiomorphic, and sometimes there are rhombic pseudomorphs of chlorite with a core of carbonate. They are also less dolomitic, the larger rhombohedra being zonal, ruddy dolomite within and clear greenish-white calcite without. Their quartz is apt to be moulded on the faces of such rhombohedra. All these limestones are much veined, both by quartz and by a carbonate, which is almost invariably white calcite.

Breccia Limestones — At a good many places the rose-green limestones are studded with angular green and purple fragments a quarter to half an inch, and sometimes as much as two or three inches, in diameter. Quite half the bulk may be composed of them, so that the limestone comes to function as the matrix of a many-coloured breccia, which is a beautiful and striking rock. All these fragments are volcanic, and those that retain definite internal textures can be recognised as the spilitic lavas. The purple ones (Plate 9), Fig. 1 are deeply hmmatised, but are full of slender felspars, often in radiating groups (E10103) [SH 386 623]. Among the green ones are some of the banded glassy spilites, and the interstitial chlorite and iron-ores are doubtless reconstructed spilite dust. These rocks are developed on a great scale at Llanddwyn. Most of them are massive, but close to the isthmus breakwater is one that is distinctly stratified, and interbedded with green spilite tuff and with a thin lava. They are therefore altered calcareous tuffs or ashy limestones, and must be due to explosions of spilitic lavas into a sea on whose floor calcareous sediment was forming.

Ellipsoidal Limestones — Some of these limestones, however, have a remarkable ellipsoidal structure, which at once recalls that of the spilitic lavas (Plate 6). In the vicinity of such rocks the inter-ellipsoidal spaces of the lavas themselves are filled with limestone, and for a yard or two from the junction the spilite ellipsoids are completely isolated from each other by it. This limestone is full of spilitic lapilli, so that the marginal portion of the lava seems to be really a spilite agglomerate, whose larger blocks are, like those in the green tuffs, ellipsoids that became detached either by explosion or by sudden cooling in water, the matrix of the agglomerate being, in thig case, calcareous. The adjacent parts of the bed of limestone also contain isolated spilite ellipsoids, a passage being thus traceable from calcareous agglomerate to ashy limestone with large blocks. Now the ellipsoids of the agglomerate are traversed by radial cracks, and their cores (evidently of lower chemical stability than their outer parts) decompose, become calcareous, and are in many cases replaced by limestone. In the spilite ellipsoids that lie within the limestone this process has gone still further, and -the whole of the core has been more or less replaced, leaving only a shell an inch or two in thickness. But the replacement is not complete, for the limestone core is generally full of small curved survivals of purple spilite (the spilite is usually hmmatised when in the limestone) lying in broken concentric rings. In the final stages the outer shell is reduced to a mere film, or may even disappear, but the carbonate will still retain an ellipsoidal structure. These peculiar limestones appear, therefore, to be metasomatic pseudomorphs after spilite-agglomerates with whose finer lapilli calcareous sediment was mingled.

Dynamical structures

are not conspicuous, even where the adjacent rocks are highly schistose. Carbonates, however they may be reconstructed under stresses, are not apt to acquire a foliation, and may even protect their enclosures from acquiring it, doubtless from the ease with which the mass yields as a whole. The northern oolites are traversed by slide planes, along which the oolitic grains are cut and shifted. Where the ashy limestones are full of fragments, these are often deformed, and impart a schistose structure to the whole. The hæmatised spilite fragments, whose 'eisenglimmer' lends itself to foliation, have become so schistose as to simulate the purple phyllites. But even where massive, it is evident that the limestones have been profoundly reconstructed. The presence of allotriomorphic felspar and of well-formed flakes of mica, reveals that they are truly anamorphic rocks. It is, indeed, somewhat surprising that calc-silicates do not seem to have been formed in them.

Graphitic Phyllite

Adjacent to the laminated outer parts of the simpler, grey, limestones are beds of soft black schist or phyllite, seldom exceeding a few inches in thickness. They yield a strong black streak, and soil the fingers, but have a faint sheen upon the foliation planes. In the northern districts they are in actual contact with the limestone, and are themselves calcareous, the carbon films of the Cemaes Limestone being really an attenuated form of the same deposit. They are composed of parallel seams of carbon, with fine granular quartz and a little white mica, parted by thin bands of calcite mosaic. The carbon is not mere dust, but is in authigenetic scales, and is evidently graphite.

The Jaspers

According to the rock in which they are found, these may be termed Limestone- and Spilitic-lava- (or briefly) Lava-Jaspers; but the two differ in habit only, not petrologically. The lava-jaspers fill the spaces between the ellipsoids of the spilites (Plate 4), so that their forms tend to be bounded by concave and intersecting ellipsoidal planes, and may perhaps be called concave ellipsohedra. Their diameter seldom exceeds a few inches in any direction. The limestone-jaspers occur in irregular nodules. Two of them attain a size of 24 x 6 feet, but this is quite exceptional. The typical jasper is a compact scarlet rock, as hard as quartz, though very brittle, and with an irregular or conchoidal fracture. Some are paler, some of a darker, purplish tint, which is commoner in limestone than in lava-jaspers. Not many are uniform in tint, the majority having a mottled aspect. Nearly all are traversed by a network of thin veins of quartz, sometimes to such a degree as to look like scarlet breccias with a quartz matrix. A spherulitic structure is often to be seen, the spherulites, though red, being of a lighter colour than the matrix. They are usually two to three millimetres in diameter, but some on Llanddwyn are an inch or more across. These are composed of radiating fibres alternately red and white, with a sort of cellular tissue in the middle. As they crowd against each other their peripheries assume a rudely polygonal form, and weathering hollow in the middle, they recall curiously a colony of corals of the habit of *Cyathophyllum regium* (p. 151). Some limestone-jaspers are composed of red irregular bodies, with many sub-angular oblong ones, lying in almost unstained quartz. Banding, or a tabular habit, is known in limestone jaspers only, and is very rare.

The rocks are composed (Plate 5), Fig. 5 essentially of quartz and haematite, with a little carbonate (doubtless dolomite, with possibly some siderite) as a frequent, and pyrite or magnetite as a very rare, accessory. No felspar, no siliceous pseudomorphs after it, have been detected even in slides cut across the junction with spilitic lava. Some of the haematite has crystallised as definite flakes of 'eisenglimmer', but most of it is fine dust. The carbonates are usually in isolated rhombohedra, some of which contain zones of haematite. The body of the rock is a quartz-mosaic which is extremely variable in texture, with a range from crypto-crystalline to such as is composed of elements .5 mm. in diameter, but most of it is of medium grain, inclining to be rather. fine. The variation is also very rapid; several types may occur within a single slide, and the finest may adjoin the coarsest. This is especially the case in the limestone-jaspers. Among the mosaic are occasionally groups of small doubly terminated crystals of quartz, whose outlines are picked out by haematite. The veins are usually much coarser than the body. The distribution of the hwmatite is no less capricious. In some tracts there may be a mere scattering of dust, in others it may be densely crowded, almost to opacity. But almost everywhere it is gathered into little spots, denser in the middle, which is the cause of the mottling already noticed. Sometimes each of these aggregates lies in the centre of a quartz grain, and is thus confined to the limits of an optical unit (Plate 5), Fig. 5.

The spherulites display several stages of development. Some are mere shells of haematite dust in ordinary quartz mosaic which has the same structure within and without the shell, so that between the nicols they tend to disappear. The first of the true spherulites are tracts of colourless mosaic in which the elements become elongated, fusiform, and radially arranged, so as to yield an incipient cross. The higher stages of development are approached by these becoming more finely and definitely radial, and at the same time picked out with spherical zones of keinatite. Some of the larger ones contain only about a dozen elements of quartz, which widen out greatly towards the margin. The most perfect (Plate 5), Fig. 6, are composed of a core of nearly colourless mosaic, full of little veins; then the principal zone, which is finely fibrous, regularly radial, and pale red; then a narrow, pale zone; and finally an outer skin almost opaque with hcematite. These display a strong dark cross between the nicols. They simulate closely the well-known structures of the rhyolites, but it should be remembered that the chalcedony of cherts may also develop spherulites that polarise with a dark cross. Spherulitic cherts with dolomite crystals have been described and figured by Miss Raisin<ref>*Proc. Geol. Assoc.,* 1903, pp. 78, 79, (Plate XIV).</ref>, who points out the remarkable resemblance of their structures to those of many felsites.

Origin of the Jaspers — From the small dimensions of the jasper-bodies, and from their mode of occurrence, it is impossible that they can have been silicified rhyolites. But the relations of some of them point to their being local silicifications of the spilites. Occasionally the red matter has an outer shell of pale greenish quartz, that seems to graduate into the surrounding igneous material. There are also (as well as the definite and dense inter-ellipsoidal nodules) rather loosely knit aggregates with ragged margins, outside which may be isolated spherulites in the midst of lava substance. Thin vein-like strings, too, may sometimes be seen.

On the other hand, felspar pseudomorphs have not been detected, even where in close contact with the spilites; and so far from their spherulites representing those of the lavas, the latter usually lack spherulitic structure at the junction. The jaspers of the vesicular spilite of Cerrigceinwen have been searched for pseudomorphs of its amygdules, but with indecisive results. For, though they are spher-ulitic, so are those in many that are not vesicular; and though some contain oval bodies that might represent amygdules, they are grouped as are the spherulites, not as the isolated vesicles. And some nodules in the midst of lava crowded with vesicles are as dense and homogeneous as any in the Island. The identity in character of the limestone- and the lava-jaspers is not in favour of their being silicifications of either of those rocks. Moreover, limestone, banded, fine, and granular, fills (just as in Scotland) some of the interspaces of the lavas instead of jasper; and on Llanddwyn may occasionally be seen to have been the first of the deposits on the walls of the cavity, and to enclose a core of jasper. It is not easy to see how such a jasper core can be a pseudomorph of lava substance.

Their modes of occurrence are, in the one case, that of cataclasts of chert nodules in deformed and reconstructed limestone; in the other, identical with that of radiolarian chert in ellipsoidal spilite, as may be seen by comparing (Plate 4) with those in the Geological Survey Memoir on the rocks of Southern Scotland. The radiolarian cherts of the spilites of the South of Scotland, moreover, pass locally into scarlet jaspers indistinguishable from those of Anglesey. Associated with the jaspers of the Mona Complex are jaspery phyllites (pp. 52, 88) which, though cherty, are unquestionable sedimentary, not chemical, deposits. The ferric oxide is doubtless a product of the hmatisation that so often affects the Gwna lavas.

The following are analyses of typical Gwna jaspers:

	I	II	III
SiO_2	88.07	93.52	
Al_2O_3	1.31	None	0.27
Fe_2O_3	10.75	6.56	1.76
Alkalies	None	None	0.51
	10013	100.08	99.70

I. Lava-Jasper, in interstices of spilite. Cerig-mawr, Newborough, 742 yards north-east of Llanddwyn Island (E10306) [SH 395 640], close to west edge of six-inch sheet 22 south-west. Anal. J. O. Hughes.

II. Limestone-Jasper. 700 yards north-east of Llanddwyn Island: a little to the east of (I). The great (20-ft.) jasper (E10307) [SH 394 638]. Anal. J. O. Hughes.

III. Limestone-Jasper. 300 yards south-west of Hendre-bach, Cerrig-ceinwen (E10012) [SH 428 744]. Anal. J. O. Hughes.

Except in their high percentage of Fe_2O_3, they compare closely with the analyses of seven cherts given in *Bull. U.S. Geol. Surv.,* No. 224, p. 297, but differ in several respects from those of nine siliceous sinters there given, in which (among other differences) there is a loss on ignition ranging from 2.29 to 7.50 per cent.

Metamorphism of the Jaspers

The structures described above, though denoting great internal alterations, are found only where the spilitic lavas have suffered little or no deformation; and are therefore older than the regional metamorphism. Elsewhere, especially in the Middle and Aethwy Regions, they are involved in that process. Torn, by reason of their hardness, from out their enclosing rock, they often become parts of an autoclastic mélange, cut into thin lenticular strips and interfelted with phyllite and with crystalline mica-schist. They then undergo internal deformation, their quartz-mosaic becoming nemablastic and their haematite foliated. The structure is not merely catamorphic, for both minerals are now new crystalline grains, and the carbonates are often perfect rhombohedra even in thorough jasper-schist. Thin quartz veins in them are cut and shifted, especially at the micaceous folia, some of which pass right through the shifted vein. The veins are also cross-foliated without being shifted (E9965). Where enclosed in limestone, the easy plastic readjustments of that rock have protected them. But in the Engan belt of the Middle Region, where they are enclosed in great flows of spilite that have been converted into actinolitic epidote-schists, they have not only become schistose but have suffered a metasomatic change. Their concave ellipsohedra have been drawn out into long lenticular augen, and they acquire the foliation just described; but concurrently with this begin to lose their colour, and finally become bleached altogether, passing into a white quartz-schist.<ref>Many years ago Dr. Horne drew my attention to a loss of colour in the Torridon Sandstone where traversed by the Post-Cambrian thrust-planes. See also ' Geology of the North-West Highlands of Scotland' (*Mem. Geol. Surv.*), pp. 581.</ref>

It would appear as if the iron must have been absorbed by the enclosing rock, and we find, accordingly, that the basic schist of this tract yielded 4.68 Fe_2O_3 as against 2.04 and 3.18 in the New-borough spilite (see pp. 74, 78) and still lower percentages in the Scotch and Cornish rocks. In this district all stages of the bleaching can be studied, but no one would recognise jasper in an isolated specimen of the final product; and it is possible that some of the siliceous augen of still more altered basic schists may have originated in this manner (pp. 118, 120).

The Jaspery Phyllites

These are fissile purple rocks, closely resembling those of Amlwch (see p. 52). They contain minute clastic quartz and white mica, and are undoubtedly hmmatitic shales, the bedding even surviving on Llanddwyn, where one of them is associated with a fine purple grit, full of broken albites, with a little tourmaline. But some are jaspery, and have a crypto-crystalline matrix, of the kind that replaces colloidal silica. Some contain oval chlorite bodies, like those in the Penrhyn slates, an analysis of which is given for comparison.

	I	II
SiO_2	63.93	63.59
Al_2O_3	17.55	16.28
Fe_2O_3	6.54	8.42
FeO	0.73	0.66
MnO	—	0.42
CaO	0.60	0.72
MgO	5.88	1.95
K_2O	2.47	2.98
Na_2O	0.34	2.14
H_2O	146	2.92
CO_2	None	None
	99.50	100.08

I. Jaspery Phyllite, 300 yards south-west of Hendre-bach, Cerrigceinwen (E10011) [SH 427 745]. Anal. J. O. Hughes.

II. Purple Slate, Penrhyn Quarry, Bethesda. Anal. Holland and Reade, *Proc. Lpl. Geol. Soc.,* 1898, p. 293. SiO_2 includes 0.58 TiO_2.

Some red slates quoted by Clarke in *Bull. U.S. Geol. Surv.,* 1900, have as much MgO as I., whose chlorite accounts for it. The excess of potassium over sodium is unusual in the Mona Complex, but a frequent character of red slates.

The Fydlyn Group

This group, well seen on the sea cliffs of the Fydlyn Inlier, is composed of peculiar white rocks of highly acid character, whose original structures are tolerably well preserved, in spite of the innumerable planes of schistose deformation. For the most part they seem to have been rather massive (Plate 25), and their whiteness is remarkable, for where slightly decomposed they soil the fingers almost like hard chalk, but are seldom compact throughout, being rough, hackly, and usually full of rounded or sub-angular quartz. The most solid cores are composed of a crypto-crystalline felsitic mosaic (now considerably sericitised) in which are large grains of quartz, eaten into by corrosion bays, and many phenocrysts of albite, with some of oligoclase. These are undoubtedly sodium felsites. Some of their sheared cores are rudely rounded, suggesting original nodularity. Other parts vary rapidly in texture, being locally free from phenocrysts, while close by they may be so crowded with broken ones, largely quartz, as to have the aspect of a white grit, with but little matrix. Yet, in these grit-like parts, the matrix is still the same crypto-crystalline felsitic mosaic, and the quartz fragments are sub-angular, often with re-entering angles. There are also bands full of small clastic felspars. Such rocks are certainly neither lavas nor sediments, they can differ but little in composition from the felsites, and must be regarded as felsitic tuffs. This is confirmed by the fact that near the junctions with the Gwna Beds, they graduate into true sediments, chiefly grit, but with thin bands of grey phyllite. Some of these felsitic tuffs are very massive. Their matrix, in its present state, cannot be distinguished from that of the true felsites, and is doubtless compacted felsitic dust. The deformation that the group has undergone has broken down the original junctions, and made it impossible, so far, to separate lavas from tuffs in the field, even on the clear cliff-sections, and to estimate the proportions of the two, but the latter seems to be dominant. From the intimate relations of the types, it is evident also that the felsites are not intrusive but effusive.

Many of the hard cores are considerably silicified, and, as these are older than the planes of deformation, which sweep round them, they are to be referred to the volcanic episode itself, as products of geyserisation that set in towards its close.

The rocks have been powerfully deformed, and their less resistant parts have become fissile. Anamorphism, however, is low, and is restricted to the production of minute white mica. The phenocrysts are not often sheared out into phacoids.

The Coedana Granite

Four principal types can be distinguished, which may be called the Normal Granite, the Porphyritic Granite, the White Mica Granite, and the Fine Veins. The first three are often foliated, and all very frequently schistose or crushed. The normal granite has a good deal of slight local variation, but is generally rather coarse, its crystals often exceeding a quarter of an inch in diameter, and in colour may be grey or sea-green, but is usually a salmon-pink, mottled with grey and with dark green aggregates. The porphyritic is a variety of the normal rock that is full of large pink felspars. The white mica type, which is marginal, is decidedly finer than the normal, and is a clean white glistening rock. The fine types, which, when their junctions are exposed, are seen to be veins, are rare. The great intrusion of the Middle Region may be called the Coedana Granite (pronounced 'Koidánna').

The minerals of the normal granite are quartz, felspars, biotite, and white mica. Accessories are rare, but apatite, garnet, and zircon are occasionally found. The biotite (which was brown) is usually chloritised, and this chlorite is often studded with secondary ilmenite and leucoxene. The nature of the alkalies of the white micas has not been determined for any of the Coedana granites. Epidote, and rarely zoisite, also occur as alteration products, but in small quantity. The rock was rather poor in micas, brown was in excess of white, which is intergrown with it; and both micas are somewhat unevenly distributed; being found in nests with several plates close together. The dominant felspar is albite, sometimes with lamellar twinning, sometimes simple, often twinned on both planes with a microcline-like structure. But orthoclase is present as well, in varying proportions, and it may be accompanied by microcline. There are some perthitic intergrowths, and veinlets of albite penetrate the orthoclase. The structure of the rock is typically granitoid.

The porphyritic differs from the normal granite in containing conspicuous phenocrysts of pink orthoclase an inch or more in length. They are distributed rather capriciously, a few yards of rock being often closely crowded with them, while in the surrounding parts they may be scanty. From a comparison of their refractive index with that of orthoclase of known composition, it is probable that they contain about two per cent. Na_2O. Some are Carlsbad twins; but they are hypidiomorphic, often only developing the pinacoidal, and sometimes no crystal faces at all. Faces, even when developed, may be invaded by any of the minerals, even by quartz, and the interior of the crystal usually encloses grains of the albite of the ground-mass. Although early, they cannot, therefore, be a first product of the consolidation unless modified by corrosion as that went on. Inclusions of the same kind are found, though on a much smaller scale, in the idiomorphic phenocrysts of Shap.<ref>Marr and Harker, *Quart. Journ. Geol. Soc.,* 1891, p. 278.</ref> In the foliated varieties there is a tendency to parallelism in the micas and to elongation of the quartz. But the foliation is never conspicuous, and scarcely affects the arrangement of the phenocrysts in the porphyritic rock.

The white mica granite is more acid, and though containing also the same three felspars, appears to be rather richer in orthoclase than the normal granite, but is never porphyritic. It contains no biotite, but is rather rich in white mica, probably muscovite. Foliated varieties are found, in which a parallel arrangement of the micas is conspicuous.

In the fine veins pink orthoclase appears to be the dominant felspar, and white-mica, which is abundant, certainly the dominant if not the only mica. One of them contains a good deal of garnet. They are the only varieties with much micropegmatite.

All these granites are more or less affected by the latest movements of the Complex. They are sometimes crushed to mere endoclasts; are traversed by innumerable seams of greenish mylonite; are often optically strained; and frequently rendered rudely schistose. But this schistosity can easily be distinguished from the true foliation, which it may traverse at any angle, the late structure striking steadily north-east, the older in more than one direction. The old foliation is not accompanied by destruction of the minerals, and sometimes its elongated quartz elements will send out rounded tongues transversely (Figure 9). Although the white mica variety and the veins are finer than the normal type, they are still truly granitoid. No sign of a chilled selvage has been found on the margin of any granite of the Complex, even in contact with the finest of the cryptocrystalline hornfels. Junctions with the crystalline hornfels are well seen in many places, especially between Tre-ddolphin and the Holyhead main road (Figure 145), (Figure 146), (Figure 147), (Figure 148), (Figure 149), (Figure 150), (Figure 151), (Figure 152), (Figure 153), and there is no degeneration of crystalline texture, even at the contact. A slight marginal greisenisation is to be seen here and there. Tourmaline appears locally in the granite close to the mica-hornfels, and at one of the junctions north of Tre-ddolphin the felspar of some inicropegmatite has been pseudomorphed in white mica. But it is evident that the rocks into which the granite found its way were already at a high temperature, as appears to be generally the case with the granites of metamorphic regions.

It is of interest to note that the Pre-Cambrian granites of Pembrokeshire are also rich in sodium.<ref>Thomas and Jones, *Quart. Journ. Geol. Soc.,* 1912, p. 387.</ref> The Coedana rock resembles them in the dominance of albite, in the titaniferous character of its biotite, and in its poverty in accessories. It differs from them in the presence of porphyritic orthoclase, in the presence of some orthoclase, microcline, and muscovite in its ground mass, and in the rarity of perthitic and pegmatitic structures. It is also nearly related to the granites of Eastern Sutherland<ref>Horne and Greenly, *Quart. Journ. Geol. Soc.,* 1896.</ref>, a relation partially disguised by the injuries inflicted by the last movements of the Complex. It differs from these somewhat in composition, for they contain more biotite, no muscovite, and their dominant felspar is oligoclase. Structurally its resemblance to their less foliated portions is much greater, especially as they contain red phenocrysts of natron orthoclase which are but hypidiomorphic and enclose many grains of the oligoclase of the ground mass. The affinities of the Coedana granite to some great Pre-Cambrian and Metamorphic granites are therefore close. Its relations to the granitoid parts of the adjacent gneisses will be discussed later on.

Hornfels

The rocks grouped under this name are all found in association with the Coedana granite. Some of them are highly crystalline, and can only be termed hornfels in accordance with the extended use of the word that has been made in recent years. The compact varieties (which predominate) may be termed Crypto-crystalline, the others Phanero-crystalline, or briefly Crystalline Hornfels.

The crypto-crystalline Hornfels

These are compact grey-green rocks with a rudely conchoidal fracture, seldom, but sometimes harder than steel, and weathering to a light cream colour. But this material, though a large proportion of the whole, usually occurs in rather slender, curving, lenticular cores, between which a decided though never strong schistosity appears, the rock remaining otherwise much the same. Sometimes a strong parallel banding that cannot be anything but bedding can be traced for a few yards, and on the moor north-west of Gwalchmai it is thoroughly stratified over a considerable area. Spotted hornfels also occurs.

The essential minerals are quartz, alkali felspar, a green mineral most of which is now chlorite, magnetite, and white and brown mica. What proportion of the colourless mosaic is felspar is difficult to determine on account of the fineness of the grain, but it must often be considerable. Some of the felspar, which is very seldom twinned, is albite, but some is negative and must be an orthoclase. The white micas are very small. Sometimes the iron ore is larger than usual, and is then seen to be octahedral, and being strongly magnetic, must be magnetite. Idiomorphic tourmaline of bluish-brown tint in small prisms is almost always present as an important accessory. Pseudomorphs after andalusite have been found at Bodafon Moor. Minute granules of sphene are often plentiful, and also leucoxenised ilmenite, from which doubtless the sphene has been derived. The spots are complex encarsioblasts of a green mineral in which, though much chloritised, portions that are still a xanthophyllite<ref>For the characters of this mineral, where better preserved, see p. 113.</ref> can be identified, though not so well preserved as in the graphite-schist. The banded varieties have the same composition as the rest.

The texture is finely granoblastic (Plate 10), Fig. 1, and cannot be called lepidoblastic even in the most foliated varieties. In the hard cores the minute micas lie in all directions, and the structure is that of a typical, hornfels.

The Crystalline Hornfels

Three principal kinds are known, Mica-Hornfels, Hornblende-Hornfels, and Epidote-Hornfels. All are holocrystalline and granoblastic.

Mica-Hornfels

The mica-hornfels is a saccharoid sea-green rock spangled with bright micas that lie in all directions. Often it has a parallel structure that is not a foliation, and it is interbedded with white fine siliceous bands in a way that is unmistakably stratification. The essential minerals are quartz, alkali felspar, white mica, brown mica now much chloritised, and iron-ores, tourmaline also rising in some beds to the rank of an essential. Cordierite has not been found. Apatite and sphene occur occasionally. Besides the white micas of the body, there are abundant white mica porphyroblasts which when in crystal units are often one millimetre and when compound often two to three millimetres in diameter. (Plate 10), Fig. 2. Tourmaline prisms may be four millimetres in length, and are of a bluish tint. In some beds are oval (not lenticular) groups of felspar seven millimetres across. Both these and the felspars of the body are chiefly orthoclase, and some of the large oval groups are composed of micropegmatite; but albite is also present. The two micas are often intergrown, and the whole mosaic is rather complex. It is thoroughly granoblastic, and there is no true foliation. Perhaps the majority of the micas of the body lie at a low angle, or nearly parallel, to the banding, but almost as many are oblique, many even at right angles to it: and the porphyroblasts of tourmaline and white mica are devoid of orientation.

Hornblende-Hornfels

This, which is found as a zone in mica-hornfels, is a dark green but light-weathering rock of medium grain, saccharoid, and with a fine, steady, parallel banding that is manifestly bedding. It is homoeoblastic, and composed of alkali-felspar, hornblende, and quartz, with minute epidote, zoisite, iron-ores, and sphene. In the colourless mosaic felspar predominates over quartz. It is untwinned, the refractive index unusually low as a whole, and as some is negative, some positive, it is evidently orthoclase with a large quantity of albite. The hornblende is of a good clear tint, and pleochroic, thus: *X,* pale straw-colour, *Y*, rather strong brownish-green, *Z,* grass-green. It is hypidiomorphic, and in one coarse band (Plate 10), Fig. 3 almost porphyroblastic, with development of the prism-faces and cleavages, but the crystals riddled with inclusions of the quartzo-felspathic mosaic. The rock is quite unfoliated, and the larger hornblendes often stand at right angles to the banding.

Epidote-Hornfels

The epidote-hornfels is a finely saccharoid, pistacio-green rock, sometimes with an even banding and well-bedded siliceous seams, but sometimes rather massive. It is a homoeoblastic mosaic (Plate 10), Fig. 4 of alkali felspar, epidote, and hornblende, with some quartz and a good deal of brown sphene, a little iron-ore and zoisite; and some chlorite, calcite, and dusty epidote that are all evidently due to alteration. The colourless mosaic is almost entirely a clear, untwinned felspar with a very low refractive index, which does not often yield a good optical figure. But the refractive index of a few grains of albite that are present is decidedly higher, so this felspar must be orthoclase, a conclusion amply confirmed by the analysis of the rock. The epidote, which has high birefringence and strong pleochroism, is in clear grains but seldom hypidiomorphic. The hornblende is very pale, with pleochroism — *X,* colourless, *Y*, pale grass-green, *Z,* pale blue-green, in ragged plates that include the other minerals, and there is a speckled variety of the rock with larger and darker hornblendes.

Unity of the Hornfels

The crypto-crystalline hornfels, though not observed to pass into typical mica-hornfels with large porphyroblasts of muscovite, becomes here and there so much less compact, with such much larger micas, as to constitute an intermediate type; and another intermediate type is a fine but saccharoid hornfels with alkali felspar and a little white and brown mica that is developed on rather a large scale on Gwalchmai Moor. The persistent presence of tourmaline also links the types. Epidotic bands link the crypto-crystalline with the true epidote-hornfels. The epidote-hornfels at Cwm rests upon a bedded mica-hornfels and is seen to graduate into this in clear section; while hornblende- and mica-hornfels come into similar relations in the section near Coedana. All the types are therefore linked up together, and must be regarded as varieties of one and the same product.

Chemical analyses

The following are analyses of different types of hornfels

	I	II	III	IV	V	VI	VI	VIII	IX	X
SiO_2	74.02	58.40	60.08	58.87	—	62.91	60.36	55.58	74.02	55.58
TiO_2	not det.	not det	not det	not det.	—	0.53	none	not det.	—	—
Al_2O_3	1213	23.42	17.93	18.74	—	16.52	16.81	13.96	23.42	12.13
Fe_2O_3	0.89	3.10	6.46	6.54	—	4.39	112	4.76	6.54	0.89
FeO	3.62	2.26	1.88	3.43	—	4.47	4.85	2.20	4.85	1.88
CaO	1.10	011	3.89	1.23	—	1.41	5.13	9.73	9.73	0.11
MgO	1.95	1.52	2.27	2.07	—	2.41	2.77	4.88	4.88	1.52
K_2O	1.89	6.59	7.21	8.97	4.04	2.57	3.69	6.97	6.97	1.89
Na_2O	3.19	0.29			1.57	2.99	3.76	0.20	3.76	0.20
H_2O(at 110°)	none	0.46	—	—	—	0.31	0.15	—	0.46	0.15
H_2O	—	—	0.17	0.31	—	—	—	—	—	—
H_2O (above 110°)	1.54	3.53			—	1.83	0.99	1.09	3.53	0.99
CO_2	none	none	none	0.42	—	0.19	none	0.63	0.63	—

100.33	99.68	99.89	100.58	—	100.53	99.63	100.00	—	—

I. Banded crypto-crystalline hornfels (E10188) [SH 329 716]; coast, 353 yards north of the 'a' of Porth Nobla. (Bone y Bedd of six-inch map.) A slide cut from close by (E11190) [SH 329 715] showed abundant clastic grains. Anal. J. O. Hughes.

II Bedded crypto-crystalline. hornfels (E10345) [SH 463 847] south end of Mynydd Bodafon; 300 yards- east by north from the '329' level, close to quartzite. Anal. J. O. Hughes.

III Crypto-crystalline hornfeis, 200 yards north of Ynys-fawr, Coedana (E10003) [SH 444 832]. Anal. J. O. Hughes.

IV Spotted xanthophyllite-hornfels (E9888) [SH 338 730]; 170 yards east-north-east of Llanfaelog Church. Anal. J. O. Hughes.

V Banded crypto-crystalline hornfels (E9972) [SH 392 777]; half mile west of Bodwrog Church. Anal. J. O. Hughes.

VI Crystalline mica-hornfels (E9806) [SH 370 767]; 425 yards west of Caer-glaw cross-roads, Gwalchmai. Anal. J. O. Hughes.

VII Crystalline hornblende-hornfels (E10002) [SH 425 825]; 240 yards north of o ' of Coedana (200 yards north-west of Maengwyn farm of six-inch map). Anal. J. O. Hughes.

VIII Crystalline epidote-hornfels (E9949) [SH 404 800] Cwm, Llandrygarn. Anal. under superintendence of Dr. Dobbie, Univ. Coil., N. Vales, to whom I am indebted for it.

IX Maximum percentages of the constituents in I–VIII.

X Minimum percentages of the same.

It will be seen at once that there is a great variety of composition, affecting every element estimated, even the aluminium; and the range of the variations can be gauged at a glance from columns IX and X. The combined alkalies range from 5.08 to 8.97. A number of different rocks must, therefore, have been converted into hornfels. It will also be noted that a mean of the separated alkalies in I, II, V, VI, VII, VIII, yields K_2O = 4.29, Na_2O = 2.00, and that in II and VIII potassium is almost the only alkali, a reversal of the proportions usual in the Mona Complex. From this it follows that orthoclase must be the dominant felspar of the fine mosaic, and that the minute white mica must be muscovite.

Origin of the Hornfels

1. *Original Structures* — are found at several places. A parallel interbanding of different kinds of material, often of coarser and finer material, is frequently to be seen both in the crypto-crystalline and crystalline varieties, which resembles in every way a true sedimentary stratification, and at a place 275 yards south-south-east of the tenth milestone at Gwalchmai thin bands of quartzite lie along this. A purple phyllite occurs within the zone 190 yards east of this quartzite. The crystalline types are completely reconstructed, but a banded crypto-crystalline hornfels a few yards from the rock of analysis No. I contains numerous undoubted clastic grains of quartz and albite (E11190) [SH 329 715], between which are the little micas of the hornfels. Similar characters are seen in a slide (' No. 9, 1899') from the same place, laelonging to Mr. Barrow. Bedded crypto-crystalline hornfels dips under the quartzite of Mynydd Bodafon. There are good natural exposures, but in 1908 a small quarry was opened at the south end of the quartzite, 300 yards east by north from the ' 329' level, in which its junction with that quartzite was completely cut through. About 30 feet of well-bedded rocks are seen (E10341) [SH 463 847], (E10342) [SH 463 847], (E10343) [SH 463 847], (E10344) [SH 463 847], (E10345) [SH 463 847], (E10346) [SH 463 847], (E10347) [SH 463 847], all their structures being parallel to the base' of the quartzite. One is a crystalline biotite-hornfels, others are fissile and fine like those which contain the andalusite, but most of them are perfectly typical crypto-crystalline grey-green hornfels (Plate 10), Fig. 1, indistinguishable from the best examples of the type. Their external aspect and internal structures are the same, they are composed of the same minerals, they have the same criss-cross' micas, and even the same small idiomorphic tourmalines. Now these rocks contain undoubted clastic grains of quartz; they are members of a well-bedded series; the one analysed yields 23.42 per cent. Al_2O_3; and there cannot be a moment's doubt as to their sedimentary nature.

2. *Chemical Composition* — From the remarkable range of composition shown in the analyses it is evident that rocks of very different character and origin have, in this zone, been converted into hornfels. One or two have the composition of acid and basic igneous rocks, another (No. II) that of a sediment, others of neither normal igneous rocks nor normal sediments. Taken singly, No. I might be supposed to have been a rhyolite, No. VII a diorite. Yet No. I has a stratified structure and contains clastic grains, No. 7 is also stratified and is a band in mica-hornfels that resembles No. VI, which is totally unlike either a diorite or any ordinary igneous rock, but resembles many sediments in composition. Nos. I, III, IV, V, again, have close community of structure with No. II, which is undoubtedly a sediment; while No. VII is related structurally to No. VIII, which cannot possibly be dioritic. Yet none of them, not even No. II, can be normal sedimentary rocks, and No. VIII, with its 9.73 per cent. of CaO and its 6.97 per cent. of K_2O, is abnormal altogether. The outstanding feature of the zone, in short, is community of structure with diversity of composition. The structure which they have in common. is not of a kind that is known to result from the alteration of igneous rocks, but is well-known to result from the alteration of sedimentary rocks, and these undoubtedly exist within the zone; yet the composition of the majority of them is not that of any known sediments. Now there is one class of deposits, and one only, in which such a range of composition is at all probable, combined with a community of original structure capable of giving rise to a community of alteration structure. That is an alternating group of bedded tuffs with psammitic and pelitic sediments into which have been showered varying proportions of pyroclastic dust; and such deposits are known to exist within the Mona Complex, which contains both spilitic and rhyolitic tuffs (pp. 57, 75, 90). The hornfels, moreover, passes laterally into the Penmynydd Zone of metamorphism, which, as will be seen, must include rocks of both sedimentary and pyroclastic origin. The crypto-crystalline hornfels with clastic quartz may therefore be regarded as composed of gritty shales with rhyolitic and other dust, the mica-hornfels may be produced from similar material, the hornblende-hornfels would be a basic, and the epidote-hornfels a calcareous tuff. Much of the crypto-crystalline hornfels has in the field a strong resemblance to the Church Bay Tuffs, in which, moreover, we find precisely the same rare, local, and pronounced but impersistent bedding.

3. *Causes of the alteration* — Among the many metamorphic types of the Mona Complex the rocks here called hornfels are unique in that they are found in one association only. The distribution of the rest is regional; the hornfels, of whatever type, clings to the Coedana granite. The crypto-crystalline hornfels is for the most part external; behaving, indeed (though small xenoliths are found), as an aureole along the flanks of the granitic tract: the crystalline hornfels is only found in the great xenoliths (one of which is a mile in length) of its interior, where the temperature would be higher and maintained for a longer time. In the crypto-crystalline hornfels granite apophyses are rather rare, but the crystalline xenoliths are riddled by innumerable sills and veins, and no chilled selvages are known.

The textures and composition of the hornfels itself are fully in harmony with its dependence on the granite. The flinty fracture, the spotting, the frequent absence of parallelism in the micas, the presence of large porphyroblasts whose position is independent of the direction of the banding, and of large ragged encarsioblasts full of small inclusions, are all characters of thermal as distinct from dynamic metamorphism. Tourmaline (which is found also in the granite at the margin), andalusite, and the chloritoids are all contact minerals, both micas are well known in that connexion, and the hornfels of Gwalchmai Moor has the structure of an adinole. The epidote rock with its pale hornblende is an impure calc-silicate-hornfels.<ref>The preponderance of potassium over sodium, so exceptional in the Complex, is also curious, and suggests that some of the potassium of the Coedana granite (the only great orthoclase rock of the Complex) has found its way out into the aureole.</ref>There can be no doubt, therefore, that the special characters which distinguish these rocks from the rest of the Mona Complex are due to the thermal influence of the granite.

Foliated Hornfels

Their frequent lack of any foliation being a matter of importance in these rocks, attention has been focussed on it. Yet the fissile-parts of the crypto-crystalline varieties are finely foliated. What is the relation of this foliation to the thermo-metamorphism? Now, tourmaline prisms are found in many slides of the foliated parts, but they never show the slightest deformation, and in some cases (E10346) [SH 463 847] cross the foliation at right angles. That foliation can be traced, uninterrupted, through the large ragged encarsioblasts of chloritised xanthophyllite, and in one case even through an idiomorphic tourmaline. It is therefore not the result of dynamo-metamorphism acting upon completed hornfels. At

Foel (p. 331) the granite is seen to cut across an old pre-intrusion folding. Evidently 'the rocks into which the granite was intruded had already undergone considerable deformation, and their fine parts acquired an incipient schistosity. When the intrusions began, the small new thermal micas developed in great measure along the pre-existing planes of cleavage; the xanthophyllite and tourmaline developing later on.

Diorites

Rocks of this type are (except in the Gneisses, whose basic members are described under the heading of that formation) both small and few, and are all either within the Penmynydd Zone or the Coedana granite. The small cores of albite-diorite that are found in some of the hornblende-schists are described on p. 115. The diorite of Llangaffo cutting is coarse, but slightly foliated even in the centre, while its margins pass into hornblende-schist. It contains greenish bodies that look like pseudomorphs after deformed porphyritic felspars, but none of the slides contain sections of them. On the Aberffraw coast at Ynysoedd Duon are some singular amphibolites, grey-green, tolerably coarse, and quite unfoliated in the middle. They are composed of large ragged plates of pale hornblende with pleochroism: *X,* colourless; *Y*, pale brown; *Z,* very pale blue-green, in a matrix of zoisite and albite. The albite is granular, the zoisite chiefly granular but sometimes eumorphic. This matrix is penetrated in all directions by good-sized plates of a white mica, chiefly grouped in aggregates that are sometimes rudely rectangular, as if pseudomorphs after a porphyritic felspar. Epidote and calcite are also present, and plates of hmmatite are intergrown with those of mica. On its margins this rock, which may be called a mica-zoisite-amphibolite, acquires a foliation, in which, however, the micas hardly participate. In an undeformed specimen (E10175) [SH 331 700] from 200 yards east of Ynysoedd Duon, Mr. J. O. Hughes found 47.06 per cent. SiO_2. The zoisite, when idiomorphic, shows good pinacoidal cleavages, and the gliding-planes parallel to the base. It displays the blue polarisation-tints beautifully, and is often zoned, the inner parts having a slightly higher birefringence. The crystals often show merely the emergence of one optic axis, but the optic-axial plane appears to be always transverse to the prism, and the bisectrix negative. The extinctions are sometimes nearly straight, but usually at about 10°–15°. Whether the amphibole of the above-mentioned rocks is in all cases original is not yet certain.

Dioritic rocks with amphibole that must be original are found at a few places within the Coedana granite, especially at Tre-ddolphin and by the side of the Holyhead main road near Treban, but the nature of some of these suggests that they may be xenoliths of the basic gneisses. Four small diorites of much more unequivocal character occur within the granite at the curve of the Caradog river near Y Werthyr. As they seem to graduate into hornblende-granite, and adjoin mica-hornfels, they may safely -be regarded as basic portions of the Coedana granite magma. But they need further investigation.

The Serpentine-Suite

On either side of the winding Strait of Holy Isle (as the channel isolating that island may conveniently be called), a number of plutonic rocks have been intruded into the New Harbour Beds. All are basic, but several types are present,<ref>A most of the slides and specimens of these rocks were kindly examined by Dr. Flett.</ref> and each of the larger masses is of the nature of an igneous complex. Isolated bodies of the same kind are found also about the mouth of the River Alaw, and among the Amlwch Beds of the north. The intrusions are composed chiefly of serpentine and gabbro, the serpentine being somewhat in excess. Coarse pyroxenites are present, and certain dolerites of the north 'appear to belong to the same suite of intrusions. Associated with them are a number of interesting metamorphic products, including talc-schist, tremolite-schist, tremolite-marble, ophicalcite, chlorite-chromite-magnetite-schist, andalusite-hornfels, epidote-hornfels, and epidosite, all of which owe either their existence or their condition to the basic intrusions.

Serpentine

Nearly all the serpentine is dark green, red varieties being rare. It is usually granular, with a clean, subtranslucent aspect. Locally it is mottled with a lighter green variety, and has then the appearance of noble serpentine'. In perhaps the greater part of the rock the only visible crystals that interrupt the general uniformity are iron-ores, but varieties containing plates of a fissile pyroxene are common. Sometimes there is a rude banding.

The granular body is a serpentine with the mesh-work structure denoting derivation from olivine. The opaque iron-ores are, when tested, found to be magnetite; but brown spinellids (chromite or picotite) are frequent. Both minerals have a tendency to cluster. The pyroxene was largely enstatite, but diallage is also present. These pyroxenes are generally scattered about in the serpentinous body, but sometimes grains of olivine-serpentine are poikilitically enclosed in them. Their plates are often large, attaining a diameter of five inches at Rhyd-bont creek, so that the original peridotites must have been coarse, and were evidently deep-seated intrusions.

The homogeneous granular material is a true dunite-serpentine; thence, by the coming in of enstatite, it passes into a saxonite-serpentine; again, where diallage is also present, it becomes a lherzolite-serpentine; while some varieties may be regarded as chromite-serpentine. But it would not be easy to lay down lines for these types upon a map.

The following analysis (No. I) was published by Prof. Bonney in 1881:

	I	II	III
SiO_2	38.62	40.12	39.58
TiO_2	not est.	tr.	0.10
Al_2O_3	4.15	0.98	3.19
Fe_2O_3	5.21	6.52	4.70
Cr_2O_3	not est.	0.28	0.20
V_2O_3	not est.	tr.	not fd.
FeO	4.34	1.21	2.76
MnO	tr.	0.52	0.34
(CoNi)O	not est.	0.15	0.16
BaO	not est.	not fd.	not fd.
CaO	tr.	0.12	1.09
MgO	33.83	35.78	36.21
K_2O		0.08	0.06
Na_2O	0.70	0.24	0.28
Li_2O		not fd.	tr.
H_2O at 105°	12.52	1.69	0.51
H_2O above 105°		12.17	10.79
P_2O_5	not est.	0.10	0.16
FeS_2	not est.	0.01	not fd.
CO_2	—	0.15	0.24
	99.37	100.12	100.37

(Two serpentines from the 'Geology of the Lizard and Meneage' are given also.)

I Serpentine, from close to the 't' of 'Pen-y-bont', Valley. Anal. F. T. S. Houghton.

II Dunite-serpentine (E5172), 70 yards west of Parc Bean Cove, south side Predannack, Lizard. Anal. E. G. Radley.

III Bastite (lherzolite)-serpentine (E5031) [SW 725 155], Poltesco Mill, Ruan Minor, Lizard. Anal. E. G. Radley.

The rock seems to have been a dunite-serpentine with a little enstatite, but contains much more aluminium than the dunite-serpentine of the Lizard. Comparison, however, must not be made too closely between analyses differing in date by 30 years.

Serpentinisation

The peridotites are highly serpentinised, fresh olivine being not yet recorded, while the fissile pyroxenes are for the most part converted into bastite. The serpentine is partly fibrous, partly in well-formed crystalline elements with varying birefringence, and some of it is nearly isotropic. Tremolite has also grown upon the plates of diallage and bastite, and sometimes the serpentine has been to a great extent replaced by carbonates.

A quasi-spherulitic variety, which has been found at several places, is also due to alteration. In this case a compact serpentine is full of pale green spherulitic bodies ranging from one-eighth to one-third of an inch in diameter, so as to simulate a variolitic spilite. The bodies tend to crowd into groups, or even into confused aggregates, which often take the form of rows like those of a spherulitic obsidian. They tend to weather out, but also weather hollow. The matrix is usually an olivine-serpentine with rather irregular mesh-work. Many of the bodies are not spherical, but sub-angular, or even rudely rhombic. They are composed of a mineral that resembles actinolite in short needles, intergrown in varying proportions with a carbonate, sometimes almost entirely of the carbonate. Concentric structure is rare, and radial arrangement, though common, is usually confined to the marginal portions, the interior being matted, with an approach to an interlacing of the needles at angles of about 55°. These bodies are therefore products of a late stage of alteration, when the serpentine wasbeing replaced by carbonates. Signs of cleavage are perceptible in some, and as the effects of malachite staining show (Prof. Bonney and Miss Raisin remark) that these cannot have been olivine, they would seem to be pseudomorphs of enstatite. Elsewhere, however, the mesh-work of olivine, still traceable by winding trains of iron-ores, may be seen to pass through the body of a spherulite. The rocks may therefore be regarded as lherzolite- or saxonite-serpentines in which the pyroxene, and portions of the olivine, have been replaced by ternary quasi-spherulitic structures that are later than most of the serpentinisation.

At Mynachdy is a serpentine rich in minute garnets, in clusters and veinlets, together with stars of antigorite. Bundles of asbestos, also, several inches long, are still to be found in it. The refractive index is 1.4 and the extinction parallel. They are therefore chrysotile.

Pyroxenites

Though important links in the plutonic sequence, and composed of large and beautiful crystals, these rocks are of small bulk, being found but rarely, and in aggregates or veins that cannot be traced for more than a few yards in any direction. The *diallage-rock* is almost wholly composed of that mineral in lustrous plates that attain an inch and a half in diameter, with poikilitically intergrown pseudomorphs after enstatite and olivine. The *enstatite-rock* may be nearly pure, containing, besides a little augite, only a few grains of a mineral that seems to be perofskite. The enstatite is bounded by the faces 010 and 110, and may be half an inch in length. Its smaller plates, broken across the cleavage, simulate a green matrix on fresh fractures. *Websterites* are also found, which were composed of diallage and enstatite with little or no olivine, while others contain a good deal of serpentine. Mineralogically, therefore, transitions can be found from all the types of pyroxenite into the peridotites. The enstatite of these pyroxenites is usually bastitised; their diallage is often fresh, but sometimes replaced by chlorite or carbonates; and both pyroxenes are locally amphibolised.

Gabbros

Enstatite-gabbro — A vein is known that consists of augite, kaolinised felspar, serpentine after enstatite, and granules doubtfully ascribed to garnet and perofskite. This rock therefore links the pyroxenites to the true gabbros. The *gabbro proper is* a pale green rock with a rather confused aspect on fresh fracture, though diallage and saussurite can always be made out on examination. Usually it is not coarse, the diallage being from one-eighth to a quarter of an inch across, but the texture may vary even in a hand-specimen. Large plates of diallage are quite rare, but some have been found an inch and a quarter across. Even where least modified, pale amphibole has been developed in and around the diallage in fringing acicular growths and compact plates. There seems no trace of enstatite or olivine. The saussurite of the matrix is composed of granular epidote and small irregular plates of untwinned felspar optically positive and probably albite. Some, however, is fine or even crypto-crystalline. A gabbro that is unusually massive has been analysed. Its differences from those of the Lizard and Skye, both of which contain olivine, are considerable.

	I	II	III
SiO_2	47.02	50.69	47.28
Al_2O_3	15.85	20.98	2139
Fe_2O_3	0.94	1.65	3.52
FeO	3.96	3.26	4.06
CaO	11.42	11.99	13.42
MgO	13.99	6.84	8.06

K_2O	0.20	nf.	0.29
Na_2O	1.91	3.36	1.52
H_2O (at 110°)	0.18	0.18	0.13
H_2O (above 110°)	4.49	0.94	0.53
	99.96	99.89	100.20

I. Gabbro, 'hyphen' of 'Pwll-pillo', at the foot of a high boss, by the lane-leading to Cerig-moelion (six-inch map) (E10213) [SH 270 772]. Anal. J. O. Hughes.

II. Olivine-gabbro, Coverack, Lizard. Anal. E. G. Radley. 'Geology of the Lizard and Meneage', p. 100 (0.16 of P_2O_3 and FeS_2 omitted).

III. Olivine-gabbro, Cuillin, Skye. Anal. W. Pollard. 'Tertiary Igneous Rocks of Skye', p. 103.

Dolerites

Those that have been investigated are now deeply amphibolised, but contain cores of brown augite and are ophitic. Their felspar is labradorite. They have chilled selvages and are thus less deep-seated than the gabbros, but are (p. 321) certainly apophyses from an unseen and doubtless gabbroid intrusion.

Mutual relations

Between the several members of the suite, neither chilled selvages nor clear intrusive junctions of any kind are known. ' But pyroxenite and enstatite-gabbro certainly vein serpentine, and are never known to vein gabbro. The distribution of the gabbro itself, as shown upon the maps, particularly its ring-dykes (Figure 122) within' the large western serpentine, point to its being later than that rock. The plutonic sequence may be taken to be: first peridotite, then pyroxenite, then enstatite-gabbro, and finally gabbro.

Associated metamorphic rocks

Talc-Schist — This is grey, platy, rather fine, usually well foliated, and very unctuous to the touch. It consists often almost entirely of talc, with a few scales of chlorite and octahedra of magnetite. Bright scales with a strong basal cleavage are present in some varieties (AP. 281). They show a uniaxial cross, or a bisectrix with a very small and variable axial angle, and are optically positive. The refractive index is very close to 1.570. They are therefore brucite. The composition of the typical rock should be compared with those of theoretical talc, of peridotites, and of the tremolite-schist, to the latter of which it is evidently related, aluminium, however, taking the place of calcium.

Tremolite-Schist — Some of these rocks are white, others have a very pale tinge of green. The finer ones are perfectly foliated and even fissile, with a silky lustre; but the prisms of colourless amphibole are often large enough to be seen easily with the hand-lens. They are composed (Plate 9), (Figure 5)) of eumorphic blades of tremolite with perfect prism cleavages, octahedral znagnetite, a little sphene, and a quantity of talc in scaly aggregates. A later generation of porphyroblastic actinolite sometimes is present, cutting the foliation. One of the most beautiful rocks in the Island consists chiefly of prisms, a third of an inch in length, of clear, colourless tremolite, with a tendency to radial grouping. From their chemical composition it is evident that these rocks are derived from the peridotites.

	I	II	III
SiO_2	56.34	63.49	53.65
TiO_2	—	—	0.06
Al_2O_3	8.21	—	3.24
Fe_2O_3	3.04	—	3.48
FeO	2.00	—	3.88
MnO	traces	—	013
CaO	0.52	—	9.23
MgO	25.43	31.75	24.51

K_2O	—	—	none
Na_2O	0.79	—	0.51
H_2O (at 110°)	—	—	0.03
H_2O (above 110°)	2.86	4.76	1.36
	99.19	100.00	100.08

I. Talc-schist (E10168) [SH 269 767] is from the same locality.) Quarry 250 yards north of Bronddel. (80 yards south-west of Plâs-coch on six-inch map.) Anal. F. T. S. Houghton. Published by Prof. Bonney in 1881. All H_2O given simply as 'Water'.

II. Theoretical talc, $Mg_2H_2Si_4O_{12}$, given by Dana.

III. Tremolite-schist (E10226) [SH 267 773], 413 yards south-west of Cae'r-sais (and 250 yards west-north-west of B.M. 32.6 on six-inch map), in a nook of a boss, close to gabbro. Anal. J. O. Hughes.

Tremolite-Limestone and Ophicalcite — These peculiar crystalline limestones fall into two groups according to the nature of the dominant silicate. A beautiful gneissose marble (E10563) [SH 260 770], composed of granular carbonates, tremolite, and talc, with some iron-ores and chromite, forms part of the same band as the radial tremolite rock just described. It resembles the limestones of the Loch Maree Group in the Lewisian Gneiss, its radial tremolites recalling those of the beautiful rock of Glen Tulacha.<ref>'Geological Structure of the north-west Highlands' (*Mem,. Geol. Surv.*), p. 235.</ref> Most of the tremolite-limestones are light in tint, but some are dark grey, and are fine and rather hard. These consist of dolomite, penetrated by a few needles of tremolite, with some serpentine. The dark tint is due to octahedral magnetite and chromite.

From the tremolite-limestones there is a gradual transition to the ophicalcites. To convey a clear general picture of these rocks is not easy. They are composed of saccharoidal carbonate intergrown in various ways with clear green serpentine. The carbonate may be white or with a tinge of green from flecks of serpentine. Generally more or less schistose, they are often banded, but very frequent is a brecciated structure, fragments of serpentine being embedded in the crystalline carbonate, and rapid passages are common from one structure to another. The beautiful ophicalcite of the old marble quarry at the 'w' of 'Pwll-pillo' (Cerig-moelion lane of six-inch map) consists of snow-white granoblastic calcite with scales and films of serpentine, an abundance of tremolite needles, talcose scales, iron-ores, and a spinel, probably chromite. About Llanfwrog there are talc-marbles, composed of talc with varying proportions of a white carbonate, sometimes calcite, sometimes dolomite or perhaps magnesite, and some chromite and magnetite. The ophicalcites are therefore serpentine-limestones, generally containing tremolite and talc, and thus connected by gradations with the tremolite-limestones, which in their turn are specially calcareous parts of the tremolite-schists.

The following analyses will enable the types to be compared, but it must be understood that the proportion of silicates varies greatly in both groups. Mr. J. O. Hughes writes: 'The effect of using hot HCl (20 per cent.) was a decrease of 8 to 12 per cent. in the insoluble residues, and increases of some 2 per cent. of MgO and 4 per cent. of Al_2O_3 + Fe_2O_3 in the solution obtained, the percentage of CO_2 being unaffected. Nos. I and IV were decomposed by hot hydrochloric, Nos. II and III by acetic acid. No Mn was found in the solutions'.

	I	II	III	IV
Insoluble residues	5.29	34.45	28.17	15.01
Al_2O_3+Fe_2O_3	6.60	0.43	0.13	4.27
CaO	32.68	26.85	38.96	27.55
MgO	14.49	7.52	0.49	14.83
CO_2	41.26	29.42	31.10	38.11
H_2O	—	1.15	1.11	—
	100.22	99.82	99.95	99.77
Percentage $CaCO_3$	58.35	47.94	69.62	49.20
Percentage $MgCO_3$	30.27	15.71	—	31.14

I. Dark hard limestone (E10217) [SH 265 770], 630 yards east of Gareg-lwyd; 233 yards south-south-east of Cerig-moelion (six-inch map). Anal. J. O. Hughes.

II. Tremolite-marble with radial structure (E10563) [SH 260 770], seven yards southeast of Gareg-lwyd new house. Anal. J. O. Hughes.

III. Ophicalcite .(E10214) [SH 266 773], Quarry at the 'w' of 'Pwll-pillo', by lane leading to Cerig-moelion (six-inch map). Anal. J. O. Hughes.

IV. Reddish limestone. A few yards west of the house at Tyddyn-dai, Amlwch. Anal. J. O. Hughes.

That these ophicalcites are metasomatic products of the serpentines is hardly to be doubted. One of them (E10388) [SH 423 914] shows the meshwork structure of serpentinised olivine preserved in dolomite and picked out in haematite dust, so it is inferred that they are carbonate pseudomorphs after serpentinised peridotites. Moreover, the cal-citisation can be dated. The rocks being essentially one with the tremolite- and tale-schists, it is evident that their calcium and magnesium are from the same source as the tremolite and talc, and that their carbonates are true minerals of anamorphism. Some of the ophicalcites are traversed by numerous veins of pale actinolite, so that the carbonate must belong to the anamorphic process, of which it is not even the last product. The low percentage of magnesium in the carbonate of No. II may be ascribed to the development of tremolite. The absence of that metal in No. III, which is the only pure calcium-ophicalcite known in the Island, is due partly to the same cause, but even more to de-dolomitisation at a late stage, during the formation of the veins of actinolite.

Chlorite-chromite-magnetite-schist — At several places a peculiar basic rock appears, which is never more than a few feet, usually only a few inches, thick. Sometimes well foliated, sometimes rather massive, it is dark green, soft, and studded with black octahedra which attain a diameter of nearly a quarter of an inch. The green matrix is a felt of chlorite with some granules of epidote and iron-ore. The nature of the chlorite has been discussed by Prof. Bonney<ref>*Geol. Mag.* 1890, pp. 539.</ref>, and he writes me that he has now no doubt that the mineral is one of the chlorites. The large octahedra were ground out of his slide and so left undetermined. If, however, they be tested by an ordinary magnet, they rise briskly on edge, but do not leap to it as would magnetite. If a fragment from a single crystal be finely crushed, the dust is found to be partly opaque, partly translucent with the deep colour of chromite. It is therefore probable that the crystals are isomorphous intergrowths of magnetite and chromite. The following analysis was published by Prof. Bonney in his paper of 1881. It is, however, of the green matrix only, the octahedra having been removed. The rock must therefore be even more basic than this analysis, and must contain a high percentage of iron with a considerable amount of chromium. It does not correspond in composition to any other known rock in Anglesey, and is doubtless a secondary product.

SiO_2	28.56
Al_2O_3	39.54
Fe_2O_3	0.99
FeO	2.87
Cr_2O_3	traces
MnO	traces
CaO	1.73
MgO	15.79
Alkalies	0.70
Water	11.09
	101.27

Chlorite-chromite-magnetite-schist, adjoining talc-schist (pp. 104, 277). Quarry 250 yards north of Bronddel (south-west of Plâs-coch, six-inch map). Anal. F. T. S. Houghton.

Deformation and metamorphism

These intrusions have been considerably affected by the dynamical metamorphism of the Mona Complex. It is probably safe to say that the greater part of the serpentine is undeformed, but such a statement, unqualified, would convey a_most misleading picture. For it is so riddled with planes of gliding that the lenticular cores of massive rock are seldom as much as a few yards in length, and usually a foot or a few inches only. Round them sweep schistose films, generally light yellow, slickensided, shiny, slippery, and unctuous to the touch. So strong is the tendency of the rock to part along these planes that hardly any others are presented on the faces of exposures, and it is often rather difficult to obtain specimens with good cross fracture. Sometimes the serpentine is thoroughly schistose for a width of 30 or 40 yards, though anamorphism is limited to the production of antigorite. It would seem as if the ease with which serpentine gives way along planes of molar movement is a substitute for the molecular movement that results in a truly anamorphic schist; and it thus appears that the serpentinisa-tion of the peridotite preceded its deformation.

In the gabbro, massive cores are far larger, often 80 yards or so in length, and from these its great steep-sided bosses have been shaped. Yet a rude parallel structure is often to be seen, and at a few places it passes into a perfect, fissile, gabbro-schist (Plate 9), Fig. 4. Reconstruction is as general as it is exceptional in the serpentine. A pale hornblende is present even in the massive cores; and when visibly deformed, this has completely replaced the diallage, streams of it winding along the planes of movement. The fissile schist is composed of epidote and fine actinolite. Both the serpentine-schist and the gabbro-schist reach, where most fissile, a further stage, and are minutely puckered.

The associated metamorphic rocks are all true crystalline schists, and in the tremolite-schists and tremolite-marble anamorphism has been carried very far. In the ophicalcites, the relations oft the silicates to the carbonate-mosaic are those which are usual in the crystalline limestones of regional metamorphism. What local conditions determined the production of such rocks, instead of merely schistose serpentine, from the peridotites, is not yet known.

Speaking generally, there can be no doubt that these intrusions, and their products, have been far more than merely deformed; they have been affected in a considerable degree by the anamorphism that has produced the foliation of the Mona Complex.

Marginal rocks

Andalusite-mica-hornfels — A wide halo of induration that surrounds the dolerites of the north is described on pp. 320–1. Its more crystalline parts are chiefly composed of criss-cross' white and brown mica, in which are porphyroblastic pseudoinorphs, now chiefly composed of white mica, but sometimes idiomorphic, zonal, and with outlines as of andalusite.

Epidote-hornfels and Epidosite — Skirting the margins of the intrusions of the Strait of Holy Isle are interrupted borders of peculiar altered rocks. Though possessing certain characters in common, such as the general presence of epidote and absence of a fissile structure, they fall into two natural-groups.

Those here termed 'hornfels' are compact, with a conchoidal fracture. In colour they range from a grey green like that of the New Harbour Beds to a pistacio green due to disseminated epidote. They are composed of quartz (often crypto-crystalline), chlorite, epidote, a little pale hornblende, and albite. That they are of sedimentary origin there is no doubt. They have a fine even banding, and some of the quartz retains an clastic aspect. This bedding is folded sharply and the folds are cut by shear lines. Along the southern shore of Rhyd-bont Creek one of them is clearly seen to be a modification of the New Harbour Beds, and at the creek-head it is full of needles of actinolite that lie in all directions and penetrate all the structures. Those here called 'epidosite ' are developed on a much greater scale. Along the southern margin of the large intrusion of Holy Isle, a zone of them a quarter of a mile wide extends for more than a mile. They are of medium grain, but rapidly variable, so as to weather lumpily and ruggedly. Weathered surfaces look well-foliated, but on fracture the fissility is found to be almost obliterated, and they are extremely tough under the hammer. In places they retain a grey-green tint like that of the Green-mica-schists, with granular and fissile bands as at Holyhead, the quartz being sometimes also 'rodded'; but these types pass rapidly into pistacio-tinted epidote-granulite in which all fissility has disappeared. The minerals of this are quartz, epidote, chlorite, and amphiboles, with some albite and carbonates. The epidote occurs both in granules, rods, and large glandular aggregates; it is partly colourless, but chiefly coloured and strongly pleochroic. The amphibole is for the most part very pale, and finely matted. The rudely lenticular seams of quartz, which contain albite and a little carbonate, are often yellow with rows of epidote granules, which occur also freely in the seams of chlorite. The quartz of some is full of slender hairs of amphibole. Many specimens (E9755) [SH 264 768], (E9758) [SH 272 769] are penetrated by needles of green pleochroic actinolite (Plate 9), Fig. 6, with good idiomorphic cross-sections and prismatic cleavages, which attain a third of an inch in length. They pierce the quartz-albite folia, sometimes at right angles, and are not cut by any planes of movement.

In the heart of the zone the rocks are highly reconstructed; but on the craggy platform above the talc-schist north of Bronddel, and by the ruin 433 yards north-west of Bodior Lane, schist with the same epidote and amphibole, contain undoubted clastic quartz; and at the '36' level, bedded jaspers are found within the zone, with their quartz seams epidotised. These epidosites must therefore be regarded as a special state of alteration of the New Harbour Beds, whose pyroclastic element probably accounts for the amphibole and epidote.

It must be admitted that the zone contains none of the minerals usually regarded as thermo-metamorphic. Yet epidosites resembling these have been found in a thermal aureole at Old Lizard Head<ref>'Geology of the Lizard and Meneage, ' p. 36.</ref>, and the destruction or prevention of fissility as well as the mode of occurrence of the actinolite points to contact alteration. The epido-site zones undoubtedly behave as an aureole to the basic intrusions, and may with confidence be looked upon as their thermal product.

Chronology — It is evident that when this thermal influence was exerted the foliation of the New Harbour Beds was imperfectly developed, though it had been initiated, and the same is the case with the epidote-hornfels, as well as with the andalusite-mica-hornfels of the north. We have seen that the serpentines and gabbros became in their turn deformed and foliated. Their intrusion must therefore have taken place during an interval, or intervals<ref>This is confirmed (see pp. 208, 211, 321) by their field-relations</ref>, of the great movements of the Mona Complex.

The Penmynydd zone of metamorphism

The Penmynydd Schists, named after a village in the midst of their principal district, are to be regarded not as a stratigraphical but as a metamorphic horizon. Several, possibly all of them, indeed, can be identified elsewhere in a less altered state. But whatever their origin, the rocks of the zone, in the condition in which they are found in it, are marked and important metamorphic types, and as such they will be considered in this section. All of them are holocrystalline schists, and next to the Gneisses are the most highly reconstructed rocks in the Island. They are:

Mica-schists

Quartz-schists

Limestones

Graphite-schists

Rutiliferous-schists

Hornblende-schists

Glaucophane-schists

Banded Marginal Rocks

The Mica-schists

The Mica-schists are by far the most extensive, being, indeed, a foliated 'country' in which lenticular masses of all the others float. Two leading types may be recognised: a flaggy or evenly foliated, and a flaser or lenticularly foliated. Intermediate types connect them, and there are sub-types of each too numerous for description here.

The flaggy type tends to be rather fine, its mica, though well and sharply formed, being usually small, though there are exceptions to this. On the whole, its aspect recalls the rocks that are found immediately above the mylonites of the Moine thrust-plane in Scotland. The essential minerals are quartz, felspar, white and brown mica, and iron-ores, accessories being unimputant. The brown mica is often chloritised, but when fresh has a moderate pleochroism. The felspar is an alkali variety, usually untwinned, but where determined is a sodium species. The flaser or lenticular type, which is more extensively developed than the flaggy, is more highly crystalline and with a greater variety of minerals. Instead of being even, it is wavy on the foliation-planes, an appearance due to its being built up of overlapping lenticular seams, one-eighth to a quarter of an inch in thickness, of saccharoid granular matter, about which bend the fissile folia. The rock is very clean and fresh, and the foliation-surfaces brilliant, with a tinge of pale sea-green upon them. The flaser structure is further emphasised by conspicuous augen and twisted lenticular sheets of white venous quartz (Plate 11).

The essential minerals are quartz, felspar and white mica. Epidote often rises to the rank of an essential. An abundance of accessories is a feature of the type. They are epidote, zoisite, garnet, sphene, zircon, apatite, rutile, haematite, biotite, chlorite, and opaque iron-ores. The felspar is albite, with an occasional grain of microcline, and this being the case, it results from the analyses (p. 112) that the white mica must be muscovite. The albite is generally clear (save for inclusions in the larger grains) and often untwinned. The muscovite is well formed, in flakes that may exceed one millimetre in diameter. The epidote is largely in yellow pleochroic prisms, with usually high but often variable birefringence, and some give the polarisation hues of zoisite. The garnets are usually small, and sometimes idiomorphic. Small flakes of blood-red haematite are a feature of the schists. Tourmaline is very rare. Some slides are so crowded with minute accessories of high refractive index that it is not easy to say what are the proportions among them of the several minerals. Delessite in radiating groups fills small fissures. The structure is granoblastic, with lepidoblastic seams. But some of the rocks (Plate 10), Fig. 5 contain porphyroblastic felspars of irregularly oval outline, deeply embayed by the matrix, more than a millimetre in length. They are albite, or rather albite-oligoclase, for the mean refractive index is about 1.538, and they seem to be both positive and negative for ordinary light. Dr. H. H. Thomas (who examined a slide) suggests, accordingly, that 2V may be nearly 90°. They sometimes exhibit binary but very seldom lamellar twinning, some are irregularly compound, and there are a few similar porphyroblasts of microperthite. The albite porphyroblasts are almost always water-clear, and their central parts are apt to be poiciloblastically crowded with long microliths, among which are epidote, zircon, rutile, sphene, iron-ores, occasionally zoisite, and rarely tourmaline. These inclusions lie for the most part with their longer axes parallel to the foliation of the rock, which thus appears to stream through the large albites; but almost as often lie obliquely, or even at right angles to it, while in a few cases the inclusion-streams are bent, as if the porphyroblasts had been turned round. Yet there is no sign of optical strain in these albites, and different inclusion-streams may even have different directions within the same crystal. Except that there is no approach to hypidiomorphism, the structures are identical in every detail with those of the albite-schists of the Scottish Highlands.<ref>Clough and Teall. 'Geology of Cowal' (*Mem. Geol. Surv.*), pp. 39, 299, plates vi, vii.</ref>

Undulose extinction is rare in the Penmynydd Zone. The quartz of the white venous augen is in some cases coarsely granoblastic like ordinary vein quartz, in others nemablastic, and then usually contains a few large plates of muscovite. Many of them have milky bands of minute cavities. No felspar has been found in these white ones. There are, however, augen composed of coarsely crystallised pink potassium-felspar with a varying proportion of quartz. The felspar was kindly determined, some years ago, by Dr. Teall, using Szabo's method.

Quartz is therefore found in these rocks in three conditions: (1) that of the granoblastic body, (2) that of certain finely granoblastic pinkish, twisted, augen, (3) that of the stout venous augen (Plate 11).

The following analyses have been made of typical Penmynydd mica-schists. One of a rhyolite has been added for comparison, and they will be discussed on pp. 122–7.

	I	II	III	IV	V
SiO_2	70.35	—	67.42	73.48	73.51
TiO_2	not det.	—	not det.	0.29	—
Al_2O_3	15.16	—	17.51	14.79	14.42
Fe_2O_3	0.53	—	1.71	0.03	0.46
FeO	4.31	—	2.27	1.04	1.49

MnO	none	—	—	trace	trace
CaO	1.23	—	2.22	0.53	1.26
MgO	1.89	—	1.32	0.43	0.33
K_2O	2.27	2.63	2.53	4.24	4.29
Na_2O	2.98	2.51	3.76	4.40	4.03
H_2O (at 110°)	0.141}	—	1.06	0.81	—
H_2O (above 110°)	1.06}				0.04
SO_3	none	—	none	0.03	—
P_2O_5	none	—	none	0.02	0.04
	99.92	—	99.80	100 09	100.23

I. Well foliated muscovite-biotite-schist. Porth Nobla, south side (E9900) [SH 329 711]. Anal. J. O. Hughes.

II. G-arnetiferous mica-schist. North-east end of Llyn Hendref, Gwalch-mai (E9993) [SH 400 768]. Anal. J. O. Hughes.

III. Typical Penmynydd mica-schist. 300 yards north-north-east of Braint Farm, at 200-foot contour (E9912) [SH 530 736]. Anal. J. O. Hughes.

IV. Foliated quartz-albite-rock, with broken phenocrysts of microcline, and a little white mica, epidote, sphene and garnet. 100 yards east-south-east of Graig-fawr, Holland Arms, about two feet from north-west margin of boss (Figure 10) (E8486) [SH 474 724]. Anal. P. Holland. *Quart. Journ. Geol. Soc.,* 1902, p. 666.

V. Rhyolitic obsidian. Medicine Lake. Anal. *U.S. Geol. Surv.*

Quartz-schists

These are white, foliated, glistening with-mica, and saccharoid on cross-fracture. They are simple homoeoblastic schists, composed of quartz, with a varying proportion, sometimes very small, of white mica. No felspar has been seen. Some of them have the aspect of quartzites, but show no clastic grains.

The limestones

The limestones are grey or cream-coloured in tint, some are mottled, some have thin dark seams. Most of them bear some resemblance to the grey Gwna limestones, but even the finest are slightly foliated, which is due to trains of tolerably well-formed flakes of mica, lying in a granoblastic base of carbonate, in which are a few small grains of quartz. The carbonate of the grey type is calcite, of the cream-coloured ones dolomite.

A series of slides taken across the limestone of Trecastell, which is a good deal more altered, show that it graduates through calc-mica-schist into mica-schist. A few limestones of the zone are far more highly crystalline, and may be described as gneissose marbles or cipolini. The Bodwrog marble, perhaps the most beautiful rock in the Island, is composed of snow-white granular calcite, with parallel flakes of well-formed white mica and some rounded grains of quartz. The marble of Erddreiniog is grey, and composed also of granular calcite, but with abundant accessories, including quartz, chlorite, iron-ores, white micas, albite and oligoclase, tourmaline, zircon, sphene, rutile, and anatase. Most of them are anhedral, but some of the anatase (identified by Dr. Thomas) has its characteristic form. These two rocks have been analysed, as follows:

	I.	II.
Residues insol. in HC1	4.96	23.30
Al_2O_3 Fe_2O_3	2.01	6.66
CaO	50.14	37.32
MgO	0.15	0.69
CO_2	42.29	30.42
	99.55	98.39

Percentage $CaCO_3$	89.54	66.64

I. 767 yards east of Bodwrog Church. Second band of limestone from west. (E10057) [SH 407 776]. Anal. J. O. Hughes.

II. Quarry by wall, south of wood, about half a mile north-north-east of Erddreiniog. (E10080) [SH 464 811], (E10081) [SH 464 811], (E11396) [SH 464 811]. Anal. J. O. Hughes.

In No. I. it would seem as if some silicate must have yielded a little to the acid, and its SiO_2 and Al_2O_3 have come down with other elements of the rock. Both rocks differ greatly from the cipolini of the Lewisian Gneiss of Scotland ('Geol. North-West Highlands'. *Mem. Geol. Survey,* p. 82), as well as from the ophicalcites of the Mona Complex. The absence of magnesium is remarkable.

Graphite-schist

Where the black schists occur within the Penmynydd Zone they are far more highly crystalline, being thoroughly lepidoblastic. Some varieties are lustrous, others dull and sooty on the foliation-surface, but all yield a black streak, one that.. adjoins the Bodwrog marble yielding a very strong black streak. A specimen from a little chasm in the cliff south of Porth Tre-castell, 200 yards south-west of the Telegraph Cable Hut (E10030) [SH 331 704] (Plate 10), Fig. 6 was examined by Mr. J. O. Hughes, who separated the graphite by destroying the rock with hydric fluoride. It amounted to 0.65 per cent., but Much richer ones are now known. The principal minerals are quartz in granoblastic seams (associated with which is a little sodium-felspar), and white mica partly in felted folic, partly in large plates. The graphite is both in dust and in foliated scales. Pyrite and leucoxene are plentiful, so that three opaque minerals are present. The residues left by the hydric fluoride contained many lustrous prisms of rutile, and tourmaline has been found in other specimens. Finally, there is a mica-like mineral with a good pleochroism ruddy-brown to dull olive-green or colourless: *X* >*Y*, *Z,* (apparently); and optically negative with a varying, sometimes considerable, sometimes very small axial angle. But the birefringence is rather low, not much exceeding 0.01, while the refractive index considerably exceeds 1.6. It is referred, therefore, to one of the xanthophyllite-chloritoids. It is intergrown with white mica, and sometimes crowded with the rutile needles, as well as minute inclusions. The structure- of the rock is highly complex. The graphite and most of the mica lie along the foliation; but the xanthophyllites are in large ragged-sided compound encarsioblasts and their basal cleavage is transverse to that foliation. Through them, however, the graphite seams run on without interruption, so that the encarsioblasts must have developed after the completion of the foliation, and in a solid rock. The little clots of the graphite seams are often frayed out somewhat along the basal cleavage of the xanthophyllite.

Rutiliferous schists

The graphite-schist is very rich in rutile; but still more is present in a dull green schist at Bwlch-y-fen (E10058) [SH 418 778], which is chiefly composed of biotite with a feeble brown pleochroism, but now largely chloritised, and some calcite seams with quartz. Iron-ores, pyrite, and apatite are fairly plentiful, and there is a little tourmaline and xanthophyllite. The rutile is chiefly in rather stout prisms that lie along the foliation, unlike the slender needles of the graphite-schist. Analysed in part by Mr. J. O. Hughes, it yielded: SiO_2=42.94, TiO_2=2.54.

The hornblende-schists

The hornblende-schists are heavy, platy, dark-green rocks, often with pistacio-tinted epidotic seams. A few varieties are nearly black, a few quite pale in tint. Their essential minerals are hornblende, epidote, zoisite, albite, sometimes quartz, and occasionally pyrite. Sphene is often plentiful, and the other accessories are a white mica, magnetite, ilmenite, apatite, and occasionally zircon and rutile. The rocks may befine, but are usually of medium grain, hardly lepidoblastic, but foliated granoblastic schists. The hornblende is in rather long blades, and pleochroic, thus: *X*, pale straw-colour, *Y*, brownish-green, *Z*, blue-green, that of the pale schists being: *X*, colourless, *Y*, nearly colourless, *Z,* pale blue-green. Most of the epidote is normal, some pale with low birefringence; but in some of the rocks typical zoisite with delicate blue polarisation-tints is quite abundant, often in long prisms. Granoblastic albite is often an important constituent; it is usually water-clear and untwinned, sometimes disseminated, sometimes in seams which contain also quartz and epidote. A few of the dark rocks contain feathery' porphyroblastic hornblende lying in all directions on the foliation-planes. It has the same optical characters as the rest of the hornblende, but is a good deal larger, and is idiomorphic, with the prism and pinacoid well-developed. Oval porphyroblasts of albite-oligoclase, poiciloblastically crowded with inclusions, are occasionally a character; they resemble those in the albite-mica-schists, but their inclusions are much smaller. Some of them are compound, and contain granoblastic quartz. A remarkable schist at Gwalchmai is rich in contemporaneous, granoblastic, pyrite, developed in thin 'schlieren' along the foliation, and therefore a true metamorphic mineral. This unusual rock is also rich in zoisite and rutile, and contains albite porphyroblasts, with some hexagonal hsamatite. The hornblende-schists of the Aethwy Region have many quartz-augen, like those in the mica-schists, some being venous, others nemablastic in texture.

Usually these rocks are well-foliated throughout, but about Holland Arms and Llangaffo there are cores with remains of igneous texture. The hornblende is larger and broader, with pleochroism: X, straw-colour; Y, olive-green; *Z,* blue-green; their albite is in large broad laths with strong lamellar twinning, and their sphene (which is abundant) is eumorphic. Parallel structure is never absent, but is often very slight, and the rock is here an albite-diorite. The metamorphic process was long, for some of the quartz-augen are cut by old faults that were afterwards healed up by crystallisation; and a few of the quartz-albite augen south-west of Bwlch-gwyn, though the main foliation bends round them, are themselves a little foliated.

The glaucophane-schist

This remarkable rock is unique in Britain, for glaucophane has not yet been detected anywhere else in the British Isles. Even in Anglesey it is, not known outside the Aethwy Region, in which there are 18 masses. It is a dense, heavy schist, very tough, and of a dark steel-blue, sometimes dark lazuli-blue, tint externally, thoroughly foliated, and decidedly but not excessively nemablastic. The body of the rock is very homogeneous, but this is varied by quartz-augen, thin quartzose and epidotic seams, and bright films of white mica tinged with scarlet scales of hematite, usually adhering to the quartzose augen. The foliation is rapidly folded, a structure well brought out by the weathering of the thin hard quartzose seams. The structures on the large scale — are usually parallel, but knots of epidosite about six inches long are not uncommon, and on the crags that overlook Llyn Llwydiarth the normal schist winds about great phacoidal masses of similar but rather less foliated schist several yards in length. Near the same place are cores with surviving plutonic texture.

The essential minerals are glaucophane and epidote; the accessories are white mica, quartz, albite, green hornblende, chlorite, zoisite, hematite and ilmenite, with a little sphene. Lawsonite has been searched for but not found. In one small quartz-knot at Castellior are a number of prisms of brown tourmaline. The aspect of the rock in thin section, which is now well known from the striking coloured plate (No. 47) in Dr. Teall's 'British Petrography',<ref>Photographic plates have been published in Mr. Adye's ' Atlas ' and in Gruben-mann's 'Kristallinen Schiefer', Tafel viii.</ref> is of unusual beauty, nearly two-thirds of it being composed of a continuos foliated weft of clear blue glaucophane, in which float the epidote and all the other minerals.

This weft of glaucophane is composed of slender prisms elongated in the direction of the vertical axis. The basal planes have not been observed, but sections of the rock taken across the foliation show that large numbers of the crystals are idiomorphic in the prismatic zone, the faces (110) meeting at the characteristic angle of 124.2° to 124.4°, being often quite perfect, sometimes combined with (010), and that both prismatic cleavages may be well developed. The refringence and bi-refringence differ but little from those usually obtained. Distinct optical pictures in convergent light are not easy to obtain. The extinction angle is normal, being about 5° in the typical blue glaucophane, but in some crystals of a feebler tint it may rise to 15°. The pleochroism is pronounced, and is: *X*, very pale straw colour; *Y*, lavender-violet; *Z,* strong sky-blue. The moderate proportions of aluminium and of water that are present in the rock show that the mineral is not gastaldite, but a true anhydrous glaucophane.

The epidote is partly in granular aggregates, but largely in idiomorphic prisms elongated in the direction of the orthodiagonal, and a good many show the cleavage. It has a high bi-refringence, and is rather strongly coloured, with the characteristic lemon pleochroism. Epidotes of low bi-refringence are less common than in the other basic rocks of the Complex; but there are a few prisms of true zoisite with blue polarisation-tints. Much of the clear green component that is present is chlorite; but there is also a green hornblende, which is intimately related to the glaucophane, sometimes eumorphically as a core within it, and graduating into it through a narrow blue-green zone, the angle of extinction sinking as the colour changes from green to blue.

These green minerals are apt to be developed on either side of epidote-aggregates in the direction of the foliation, so as to form with the epidote small compound augen. The thin granoblastic lenticular seams of colourless minerals are largely quartz; but contain a little water-clear felspar. This has a much lower refractive index in all cases than the quartz, and in some cases undoubtedly lower than 1.536: it is optically positive; and sometimes displays lamellar twinning with extinction angles of about 8°. It is therefore albite. Bordering the siliceous seams are often trains of well-formed plates of clear scarlet huinatite, and there are small schlieren of ilmenite, sometimes passing into hzematite along their edges. The granules of sphene are very small, and rather rare, and may have been developed from the ilmenite.

In many slides hardly any white mica can be seen, but there is a good deal in the rock as a whole, concentrated, however, into the films alluded to. It is in well-developed plates, often as much as a millimetre in diameter, many of which display a perfect optical picture in convergent light, with an acute bisectrix emerging nearly at right angles to the cleavage, and always optically negative. Some of the plates, however, have undergone much optical distortion, producing undulose extinction and disturbance of the optic axes. When free from this, the axial angle is a wide one. The refractive index and birefringence are indistinguishable from those of muscovite. Some flakes of this mica were detached, freed from other minerals, and destroyed by hydric fluoride. The solution was examined spectroscopically, and Mr. J. O. Hughes reports that it displayed the spectrum of sodium strongly, without any trace of the spectrum of potassium. This mica, therefore, is paragonite.

The large epidosite knots consist of granoblastic epidote with short needles of glaucophane, and are quite unfoliated. The quartz-augen are of the same types as those in the green hornblende-schists. Thin quartz veins cut the foliation at right angles, but contain a little glaucophane and are themselves foliated, so that they must belong to an interval in the metamorphism. There are also lenticular bands of granoblastic quartz, with epidote, in which are plates of paragonite and many needles of glaucophane; and these, though seldom exceeding an inch in thickness, may be allied to some of the siliceous glaucophane-schists analysed by Washington.

The rocks of plutonic aspect occur as phacoids a few yards in length, floating in ordinary glaucophane-schist, compared with which they are rather coarse. They are composed of lenticular tracts of glaucophane (in which is a little green hornblende) inosculating with similar tracts of granoblastic epidote, zoisite, quartz, and albite, with aggregates of sphene. Some of the glaucophane is in broad plates, which may lie in any direction. The rock is a modified and foliated glaucophane-diorite.

The true glaucophane-schist is a rock *sui generis,* and is found in large tracts of its own. But some of the green hornblende-albite schists contain small quantities of a blue-green amphibole with low extinction angles, as well as of real glaucophane, so that intermediate types of rocks certainly exist.

The following analyses will enable this glaucophane-schist to be compared with the hornblende schist and with standards.

	I	II	III	IV
SiO_2	45.87	47.47	47.859	57.67
TiO_2	not det.	not det.	1.376	—
Al_2O_3	18.80	15.25	15.614	11.07
Fe_2O_3	5.72	8.22	4.921	3.20
FeO	5.44	719	7.050	9.68
MnO	trace	trace	0.077	0.06
CaO	11.64	11.32	9.113	0.95
MgO	6.76	5.96	6.328	9.85
K_2O	1.99	0.56	0.822	0.42
Na_2O	2.61	2.11	3.210	6.80
H_2O (at 110°)	0.05	0.04	0.161	0.12

H_2O (above 110°)	1.35	213	2.789	0.36
P_2O_5	not det.	—	0.037	—
CO_2	not det.	—	0.696	—
	100.23	100.25	100.053	100.18
Spec. Grav.	2.21	3.77	—	—

I Hornblende-epidote-albite-schist (E9914) [SH 520 734]. 400 yards west of Sarn-fraint Bridge. Anal. J. O. Hughes.

II Glaucophane-epidote-schist (E9829) [SH 536 715]. Quarry 250 yards east-southeast of Column near Tubular Bridge. Anal. H. S. Washington. *Amer. Journ. Sci.* (1901.)

III. Average of nine basic glaucophane-schists given by Washington. *Op. cit.,* Nos. I–VI, VIII–X.

IV. Glaucophane of Syra. Anal. H. S. Washington. *Op. cit.*

The specific gravity of II is rather above a mean of the specific gravities of glaucophane and epidote. That of I is much lower than a mean of those of green hornblende, epidote, and albite; low even if we suppose a considerable excess of albite, which is visible in some slides. It will be seen that I contains much more potassium and less iron than II. Comparing II and III, the glaucophane-schist of Anglesey is seen to be a tolerably typical example of its class, but rich in ferric iron and in calcium, poor in both alkalies and presumably in titanium, as that was not estimated. In view of the proportions of its alkalies, it is of interest to note, that its amphibole, its felspar, and its mica, being glaucophane, albite, and paragonite, are all sodium species.

Origin of the glaucophane-schist

It is usually assumed that glaucophane-rocks, that of Anglesey included, are derived from gabbros or other basic intrusions. In the spring of 1903, however, the present writer, having found that the basic schists of the Gwna Beds (see pp. 76–8) are derived from the spilitic lavas, that amphiboles develop in those schists as they approach the Penmynydd Zone of metamorphism, and that in several places they contain a little glaucophane; began to seek for evidence on the possible derivation of the glaucophane-schist from the lavas. At that time the lavas had not been analysed, but the question at once arose as to what had become of their jaspers in the process. In the course of the summer it was found that the jaspers became bleached at a moderate stage of metamorphism (see p. 88), and the suggestion occurred that the quartz-augen of the glaucophane- and hornblende-schists might represent them. Quartz-augen, it is true, occur also in the mica-schists, but it was found that a skin of haematite usually surrounded those in the basic schists, which might represent the discharged iron of the jasper. When the lavas were analysed, it appeared at once that a common origin was possible. In 1911, Dr. Teall, quite independently and without knowing of any of this evidence, suggested, in a letter to the present writer, that glaucophane-schists might be derived from pillow-lavas, asking if there was any field evidence for such a connexion; and in 1912, Mr. J. O. Hughes, independently of both, suggested the connexion on the ground of the analyses alone<ref>Since writing the above, I have obtained a copy of a paper by Rosenbusch "Zur Deutung der Glaukophangesteine" (Ak. Wise. Berlin, 1898), in which he gives a study of some glauc-amphibole rocks from California regarded by Palache as altered tuffs. He considers them to have been "diabase- or spilite-tuffs', and regards their fragments as diabase- or spilite-lapilli, but speaks with reserve, the nature of the fragments being difficult to determine. It will be remembered that spilitic lavas had pot at that time been very closely studied.</ref>. If the analyses on p. 74 be compared with those on p. 118, it will be seen that the rocks are closely allied in composition, especially in the relations of their alkalies. The difference is chiefly in the ferric iron, a difficulty that may perhaps be surmounted by supposing that the original of the glaucophane-schist had become haematised at an early stage of its history, a change that is known (see pp. 73–4) to have affected the Gwna spilites very widely.

Garth Ferry — Now, in the basic mass that ranges south-westward from Garth Ferry, a rather dull glaucophane-epidote-schist (E9526) [SH 578 740] is quarried in the steep wood above the road. Its glaucophane is pale, but has the usual characters. Followed across the streamlet to the south-west, glaucophane diminishes, the rock becomes duller, and at the end of the crag in the wood (called Coed Berclas on the six-inch map) has become a chlorite-epidote-albite-schist (E11088) [SH 578 740] with traces of igneous texture, which differs in no way from those that are known to be derived from the spilitic lavas and albite-diabases. There can be no doubt of its continuity with the glaucophane-schist, for though exposure is not absolutely continuous, the crag feature is, and the basic rock is accompanied all along by a thin band of peculiar greenish mica-schist which can be distinguished from the rest of the Gwna Green-schist.

Yr-allt — The basic band that ranges along the road at Pedair-groeslon and Yr-allt is, as far south as Yr-allt, a green chlorite-epidote-schist rich in ternary albite (p. 367), but at its southern end a good blue glaucophane-schist appears. The two types are not seen in continuity, though they lie on the same line of strike. A little to the north-east of Yr-allt, however, the green chlorite-epidote-albite-schist contains (E6092) [SH 552 733] a number of crystals of almost idiomorphic glaucophane. The prism-cleavages are unusually well developed, and the pleochroism is pronounced and perfectly characteristic. The band lies in a zone of progressive anamorphism, on its eastern side being Gwna mélange with lenticular grits, on its west Gwna Green-schist with larger micas than usual, but with typical nemablastic pencilling; 50 to 150 yards beyond which the Penmynydd mica-schist comes on. The continuity, therefore, of the two basic types need not be doubted. We have in the rock (E6092) [SH 552 733] an evident passage-type, in which glaucophane is beginning to develop, albite and chlorite nevertheless remaining in large quantity. The size and idiomorphism of the glaucophane, however, are an unexpected feature in such a type.

Llaniestyn — At the farm by Llaniestyn Church is a dull chlorite-epidote-schist (E9691) [SH 586 797] with fine pale amphiboles, in which are large deformed phenocrysts of albite and oligoclase that still retain lamellar twinning, and evidently once a lava. In the same large basic mass, south-east of Ty-du, a fine glaucophane-schist strikes towards this lava.

Llandysilio — A little glaucophane is also found in the chlorite-epidote-albite-schist (E10208) [SH 553 716] and analysis] in the Gwna Beds on the shore east-south-east of Llandysilio Church islet, which lies in the same anamorphic zone as the rock of Yr-alit.

Inferences — There can be little doubt, therefore, that these four imperfect glaucophane-schists are modifications of the spilitic lavas of the Gwna Beds. Were no other evidence forthcoming, there would be no hesitation in identifying the perfect ones of the Penmynydd Zone with the same lavas, though it would be unwise to lay stress on an identification of their quartz-augen with the Gwna jaspers. Their occasional phacoidal structure, and especially their large knots of epidosite, are certainly reminiscent of the ellipsoids of the lavas. No quartzite or limestone has been found with them, so the original rock is probably not the Llanddwyn spilite, but may be the Engan spilite (pp. 76–8), with which no quartzite or limestone are associated. The cores of glaucophane-diorite and zoisite-amphibolite might easily have been derived from the small associated sills of albite-diabase.

On the other hand, we have seen that the glaucophane-schist is linked by intermediate mineralogical types to the green hornblende-schists, and that some at any rate of those must be intrusive, as they have cores with good plutonic texture. From the presence of cores of green hornblende in some crystals of glaucophane, it has been inferred that the blue has been produced from the green amphibole. But the glaucophane of Garth Ferry has developed in a rock that must have been pyroxenic without any development of green amphibole as an intermediary. Whichever the origin of the typical glaucophane-schist, it must have been produced either from a hornblende-albite or an augite-albite rock; most of the elements of the albite going to the production of epidote, the sodium being transferred to the ferromagnesian mineral so as to produce glauco-phane, and a little albite remaining over in a reconstituted form.

Dr. Teall points out to me that the higher density of glaucophane-schist implies that it was pressure that determined whether the sodium should enter into albite or into glaucophane. Now, in the Penmynydd Zone the hornblende-albite-schist and glaucophane-schist occur side by side, and there is not the slightest evidence of any greater pressure in or around the latter. Under dynamo-metamorphism, the outer portions of a deep-seated albite-diorite containing 1.99 per cent. of K_2O would tend to produce a green hornblende-schist with some reconstituted albite; while a spilitic lava, having consolidated originally under low pressures, would, when passing into an amphibolitic schist of some kind (as it could not fail to do), tend to transfer its sodium to the high-pressure mineral, and give rise to a glaucophane-schist. The uniformly fine texture of the glaucophane-schist over large areas also points to a fine rock as its origin, for basic intrusions of such size could hardly fail to show coarser centres, whereas the glaucophane-diorites referred to are known only in one place and are quite small.

It therefore seems probable that much of the glaucophane-schist has been produced from the spilitic lavas themselves; but it must also be admitted that parts of it may represent the intrusive portions (not very deep-seated) of the same magma, which had consolidated at still lower levels as coarse albite-diorite, now partly transformed into albite-epidote-hornblende-schist.

Banded marginal rocks

Along the margins both of the hornblende- and the glaucophane-schist the mica-schist often assumes an unusually compact and flaggy structure. This material, which contains very little mica (sometimes none at all), is rich in albite, usually also in epidote, sometimes in zoisite as well. It is a typical homœoblastic quartz-albite-epidote rock. About Holland Arms and elsewhere long narrow lenticular strips of it occur as inclusions in the hornblende-schists. They lie along the foliation planes, and such foliation as they themselves possess is conform'able to that. In many places, especially on Mynydd Llwydiarth, this material alternates rapidly with both the amphibolitic schists along the junctions, so that there is a zone of interfelting, sometimes forty yards in width. On the crags north-east of Tyn-y-mynydd ('west') this is so pronounced as to give rise to what might be called strong banded gneisses, but that they have not the coarse granitoid texture that is usually implied by that term. In one crag of hornblende-schist nine feet wide, seven acid bands were counted, contrasting strongly with the dark ones. But both acid and basic bands may be so thin as to be little more than films. In these finely banded rocks the white seams are granoblastic albite and quartz with a few garnets, the dark seams chiefly straight prisms of hornblende with many of blue-plarising zoisite (some of which have cores of epidote), some iron-ores, and rutile. Often the junctions are perfectly sharp; at other times there is a narrow zone of passage that is probably a reaction-rim between the acid and the basic matter.

Now, whatever the origin of the mica-schists, it is evident that this compact modification depends on the presence of the basic schists. We have seen that some of the latter contain coarse dioritic centres. There is therefore presumptive evidence that these were intrusive into the original material of the mica-schist, that the inclusions are xenoliths, and that the banding is due to rolling out of thin branching sheets at the margin of a basic sill. The richness in albite of the compact acid rock, and its texture, are suggestive of its having been an adinole, a kind of material that is known to possess great powers of resistance, and thus to retain its compactness under dynamic metamorphism. That this material is found on the margin of the glaucophane-schist of Llyn Llwydiarth points to that particular mass having been intrusive, and it is the one in which the cores of glaucophane-diorite occur.

Origin of the Penmynydd Mica-schists

Survivals of original textures

Remains of original structures have been found at four places only; and as in three cases these are igneous, in one sedimentary, it is evident that the problem is not a simple one. The field elations also indicate that the rocks must have had a heterogeneous origin.

Holland Arms — In the Aethwy Region, at a craggy knob 100 eet in width, about 100 yards east-south-east of Graig-fawr, Tolland Arms (Figure 10), close to the margin of the mica-schists, are some 30 yards of a compact, fresh, grey, light-weathering rock with a conchoidal fracture. Most of it has a foliation (across which, however, it breaks quite readily), and it passes on the south-east into normal mica-schist. North-westwards this foliation rapidly diminishes, and, just at the margin of the knob, disappears altogether. At this point the rock (E8485) [SH 474 724] (a slide cut by Dr. Callaway) is a granular aggregate of alkali-felspars and quartz, with a little epidote and sphene, the felspar being albite, with (apparently) some oligoclase, orthoclase not having been identified, though certainly present. This rock (E8485) [SH 474 724] is essentially a felsite. But it is not unmodified, for the mosaic is granoblastic rather than felsitic, and some larger albites, which appear to have been phenocrysts, have lost their idiomorphic outlines. From this point, for 35 feet to the south-east, the surface of the knob is clear and bare, and Dr. Callaway had sliced a series of eight more specimens (E8486) [SH 474 724], (E8487) [SH 474 724], (E8488) [SH 474 724], (E8489) [SH 474 724], (E8490) [SH 474 724], (E8491) [SH 474 724], (E8492) [SH 474 724], (E8493) [SH 474 724] taken from it at short intervals. Of the first of these

(E8486) [SH 474 724], taken at a point two feet from (E8485) [SH 474 724],<ref>The specimen from which (E8485) [SH 474 724] itself was cut had unfortunately been lost some time before when sent for analysis.</ref> he had an analysis made (p. 112). Dr. Teall, when visiting the spot with the present writer in 1911, also took a series of four slides (E9170) [SH 479 726], (E9171) [SH 479 726], (E9172) [SH 479 726], (E9173) [SH 479 726] at intervals across the knob. The combined series demonstrate a steady passage from unfoliated felsite into mica-schist. The body of the rocks is composed of granoblastic albite and quartz, with many minute grains of epidote, sphene, and garnet, foliation being imparted by an increasing proportion of white mica, a little brown mica developing as well. The quartz and albite show signs of strain and fracture. In the midst of this ground mass lie lenticular coarse-grained aggregates of microcline, also showing signs of strain, which probably represent broken-down phenocrysts of a potassium-felspar. That these are absent from (E8485) [SH 474 724] is probably a mere accident of slicing.<ref>The rocks recall externally and microscopically the halleflintas of if to, Sweden; but in those rocks the mosaic is coarser and rounder in grain, with more brown mica, while their phenocrysts are almost wholly quartz.</ref> The felspar of small pegmatitic knots which begin to develop is also microcline. Now potassium-f elspars have not been observed in the normal, micaceous Pen-mynydd schist; and it is noteworthy that even in this knob microcline decreases as muscovite increases. Comparing the analysis of (E8486) [SH 474 724] with that of a typical rhyolite, it becomes evident that it, and consequently the mica-schist of at any rate the immediate vicinity, must be derived from an albite-felsite in which were phenocrysts of orthoclase or microcline, and that the muscovite of the schist is derived from the latter, while the albite survives the reconstruction.

Gaerwen — This conclusion is confirmed by finding that a compact, unfoliated, rock, near Gaerwen Junction (E9480) [SH 475 704], whose matrix closely resembles (E8485) [SH 474 724], contains, as well as microclines, rudely rhombic pseudomorphs about two millimetres in length. They are now composed of granoblastic albite and quartz, and may be regarded as albitised and silicified phenocrysts of orthoclase.

Ynysoedd Duon (1) — The other cases are on the coast of the Middle Region at Ynysoedd Duon. Some 200 yards to the south of the southern islet, on the north cliffs of a chasm, are massive cream-coloured bands composed of a crypto-crystalline mosaic full of broken phenocrysts of albite, quartz, and micro-perthite. The rock, though crushed, is not much reconstructed, and is undoubtedly a sodium-felsite (E9184) [SH 328 698]. It therefore appears that felsitic igneous rocks enter into the composition of the mica-schists in the Middle as well as in the Aethwy Region.

There is no direct evidence as to whether this felsitic material be intrusive or effusive. The included acid strips in the hornblende-schists might be (and have been) regarded as intrusive veins. But they have no transgressive junctions, and there is nothing to prevent their being regarded as xenoliths, as suggested on p. 121. And, as no cores with plutonic texture have been discovered in the felsitic mica-schist, whereas cores of the kind survive within the basic schists, it would appear probable that the latter are intrusive in the former, the intrusions being anterior to the dynamic metamorphism.

Ynysoedd Duon (2) — About 100 yards to the south of the southern islet of Ynysoedd Duon, a flaggy mica-schist appears on the low cliffs, upon whose weathered faces are little grains of clastic quartz, and in thin section (E11086) [SH 329 699] it proves to be a blasto-psammitic schist crowded with fragments of albite and quartz now partially incorporated like those in the Green-Mica-schists of the New Harbour Group, and in about the same stage of metamorphism. But it is very rich in albite, and may be in part of pyroclastic origin. Sedimentary matter was therefore present among the original materials of these rocks.

Marginal phenomena

Let us now consider the field relations of the zone. Its mica-schists adjoin the Gwna Beds along many miles of boundary, not only of the main masses but of outliers and inliers; and except where basic rocks come against the line, the Gwna material is invariably the Gwna Green-schist, which has been shown (pp. 67–9) to be sedimentary in origin. We have already seen that clastic structures disappear as we pass from the Gwna Grits to the Gwna Green-schist. If, further, from a tract of Gwna. Green-schist we pass into a tract of the Penmynydd Zone, we find, first, that there is perfect conformity between the foliation planes; next, that the character of the schistosity remains the same, except that nema-blastic texture disappears; and thirdly, that there is a rapid rise in metamorphism. As the margin is approached, chlorite begins to disappear, green (and sometimes brown) mica to develop; white mica to increase in quantity and very greatly in size and individualisation of the flakes; epidote, zoisite, apatite, sphene, and garnet appearing when the junction line is reached. Small porphyroblastic albites develop locally, and the texture of the body rises from crypto- to granoblastic. When basic schists are present, green and blue amphiboles take the place of chlorite. That the change is not catamorphic but anamorphic is shown by the characters of the minerals along the junction. The crystals of the Penmynydd Zone are not cataclastically broken down. The bladed amphiboles of the basic schists, for example, are not crushed as we follow them back towards the Gwna tracts, they diminish in size, and in the zone of passage are slender, but perfect, actinolitic needles. These changes can be observed anywhere along the boundaries. But there is perfect exposure of the junction itself at five places at least, and in each case there is an uninterrupted passage.

Aberfraw — One of these is on the Aberffraw coast, where the main boundary runs out to sea 833 yards south by east from the island church, and has been examined by Dr. Horne and Mr. Clough, with the writer. It is at a deep chasm, in which there is probably a fault, but the junction is not in this chasm, it is at the brow of its northern cliff. At one place there is a small crush, but it is insignificant, and passing obliquely into the cliff, leaves the passage visible on either side of it. Typical quartzose Gwna Green-schist passes into typical Penmynydd mica-schist, the structures on the large scale remaining unchanged. In the bay north-east of Braich Lwyd is an inlying strip of Penmynydd mica-schist, with limestone and graphite-schist. A little west of the cove at the nook of this bay a buttress runs out eastward from the cliff, and on it is another exposure of the junction, which is again a passage from Gwna schist with grit and jasper to siliceous mica-schist with small surviving clastic grains. Slices taken from close to the boundary show that the Gwna schist is unusually micaceous, the Penmynydd schist less so than usual, but still perceptibly better crystallised than the other.

Mynydd Llwydiarth — The third and best exposure is in Mynydd Llwydiarth. North-east of the 'h' is a cottage, called on the six-inch maps (Figure 11) Hafod Leucu, by which a footpath passes eastwards through a gap in crags. If we walk 130 yards east along this path, and then turn south for 50 yards, we find a crag facing east, on which is seen the junction. To its west is typical Penmynydd mica-schist with great sills of hornblende-schist. To, its east is equally typical Gwna Green-schist, with innumerable lenticles of chlorite-epidote-schist. The Gwna schist has lost all clastic grains, but is very siliceous, full of nemablastic augen of quartz, and silky with sericitic mica. This type can be followed as far as the crag's foot (the fault that comes northward having passed eastward away from the boundary) where it is still the same, though its micas are becoming slightly larger. Then in a yard or two of bare crag, there is a rapid increase in their size, they become distinctly individualised, the nemablastic texture is replaced by granoblastic, the rock becomes saccharoid, and at the crag's brow is typical Penmynydd mica-schist. The section was visited by Dr. Teall with the writer in 1911.

The Strait — The fourth is on the Menai cliffs between Glyn-y-garth and Craig-y-don, where the Gwna Green-schist develops locally higher crystalline types than usual (pp. 360–1) and passes imperceptibly into mica-schist that if found in a tract of the Penmynydd schists would not be separated from them.

Llanddona — A fifth is at Wern, Llanddona, where a large glauco-phane-schist occurs among the Gwna Beds. Approaching this from the south, it is found that the Gwna rocks, there very siliceous, begin to develop larger micas, until close to the glaucophane-rock they might be treated as Penmynydd schists. There is no change either of structure or material, but only of crystalline condition. Along its margins, therefore, it is certain that the Penmynydd mica-schist has been derived from rocks of sedimentary origin.

An Horizon within the Zone

Further, we have seen that in the Middle Region a quartz schist, a crystalline limestone, and a graphitic schist are found within the zone. Now these rocks do not occur in a merely sporadic manner; they are menibers of a tripartite group, of which, according to the accidents of thrusting and erosion (pp. 192–4, 343–4), one, two, or all three may be found together. But it will be remembered that a quartzite, a limestone, and a graphitic phyllite are found as a similar group within the Gwna Beds. There they graduate by change of composition into the adjacent phyllites, and here they likewise graduate into the mica-schist.

Chemical composition and inferences

In both regions, therefore, it is certain that the Penmynydd mica-schists must be derived in part from felsitic igneous material, in part from the sedimentary material of the Gwna Beds.

When once, however, we leave the margins of undoubted felsite and undoubted sediment, and pass out into the country of highly anamorphic schist, no criterion has yet been found for separating, in the field, schist of the one origin from schist of the other. Yet, pending such discovery, some idea may be arrived at of the general nature of that country. Consider the analyses (p. 112). No. IV corresponds so closely with No. V. that there can be no doubt of its being a true rhyolitic rock, its alkalies being high even for a rhyolite. But in the others, while they approach the composition of a rhyolite, there is a marked falling off in alkalies, though these are still not much below the rhyolitic average. There is an increase both in calcium and magnesium, and a very serious increase in iron, especially in ferrous iron, the proportions of all three elements exceeding those characteristic of rhyolitic rocks. That these great tracts of schists were produced from uniform felsitic sheets is therefore impossible. Comparing the analyses with those on p. 70, it will be seen that in proportion as they depart from the composition of a felsite they approach that of the Gwna Green-schists. If, however, we exclude Nos. IV and V of the Gwna Group, which are exceptionally micaceous, we find that in the Penmynydd Zone there is a decided increase of potassium. Now the passages from Gwna Green-schist described above, although undoubtedly continuous, are curiously rapid, the change coming on in the course of a few yards, and the new type reaching its average degree of development within a quarter of a mile. That progressive metamorphism should produce this result without any concurrent change in the original material seems impossible, and accordingly we find an increase of white mica, which must mean an increase of potassium. Dynamo-metamorphism, indeed, could not have produced continuous passages between the products of sediment and those of solid felsite along miles of junction that must, in such ease, have been originally well defined. Pyroclastic matter, however, may mingle with sediment in any proportion. If, therefore, we suppose the Penmynydd mica-schists to be composed of rhyolitic dust and tuff, with rhyolitic lavas on some horizons and bands of sediment on others, all the phenomena they present can be reconciled.

The occasional survivals of igneous and clastic structures might be expected in specially resistant beds. The analysis of column IV would be that of a pure flow of rhyolitic lava; those of I and II representing rhyolitic tuffs with admixtures of sediment. The compact quartz-albite-epidote rocks could be regarded as modified adinoles produced from fine ashy sediment in aureoles around and xenoliths in the basic intrusions. The zones of passage at the junction with the Gwna Green-schists find an explanation when regarded as zones of alternation where (as in the well-known ashy grits of Snowdon) felsitic tuff and ashy sediment were mingling, and (assuming the Penmynydd schists to be the older) explosions of rhyolitic dust were gradually ceasing to mingle with the sediments. A passage of this kind is, in fact, visible at the junction of the Fydlyn group (see p. 90) with the Gwna Beds of the northwest; and it is a rapid one. Such a zone of passage, when subjected to crystalline reconstruction, would show an abnormally rapid progressive metamorphism, for the alkaline volcanic rocks would recrystallise much more readily than would the sediments, and, if rich in potassium, would at once yield an abundance of muscovite, so that there would be a rapid passage from a dull sericitic schist into a lustrous mica-schist, which is the characteristic feature of the zone in question.

The Coedana Granite and the Zone

Further evidence as to the origin, and also as to the age of the Penmynydd metamorphism is obtained along the edges of the Coedana granite. From Coedana to Gwalchmai the two rocks come together without any intervening zone of hornfels, two small granites lie along the junction of hornfels and mica-schist on either side of Ty-croes, and at Gwalchmai village one lies within the mica-schist. Now when the granite is exposed close to the Penmynydd Zone it is intensely sheared, and fine granoblastic matter like that of the mica-schist appears within it; while thin seams of granitoid matter are to be found within adjacent mica-schist that shows no sign of cataclastic deformation or thermal alteration. There are no transgressive junctions, and sometimes the granite fades off into mica-schist. It is certain, therefore, that the granite is involved in the Penmynydd metamorphism. To some extent it has been incorporated, but the evidence points to this being merely marginal, and that there has been no bodily transformation of granite into mica-schist. West of Bod-wrog Church, not only is the transition too sudden, but the schist is a quartz-schist, far too siliceous to represent the granite, and the junction is evidently an old intrusive margin sheared and recrystallised. In a slide from Bodwrog Church (E8484) [SH 412 786] the junctions of a half-inch sill are still quite sharp on one side, though incorporation has begun in other parts of it. Finally, the outer margin of the hornfels, as may be seen on the coast near Porth Nobla (pp. 332, 342) assumes gradually the structures of the Penmynydd Zone. The Penmynydd metamorphism is therefore subsequent to the intrusion and consolidation of the Coedana granite.

Conclusions

From the foregoing evidence it is clear that the Penmynydd rocks are a metamorphic, not a stratigraphic zone; and that the original rocks involved are partly sedimentary, partly volcanic, the latter being both effusive and pyroclastic; partly also, though to a small extent only, plutonic. The great body of alkaline mica-schist must be derived from felsitic lavas and tuffs, and there is good reason to suppose that these belong to the Fydlyn Group. The sedimentary material is undoubtedly that of the Gwna Group, and includes its alternating grits and phyllites, as well as its quartzite, limestone, carbonaceous-phyllite division. The basic schists are derived, there can be little doubt, from the Gwna spilitic suite, whose effusive and intrusive members seem both to be represented. The Coedana granite is also involved, but only to a small extent, along the margins. All these rocks are converted into holocrystalline schists of different kinds, the glaucophane-schist being a special feature of the zone. The metamorphism is later than the intrusion and consolidation of the Coedana granite.

The Gneisses

These are coarse, granitoid in texture, and more deep-seated and plutonic in aspect than the other foliated rocks of the Complex. The term as here used includes basic rocks which will be called hornblende-gneiss, and biotite-gneiss or gneiss proper, which will be termed briefly 'the Gneiss'.

Hornblende-gneiss

This term will be used in precisely the same sense as it is on p. 42 of the Memoir on the North-West Highlands of Scotland; that is to say, it will include not only well-banded rocks and rudely-banded rocks, but also what might be called foliated, and even unfoliated, diorite. As it is, however, doubtful whether the original material had the chemical composition of a diorite, that word will be employed for local description, only, and not for the formation as a whole. Nearly all are dark, heavy, rocks, the banded gneisses having a totally different aspect from that of the hornblende-schists of the Penmynydd Zone. Four principal types may be recognised a coarse, dark, massive rock of dioritic aspect (Plate 12), Fig. 4 sometimes unfoliated, but usually with a rude foliation; secondly, a rock of similar texture, but of much lighter tint; thirdly, a dark, granoblastic gneiss, usually well, but sometimes rudely banded, and Df medium grain (Plate 12), Fig. 1; and fourthly, a similar gneiss, but finer, harder, and lighter in tint. The third is perhaps she most widespread, though the first must nearly equal it: the second and fourth are not so plentiful. But this classification is merely of leading types; innumerable gradations exist, so that neither words, drawings, nor photographs can convey any adequate picture of the constantly varying character of the gneiss. For example, on a boss 230 yards east-south-east of Pen-yr-orsedd, five types were noted in only a yard or two, from coarse light material, through normal gneiss of the third type, into a hornblende-rock almost black, all interdigitating along a rude foliation-banding. In this variety of composition the hornblende-gneisses of the Mona Complex recall the amphibolitic members of the Lewisian Gneiss of Scotland, to which they are closely related in other characters, to be described below.

The minerals identified are hornblende, felspar, biotite, quartz, epidote, zoisite, sphene, ilmenite, magnetite, pyroxene, apatite, zircon, rutile, garnet, pyrite, orthite, chlorite, leucoxene, and natrolite.

The only essential minerals that are always present are hornblende and felspar. But biotite, quartz, epidote, and even sphene, rise in one variety or another to the rank of essentials. Thus, we have hornblende-felspar rocks, hornblende-felspar-quartz rocks, horn-blende-felspar-quartz-biotite rocks, hornblende-felspar-sphene rocks, and hornblende-felspar-epidote rocks.

All the felspar that yields definite optical reactions is albite. Much, however, is turbid, and oligoclase is probably present, for some crystals with ill-preserved lamellation appear to extinguish at very low angles; but albite is undoubtedly the dominant felspar. It is partly twinned, partly simple, and in all the types occurs in the isodiametric interlocking grains characteristic of plutonic products.

Different varieties of hornblende are found to characterise different types of rock, with pleochroism:

X, Pale straw-colour; *Y*, pale brownish-green; *Z,* bluish-green.

X, Straw-colour; *Y*, brownish-green; *Z,* deep-green.

X, Colourless; *Y*, pale brownish-green ;_*Z*, pale-green.

The first variety is usual in the rocks of dioritic aspect; the second in the dark bands that make up the bulk of the banded gneiss; the third (which has the unusual absorption *Y* slightly> *Z* > X) in the lighter bands with biotite and quartz. All these hornblendes have a broad, short habit, never bladed or acicular, and though usually a little longer in the direction of the vertical axis, may have their greatest dimension transverse to the prism. They are never eumorphic, but a slight tendency to development of the prism faces may be noticed, and the cleavages are strong. There is no reason to doubt the original nature of all these hornblendes, but slender needles of secondary actinolite are found in albite near Holland Arms. The biotite. has been brown, but is often much chloritised, the pleochroism, where it survives, being pronounced but moderate.

The quartz occurs as rounded grains included in the albite and hornblende, or as a mosaic with the albite.

Epidotes are very abundant in some of the rocks. In the Middle Region they are clear pistazite with the usual pleochroism, and some of them may be original, that is, products of the metamorphism, but others that are found in veins must be later, though probably not much later. A few dark-brown grains that appear to be biaxial are probably orthite. In the Holland Arms district an epidote that is dusky with minute inclusions is an important constituent. Its crystals are often elongated, sometimes along the orthodiagonal, but sometimes along the traces of the principal cleavage, which is presumably basal, and are scarcely pleochroic. Nearly all of them have a high birefringence, but sometimes they vary towards zoisite. Some of the large albites of this area are crowded with sheaves of slender prismatic epidote and of true zoisite disposed often with great regularity. This must be regarded as a stage of saussuritisation, but spaces of clear albite remain which retain their optical integrity. It is in these felspars that the needles of actinolite are found. In others the albite has been wholly replaced by granular zoisite. The large dusky epidotes are often found in contact with the sheaves of slender epidote after albite, but the boundaries are sharp. Most of the Holland Arms and Gaerwen slides are old and thick, but these rocks offer interesting studies in saussuritisation.

Sphene is remarkably abundant as an accessory, and as above stated, is sometimes an essential. It also attains unusual dimensions, one or two crystals being as much as 2.5 millimetres in length (Plate 12), Fig. 2. Usually it is in irregular grains, but these large crystals, though' anhedral, are elongated precisely in the direction of the prismatic cleavage, which is strongly developed. They are deeply embayed by the hornblende and albite, and contain inclusions of leucoxene. The smaller sphenes may be colourless, but these large ones are brown, with the usual pleochroism.

Ilmenite, often leucoxenised, appears to be more plentiful than magnetite.

A pale-green pyroxene is occasionally found in the Middle Region, but in small quantity. It is anhedral, does not form cores to the hornblende, and both minerals appear to be independent and original. It is of interest to note that it is found in the well-banded gneissoid facies.

Apatite, in short hexagonal prisms, is remarkably abundant. The remaining accessories are never plentiful, garnet being rare.

Pegmatite, and textures

Pegmatite (Plate 13) (using the term in the wide sense in which it is used in the Memoir on the North-west Highlands of Scotland, for graphic structures have not been observed) is, in the form of veins, lenticular knots, and thin seams, a most important constituent of the hornblende-gneisses, and is intimately bound up with their history. All its felspars, however, are sodium-felspars. Out of 14 pegmatites that were examined the felspar of nine was albite, of four, albite-oligoclase, and of one, oligoclase. They are therefore essentially sodium- or albite-pegmatites. Nor are they very acid, for quartz is in smaller quantity than felspar, and there is often a little hornblende and chloritised biotite. Some are composed of nearly pure albite in crystals an inch or so in length with exquisite lamellar twinning. An interesting feature is that the gneiss is almost invariably darker at its junction with them; even when a vein cuts across a number of bands each band is darker when it comes against the vein, and they are often sheathed with biotite or edged with a zone of large hornblendes which are deep-green for rays vibrating parallel to Z, like the hornblendes of the banded gneiss. Their composition is of great importance, for it points to the inference that they are not to be regarded as apophyses of the Coedana granite. That is a mixed albite- and orthoclase-rock, and it is extremely unlikely that its apophvses should be sub-acid albite-pegmatites. Albite, on the other hand, is the felspar of the horn-blende-gneisses themselves, and it is therefore more probable that the pegmatites are products of magmatic differentiation from the original of the hornblende-gneiss itself.

The unbanded rocks, which are commonly quartzless, are typically granitoid in texture. The banded rocks are granoblastic, rather coarse in grain, though less so than the unbanded, and the darker ones are also often quartzless. The finest are the lighter bands with quartz and biotite. All are veined by and interbanded with pegmatite.

Biotite gneisses without hornblende are also present, but they will be discussed further on, as they may be foreign to the group.

Development

The development of the hornblende-gneiss can best be studied in the Middle Region, between Treban alluvium and Llandrygarn Church. The most primitive type, which is seen in many places, appears to be a massive, mottled rock (Plate 12), Fig. 4 full of rudely oval dark bodies, about three millimetres in diameter, in a grey matrix. It is a hornblende-albite rock with a good scattering of ilmenite and apatite. The dark bodies are not phenocrysts, but groups of broad green hornblende, and the matrix is granitoid albite with smaller hornblendes. The structure is not normally igneous, and suggests that segregation has already set in. In rock of this kind, 160 yards south-south-west of Llandrygarn Church, a rude nodular structure has arisen, black nodules being surrounded by shells of the mottled matter. At the 'T' of 'Pandy Treban' drawing-out of the mottled matter has begun, and in the midst of this, rude black clots isolated by tracts of granular albite are beginning to be drawn out also (Figure 12). In many places, as at the south end of Werthyr alluvium, tracts of partly drawn-out mottled matter (in which, however, the cleavage of the large hornblendes may be encarsioblastic) begin to be isolated by streams of granoblastic gneiss like that of the banded rocks. With the growth of these there is a transition to the granoblastic banded gneiss itself.

For the sake of simplicity the pegmatites have been, so far, ignored. But they appear at quite an early stage, and take part in the process throughout. Their first appearance is in the nodular rock of Llandrygarn, throughout a large part of which the black nodules are isolated, not merely by the mottled hornblende-rock, but by veins and shells of pegmatite. Close by, at the farm next the church, this aggregate has been drawn out into a gneiss with short, rudely lenticular banding. Various further stages may be seen to the west of Clegir-mawr until we reach the perfect banded gneisses, with pegmatite seams, well seen on Craig-yr-allor, between Clegir-mawr and Treban. The banding has, in the meantime, become still more accentuated by the development of the finer granoblastic type with biotite and, which may be supposed to have originated from reaction between drawn - out quartz-albite-pegmatite and normal hornblende-gneiss. As a few large plates of biotite may be found in the unfoliated rocks, there seem to be two generations of that mineral. The banded gneiss thus consists of granoblastic horn-blende-albite rocks, rich in sphene, and of various shades of darkness, with the finer biotite-quartz bands, the banding being accentuated by innumerable seams of pegmatite, the whole complex being folded. But the production of pegmatite had by no means come to an end. Short, stout knots of it (as well as of pure quartz) appear between the bands of the gneiss (Figure 13). (Figure 14), (Figure 15) probably produced at a late stage of the process. And after the banding was complete, great sills and veins of it were introduced, cutting across the banding, isolating sub-angular blocks of gneiss, turning some of them round, and producing what may be called plutonic breccias of the most perfect kind. By an unfortunate oversight some of these best sections were not photographed, but the annexed drawings ((Figure 16), (Figure 17), (Figure 18)) will convey an idea of them. Pegmatites have also come in along, and 'healed up' small faults in the banded gneiss, thus giving an insight into the long duration of the process.

Comparisons

To readers who are familiar with the Lewisian Gneiss of Scotland the basic parts of that great formation will doubtless have been recalled by the foregoing description. The resemblance is indeed remarkable. The rocks correspond to those of Group III. of the scheme given on p. 43 of the Memoir on the North-West Highlands, and the gneisses correspond so closely in microscopic structure that the figures on (Plate 42) of that memoir might represent the granoblastic types found in Anglesey. In both cases quartzless rocks form a large portion of the mass; and in both also a little pyroxene accompanies the hornblende and stands in the same relation to it. The principal points of difference are first, that the peridotic and pyroxenic rocks of the Lewisian Groups I. and II. have not been found in the Mona Complex; and, secondly, that the basic gneisses of this Complex are sodium-gneisses, the felspars both of hornblende-rocks and pegmatites being either albite itself or falling within the limits Ab–Ab5An1. As an appendage to their sodium-content<ref>See Thomas and Jones, *Quart. Journ. Geol. Soc.,* 1912, p. 389.</ref> they are also. titanium-gneisses, being unusually rich in ilmenite and sphene, and contain besides a large quantity of apatite. The structures visible in the field, especially the relations of basic to pegmatitic matter, are the same in both cases. Indeed, all the phenomena illustrated in plate 6 to 14 of the Memoir on the North-West Highlands, and discussed by Dr. Teall in its fifth chapter, can be seen, on a smaller scale, in Anglesey. That they should be displayed on a smaller scale is to be expected, for perhaps the most remarkable circumstance of the parallel is that, whereas the plates quoted are selected from a tract 60 miles in length, the corresponding stages in Anglesey are all to be found between Treban alluvium and Llandrygarn Church, a space of rather less than two square miles.

Granitoid biotite-gneiss or gneiss proper

This is the most deep-seated member of the Mona Complex, being a combination of a granitoid with a foliated element itself highly crystalline.

The granitoid component

The minerals are quartz, felspar, biotite, and white mica, with a little sphene, apatite, and zircon, but these accessories are in small quantity. The quartz is of the type usual in granites. The biotite, which is in fair-sized flakes, has been brown, but is commonly chloritised with separation of leucoxenised ilmenite, showing that it was titaniferous. There is more of it than of the white mica, but not very much of either. The dominant felspar is albite. No potassium-felspar has been detected. Dr. Teall, after examining the ground with the writer, compared the felspar of four of the granitoid bands of Henblâs with four specimens of the Coedana granite. All of the latter contained orthoclase (p. 91), the former only albite with a possible inclination to oligoclase. In a series, also, of many, slides and powders taken from the Middle Region, from the Nebo and Gader Inliers, and from Mynachdy, the writer has found that albite is general, but that some of the rocks contain a considerable proportion of oligoclase. No porphyritic felspar is known. The rocks may therefore be described as albite-granites containing in some places oligoclase. Whether the white mica be muscovite or paragonite has not yet been determined. The structure is typically granitoid, and of coarse to medium grain. The rocks differ, therefore, from the Coedana granite both in structure and in composition. Not only are phenocrysts absent, but so is orthoclase, all their felspar being of sodium or sodio-calcium species. The magmas were evidently different.

The foliated component

includes mica-gneisses of three types and also some crystalline limestones.

Mica-gneisses — The minerals identified in the mica-gneiss are quartz, felspars, biotite, chlorite, muscovite, hornblende, magnetite, ilmenite, sphene, leucoxene, rutile, sillimanite, garnet, idoerase, tourmaline, zircon, apatite, graphite, epidote, and talc.

The quartz is often in rather large grains, and though usually clear may be so crowded with minute inclusions as to be hardly less turbid in aspect than the decomposing felspar. The dominant felspar is probably albite or albite-oligoclase, but these rocks differ from all the rest of the Mona Complex in the importance of oligo-clase. It is present in many of them alongside of albite, in a good number is the principal, and in some appears to be the only felspar. Both it and albite are often in large grains, with or without lamellar twinning, intergrown granoblastically with the quartz. Potassium-felspar has been found only once, and that where (p. 323) there is reason to suspect an apophysis of the Coedana granite.

The biotite, often in large flakes, though much chloritised, is frequently well preserved, and is deep-brown in basal plates. It has a stronger pleochroism than the other micas of the Complex, being pale straw for rays vibrating at right angles to, very deep-brown, sometimes reddish-brown, for rays vibrating parallel to, the base. As it is also very nearly uniaxial in most cases examined, and is (see analysis No. I, p. 137) rich in FeO, it is evidently a haughtonite. The gneisses of the Nebo and other northern inliers are brilliant with a large white mica, which is almost uniaxial, and is a bleached biotite. Parts of the crystals are occasionally still brown and pleochroic, the bleaching having proceeded along the cleavage, so as to simulate intergrowths of muscovite. The bleaching is accompanied by separation of clots of iron-ore and needles of rutile. But the biotite retains its optical properties, especially its high, negative, bi-refringence.

The true white-mica, which from the analyses (p. 137) must be regarded as muscovite, varies a good deal in axial angle. Both micas develop the basal planes well, those of the biotite nearly always lying along the foliation; but the muscovite is occasionally in stellate groups. Theyareoften intergrown, but the muscovite sometimes pierces the biotite (E9935) [SH 375 781] at a high angle to its cleavage planes. Whether hornblende is to be regarded as a mineral of these rocks is not quite certain, for it is possible that those in which it is found belong really to the group described above, though there are cases in which it is hardly in excess of a biotite of the type just mentioned. The chlorite is probably always a pseudomorph of biotite. is generally crowded with leucoxene, and sometimes with needles of rutile, showing that the biotite, as in other sodium rocks mentioned in this chapter, is highly titaniferous. Rutile occurs also as an independent mineral. How much of the dark iron-ore is magnetite is uncertain, but reflected light so often reveals a faint brown tint or a passage into leucoxene that ilmenite is almost certainly in excess. Some sphene is usually present, sometimes in the characteristic double wedge, and sometimes in large grains, though never attaining the size of those found in the hornblende-gneiss. Zircon is frequent, but tourmaline rare. Apatite, in broad hexagonal prisms of considerable size, is often extremely abundant, usually in the quartz-felspar mosaic. Garnet is far more generally present and far more abundant than appears at first sight, for, owing to its bad state of preservation it eludes observation in the field, retreating into cavities and weathering to a dull rusty tint. But there are seams in which it makes up nearly half the rock. It was of a good rose-colour when fresh, and never euhedral, but occurring in large einbayed porphyroblasts (which at Gwyndy are nearly half an inch in diameter) often crowded with inclusions of quartz, biotite, and other minerals. A wholly fresh garnet is hardly to be seen, the mineral having always a mesh-work structure like that of olivine, along which it is traversed by canals of pseudomorphic products most of which are green; and sometimes it is completely pseudomorphed. The principal product is a chlorite, but there is also quartz, and a colourless fissile substance which, from its high bi-refringence and low refractive index, appears to be talc (E10838) [SH 49 90].

In some of the gneisses of the Nebo Inlier, on the northern side of Porth Helygen, there are, as well as rose-coloured garnets, abundant porphyroblasts, about four millimetres in diameter, of a clear, glassy, grass-green mineral, which weather into hollows. Those cut through in thin section are unfortunately in very bad condition, but show signs of a pair of cleavages at right angles unlike the curved cracks of garnet. The mineral has a high refractive index and low bi-refringence, and, so far as can be made out (though no good optical figure has been obtained), seems to be uniaxial. From the powder of a better preserved crystal Dr. Thomas considers that it is almost certainly idocrase. Graphite also occurs on the same coast, and being partly foliated with the gneiss, may be original. It was determined chemically on a specimen from Rhosmynach-isaf by Mr. J. O. Hughes.

Sillimanite — After the quartz, felspars, and biotite, this is the most abundant mineral of the gneisses, and is undoubtedly the most significant in regard to their nature and origin. It is rare in the most highly granitoid portions, but in some of the coarse lepido-blastic parts is extremely abundant, imparting to them, indeed, a nemablastic texture. The richest localities are the coast of the Nebo Inlier (E9527) [SH 491 909], (E9528) [SH 491 909], (E9529) [SH 490 901], (E9534) [SH 491 910] (Plate 12), Fig. 3, Fig. 5 and the valley south-east of Llechcynfarwydd Church. There are three modes of occurrence—in quartz as 'faserkiesel', in biotite, and alone. The crystals are the usual slender needles. They generally taper, but here and there the basal plane may be detected, and sometimes traces of the prism-faces. Cross-jointing is often seen, and it may extend across bundles containing many crystals. Some of the sillimanite of the coast east of Llanwenllwyfo Church (E9529) [SH 490 901] is pleochroic. This is imperceptible in single needles, but can be observed in parallel bundles of them, the effect being thus intensified. The absorption is *Z* (*Y*, *X*), and the tints are *Z,* moderate olive-green; (*Y*, *X*), pale straw-colour. The stability of the mineral is strikingly illustrated where the gneiss is decomposed, it and the quartz being sometimes the only components that retain their optical characters. Where occurring in quartz, it forms dense aggregates of faserkiesel, easily recognisable on the rugged weathered surface by its fibrous texture and its tint of pale foam-green. Sometimes such an aggregate crowds the whole of a quartz-grain, while the adjacent grains contain none at all; sometimes the aggregate decreases in density, the surrounding grains being pierced by innumerable separate single needles. Occasionally, a long delicate needle of sillimanite may be seen to pass from one grain of quartz into another that has a different optical orientation. In the biotite, it may also occur in aggregates, but for the most part lies along the cleavage-planes, disposed in three systems that intersect at angles of 60°, so as to enclose equilateral triangles (like the rutile figured by Rosenbusch, *Micr. Phys.,* (Plate 20), (Figure 5), and so presumably parallel to the rays of the pressure-figure. But the mineral occurs also in tracts of its own, close bundles of needles, in which no binding quartz or biotite can be detected. Little ones are plentiful in thin sections; but on the coast east of Llanwenllwyfo Church, on the foliation-surfaces of brown biotite gneiss, are oval tracts an inch in length of clear sea-green sillimanite. Fragments from the cleanest parts of these, teased out, are seen under the microscope to be composed of pure sillimanite. For the most part it is nemablastically foliated, but may also be found in stellate groups.

Limestone — A massive grey crystalline limestone occurs at several places in the Nebo Inlier. Its carbonate is nearly all calcite, but it is rich in silicates and heavy minerals. Conspicuous among these is brown sphene, often in double wedges, sometimes pseudomorphed in leucoxene. Albite in large grains is abundant, and there is a little quartz. In some of the slides (E10568) [SH 489 911] a colourless pyroxene is plentiful. It is always anhedral, but the prismatic cleavages are very well developed, and some of the crystals have a diallagic striation. A pale green hornblende, which is present, appears to be derived from it; and there is a brown mica with a rather wide axial angle. Apatite and zoisite also occur. There are a good many serpentinous pseudomorphs after a stout prismatic mineral (E10265) [SH 480 902] with rude pyramidal terminations, which Dr. Teall refers to forsterite, as they have the habit assumed by that mineral in the Glenelg and other limestones. One contains a small fresh core which extinguishes parallel to the major axis of the pseudomorph, thus confirming Dr. Teak's view. The abundance of calcite is therefore assignable to de-dolomitisation. Some an-hedral grains of an isotropic mineral with a faint brown-rose colour and high refractive index are seen in one slide (E204). Unfortunately it was not possible to compare their refractive index with the pyroxene. But as they are all perfectly fresh, which the garnets of the gneisses are never known to be, they are referred provisionally to spinel, on account of their associations. The minerals of this limestone are therefore: calcite, albite, quartz, apatite, zoisite, sphene, leucoxene, pyroxene, hornblende, chlorite, biotite, serpentine, forsterite, and spinel.

Chemical analyses

The following analyses have been made by Mr. J. O. Hughes.

	I	II		III
SiO_2	54.01	68.09	Residues insol. in HCl	37.60
Al_2O_3	21.19	17.44	Al_2O_3	2.44
Fe_2O_3	1.43	4.81	Fe_2O_3	3.07
FeO	10.27	—	CaO	29.21
CaO	1.08	—	MgO	2.22
MgO	1.74	—	CO_2	25.60
K_2O	3.94	—	H_2O	not det.
Na_2O	1.83	—	—	—
H_2O (at 110°)	0.60	—	—	—
H_2O (above 110°)	2.71	—	—	—
	99.04	—	—	100.14
			Percentage $CaCO_3$	52.16

I. Albite-biotite-sillimanite-garnet-gneiss, 617 yards east-south-east of Llecheynfarwydd Church (at 'yd'), in angle between road and farm lane of Tyddyn-gyrfa (six-inch map) (E9939) [SH 386 808].

II. Albite-muscovite-biotite-gneiss, with a little sillimanite and garnet (E9887) [SH 474 725] and AP. 79] 217 yards north-north-east of Old Windmill (and 63 yards north-west of Graig-fach, six-inch map), Holland Arms.

III. Forsterite-limestone (E10266) [SH 488 911], 170–260 yards north-east of Rhôs-mynach-isaf, at contour. Nebo Inlier.

The high percentages of Al_2O_3 and of FeO in No. I will at once be noticed.

Nature and relations of the components of the gneiss

These components may be roughly classified as follows:

A. Fine hard siliceous bands

B. Coarser granular biotite-gneiss

C. Coarse flaky biotite-gneiss

D. Crystalline limestone

E. Granite or pegmatite

Of these, D is rare, and A never present in large quantity. B and C make up the great body of the gneiss, in so far as it is tolerably free from granitoid matter. The hard bands (A) are composed of quartz, albite, and a little biotite. The texture is always finely granoblastic, but some of the rounded quartz weathers very much like clastic grains. The second type (B) is also granoblastic, but rather coarsely so, and its quartz and felspar are often elongated along the foliation, the albite in large grains with lamellar twinning. Short, wavy, lenticular micaceous seams occur in it, and by increase of these it may pass into the third type (C). This, though often extremely micaceous, with biotites that may be four or five millimetres in diameter, is hardly lepidoblastie, coarse granoblastic felspar and quartz generally making up a large part of it, and the biotite being often in good thick plates. Its structure is typically lenticular and its foliation undulose. It is in this rock that oligoclase tends to exceed albite, and that sillimanite and all the more unusual minerals are apt to be found. The prevalent types may thus be briefly described as albite-biotite-gneisses, oligoclase-albite-biotite-gneisses, oligoclase-albite-biotite-sillimanite-, and oligoclase-albite-biotite-sillimanite-garnet-gneisses.

Origin of the foliated components

Before describing the way in which they are modified by the granitoid element (E), it will be well to consider the probable nature of the original materials. The first (A) is highly siliceous, more so in many cases than any known igneous rock. The second (B) is quartzo-felspathic, and might have been derived either from an albite-granite or from an albite-grit, albite-arkose, or albite-tuff. The third (C) closely resembles many rocks of the Scottish Highlands that are certainly pelitic sediments, such -as the wavy mica-schist of Suisgill, Sutherland, described by the present writer.<ref>*Quart. Journ. Geol. Soc.,* 1896, p. 643.</ref>

From the analysis No. I (p. 137), it is seen to be highly aluminous. No igneous rock, save some of exceptional composition that differ totally from it in their other components, contains anything like such a percentage of aluminium. But the specimen analysed was collected in the year 1901, and many examples of the type that have since been found contain far more sillimanite, and also more garnet, some being, indeed, mainly composed of quartz, sillimanite, and garnet, or of quartz, sillimanite, and biotite. The percentage of Al_2O_3 in specimens lately collected must exceed 30.00. Even the specimen analysed<ref>The percentage of iron, especially of FeO (evidently derived from haughtonite) is remarkable, but there must be quite as much in the Suisgill mica-schists.</ref>, and still more so those just mentioned, could not have been derived from anything but pelitic sediments. And the mineral sillimanite itself is now well established to be a characteristic of such sediments when subjected to a high grade of thermo-metamorphism. If such, however, be the origin of type C, then types A and B, which graduate into it, must be regarded as psammitic sediments, siliceous and felspathic respectively; and type D, the crystalline limestone, may reasonably be looked upon as an impure calcareous deposit. The balance of evidence, therefore, is at least in favour of regarding the rion-granitoid elements of the gneiss as of sedimentary origin.

Relations of the granitoid element

Now the granitoid component is related to the foregoing coin-ponents in seven different modes, arranged here in order of intimacy, the degree of intimacy reached in the last three being very high, and in the last the highest yet known in the study of gneissose rocks. They are: (1) Veining; (2) Flooding and Isolating; (3) Banding; (4) Lenticular Interfelting; (5) Permeation; (6) Granitoid Gneiss; (7) Gneissoid Granite. But it must be understood that these modes are not sharply separable; they merge gradually into one another, more than one being present in most portions of the gneiss.

(1) *Veining,* in the sense of granitoid strings of small width cutting the Gneisses at high angles, is quite subordinate. (2) *Flooding and isolating* by well-defined streams and sills of granite or pegmatite with sharp edges (the usual relation of the Coedana granite to the hornfels) is also subordinate. Good examples, however, are to be seen at Llandrygarn (Figure 19), (Figure 20), where the included and split fragments of albite-biotite-gneiss retain the dip and strike of the invaded mass. (3) *Banding.* This is displayed on a grand scale at Henblâs (Plate 15), where an oligoclase-albite-biotite-gneiss of types B and C, with some hard siliceous beds of type A and also some thin hornblende-gneisses, is injected *lit par lit* by conspicuous white and pale-salmon-tinted albite-granite. The dips are low and the phenomena are exposed on clear escarpments. Alternation is rapid, the chief granites being about six inches, the lesser ones about one inch thick, at intervals varying from six to twelve inches. The margins of the granite, which is usually but not always unfoliated, are for the most part sharp, but there is not the least sign of a chilled selvage. Here and there a little nebulosity can be seen at a margin. Whatever the origin of the granite, the relations locally are those of injection, for though most of the bands are thoroughly conformable, yet here and there they can be seen to truncate the foliation of the gneiss at a low angle and to send off tongues. There is also *lit par lit* injection of more than one phase, for at one place a 12-inch granite band (Figure 21) turns round a little, and truncates a number of thinner granite bands. Some of the larger bands are double, with a thin film of gneiss between, and some contain thin lenticular inclusions, thus linking this to the preceding mode. Regular interbanding, though so pronounced at Henblâs, is on flee whole not common in the gneissose areas. (4) *Lenticular Interfelting,* in varying degrees, is the most widespread of all the modes. Stout, knotty lenticles a foot or more in length are well seen on the coast of the Gader Inlier (Plate 14), and (Figure 22), (Figure 23). A moderate stage of intimacy is well seen at Tyddyn-gyrfa, where the sillimanite-garnet-gneiss that was analysed contains a large number of seams of rather coarse pegmatoid matter a foot or so in length, which may swell out in the middle to an inch or more in thickness. Often they do not thin off steadily, but by a succession of smaller and smaller expansions. Even where moderately developed, this mode is more intimate than that of the banding, for the pegmatites are often split and apt to be bordered by thinner ones, thus tending to graduate into the gneiss. As they increase in number this effect is greatly intensified, for they take one another's places by overlapping *en échelon,* until a stage is reached where pegmatites of varying thickness occupy as much space as the intervening gneiss (Figure 24). The lenticular masses then begin to anastomose, thus transgressing the foliation of the gneiss, and isolating it as lenticular inclusions, the relations being, however, far more intimate than in mode No. 2. The micaceous C type seems more susceptible of this mode than the others are, but at Gwyndy crags the B and A types are present as well, the whole complex rolling gently about, with here and there a good sharp fold. Granitoid and gneissoid materials now begin to pass into each other, partly by rapid alternations of thinner and thinner seams, partly by fraying-out of the ends of biotitic folia into albite-pegmatite or granite (Figure 25). But the dark biotitic rock is being at the same time prepared, as it were, for such passages, for spots of albith and little quartz-albite augen are now appearing within it, making it quite ready to graduate into foliated albite-granite either along or across the strike. (5) *Permeation.* Along the sides of a complex of this kind graduation will take place, through ranges of closely overlapping lenticles of both dark and light-coloured matter (themselves ill-defined both on their flanks and at their ends) into vague mixed types very difficult to describe in words, in which there is no banding, but cloudy lenticular tracts of granitoid matter inextricably confused with biotitic gneiss, itself cloudy with innumerable albites. No name but that of permeation-tracts can be given to the products of this mode, in which the union of the igneous and the other element is well-nigh complete, if not complete, and the proportions of the two are balanced. (6) *Granitoid Gneiss.* Yet the proportion of granite may still increase, the product being a well-foliated gneiss, but a granitoid one, composed of undulating lenticular films (Figure 26) of biotitic matter, themselves all cloudy with albites, graduating in all directions into granitic streams with elongated elements of quartz and albite, in and among which they float. (7) *Gneissoid Granite,* the final term, is an albite-granite with a foliation that is due to the presence of thin impersistent films of biotitic gneiss full of small albite spots, dying off at last into mere trains of biotite, floating in a stream of granite.

The less intimate modes (1) to (4) can be well studied on the coast of the Nebo Inlier, all the modes (the banding at Henblâs, the fourth mode at the crags that overlook the road just south-east of Gwyndy), in the Middle Region, and the advanced modes (5) to (7) at the same crags, and on the great sea-cliffs of the Gader Inlier.

Comparisons and conclusions

The phenomena of these granitoid gneisses must, like those of the hornblende-gneiss, have recalled to the reader certain districts in the Scottish Highlands. But the parallel in this case is not so much with the Lewisian gneiss (except, to some extent, the district between Cape Wrath and Laxford<ref>'Geology of the North-West Highlands' (*Mem.. Geol. Surv.*), pp. 103–125.</ref>, as with the Forfarshire country described by Mr. Barrow<ref>*Quart. Journ. Geol. Soc.,* 1893, p. 330.</ref>, and the parts of Eastern Sutherland described by Dr. Horne and the present writer<ref>*Quart. Journ. Geol. Soc.,* 1896, p. 633 (on work ending in 1895).</ref>, whose description has been extended by Dr. Crampton and others in the Annual Summaries of the Geological Survey from 1909 onwards. The behaviour of the granites is the same throughout, but the parallel with Eastern Sutherland is much more complete than with Forfarshire, for the great orthoclase pegmatites and the zones of kyanite and staurolite have not been identified in Sutherland or Anglesey. The resemblance to Eastern Sutherland, indeed, is extremely close. There are certain differences. Independent foliation in the granite, rare but present in Eastern Sutherland (*op. cit.,* p. 644, (Figure 3)), has not been found in the Mona Complex. Orthoclase appears to be absent from both the gneiss and its granites in the Mona Complex, nor is the granite ever porphyritic, and albite is its dominant felspar instead of oligoclase. The felspars of the pelitic-gneiss itself, however, do not present the same contrast, for oligoclase is abundant in the Mona gneisses, though there is, indeed, more albite than had been identified in Sutherland by 1895. Anglesey is, however, greatly inferior to Sutherland with regard to the state of preservation of the rocks, which are often so decomposed that no freshly fractured surfaces can be obtained, although the structures are beautifully displayed upon the weathered crags. In every other particular the parallel is complete. In both cases there are the same types of original material, siliceo-psammitic, felspatho-psammitic, pelitic, and calcareous, and they have undergone the same types of anamorphism. Sillimanite and garnet are abundant in both, but the development of sillimanite is greater in the Mona Complex than in Sutherland, and approaches that of Forfarshire specimens collected by Mr. Barrow. Finally, every mode of the relations of the granite (save independent foliation) that is known in Sutherland is perfectly reproduced in the Mona Complex. But the development in Anglesey is not, in this case, a miniature', as is that of the hornblende-gneiss; for it is found in four separate inliers — the Middle Region, Gader, Nebo, and Mynachdy, and the gneiss of Holland Arms indicates an extension to the Aethwy Region, suggesting a development co-extensive, at the very least, with that of Anglesey itself, and probably (see p. 252) very much larger. Granitisation, indeed, of this kind, is far from being a mere marginal phenomenon; it is doubtless regional.

Foliation

The varying developments of this have been described under the head of the petrology of the different members of the Mona Complex. In crystalline character there is the widest possible range, embracing almost all grades, from the faintest signs of anamorphic reconstruction to the permeation-structures of the deep-seated granitoid gneisses and gneissoid granites. Of the various types of crystalloblastic<ref>The terminology of Grubenmann wears, it must be confessed, a somewhat ponderous, not to say grim-visaged aspect Yet it is the only one that has been devised as a systematic expression of the textures of the crystalline schists, and has therefore been adopted in this book. We may hope that a petrologist who is also a classical scholar may some day devise one that is a little less formidable.</ref> texture, the leading ones, granoblastic, lepidoblastic, and nemablastic, are all widely developed; and of the special types, the poikiloblastic, diablastic, porphyroblastic, and encarsioblastic, are often to be seen. Of relict- or palimpsest-structures, the igneous rocks in various stages of incorporation yield blastogranitic, blastophitic, and blastoporphyric; and the sedimentary rocks in like manner the blastopsephitic, blastopsam-mitic, and blastopelitic textures, corresponding ones being yielded by the pyroclastic rocks. What may, perhaps, be called blasto-venous textures result from the incorporation of the quartz and quartz-albite venous sills.

The various grades of anarnorphic reconstruction are distributed in an involved and, apparently, capricious manner, but really according to definite laws. Those laws cannot, however, be discussed with advantage until after discussion of the tectonics and the stratigraphy. They will, therefore, be found on pp. 237–241.

General mineral characters of The Mona Complex

A short study of its minerals will serve to bring out certain characters that attach to the Complex considered as a whole, some of which are common to its igneous and to its sedimentary members, and have influenced the subsequent history of the whole region. Comparisons and contrasts with other foliated complices will doubtless be suggested by them.

The minerals identified are as follows: quartz; the felspars orthoclase, microcline, albite, albite-oligoclase, oligoclase, andesine-labradorite, and labradorite; the micas muscovite, paragonite, seri-cite, green biotite, biotite, and haughtonite; the amphiboles dark-green hornblende, blue-green hornblende, pale hornblende and actinolite, tremolite, asbestos, and glaucophane; the pyroxenes enstatite, augite, diallage, colourless and green diopside; serpentine, chrysotile, bastite, antigorite, brucite, and talc; the chlorites penninite, clinochlore, and delessite; the carbonates calcite, dolomite, and rhodochrosite; the iron-ores pyrite, magnetite, picotite, chromite, hematite, and ilmenite; the other titanium minerals perofskite, sphene, leucoxene, rutile, and anatase; the epidotes pistazite, pale epidote, orthite (?), and piedmontite; zoisite; natro-lite; tourmaline, xanthophyllite-chloritoid, andalusite, sillimanite; zircon, apatite, graphite, axinite, forsterite, spinel, garnet, and idocrase.

The Felspars — Now, the most salient fact in the composition of the Mona Complex is the extraordinary predominance of albite-felspar. Orthoclase is hardly known outside the Coedana granite and its hornfelses; microcline outside the less altered parts of the Penmynydd mica-schists; andesine-labradorite is known only in the basic intrusions of Caerau; labradorite only in a few cores of the albite-diabases; oligoclase is a component of the biotite-gneisses. In all these rocks, moreover, there is also an abundance of albite, especially in the Gneisses. But in every other member of the Complex, acid or basic, igneous or sedimentary, original or metamorphic, which contains a felspar at all, the felspar is albite. And as many of the grits and mica-schists are highly felspathic, the quantity of albite must be enormous; and the Complex must therefore be in great measure a sodium-complex. Idiotnorphic albite is known only in the undeformed parts of the spilitic lavas and their suite. The long history of some of the felspars is shown by the fact that the albite of the spilitic suite can often be seen to be secondary after a basic felspar which has decomposed, and that therefore, where reconstructed in anamorphic schists, it has become a ternary albite. Some degree of decomposition is commonly found in the felspars of the Complex, and it is usually of the micaceous type rather than the kaolinous. Its disposal in the grains is of interest. In the granites and in all the Gneisses it proceeds inwards from the periphery, so that fresh felspar tends to survive as cores in the interior. In the blastopsainmitic schists the reverse is the case, the core being full of decomposition-products and the margin fresh though in optical continuity. ((Figure 27) and (E10131) [SH 217 805], (E10151) [SH 241 829], and others.) The decomposition in this case would therefore seem to belong to that remote period of weathering that preceded the deposition of the sediment; and the reconstitution of the margin to the period of metamorphism, during which alkaline solutions must have *f,* been permeating the rock. Sometimes (Figure 27) and (Plate 2), Fig. 2 there is a ring of decomposition-products, which would seem to mark the inward limit of old weathering, so that an old, fresh core is now in optical union with a reconstituted fresh periphery.

The Micas — The white-micas of the Complex also reflect its alkaline composition, but in a different way. In several cases, where the only abundant alkali-minerals are a felspar and a mica, it has been possible to show (pp. 45, 49, 112, 135) that the mica must be muscovite, because analysis of the rock reveals a considerable proportion of potassium, which cannot have been yielded by the felspar, that being albite. In some of the Penmynydd mica-schists it can be further shown that this muscovite is a product of the reconstruction of microcline, for that felspar disappears as the muscovite develops. Albite is evidently far more stable than orthoclase under dynamic metamorphism, and reconstructs itself as new albite. Yet paragonite has been produced. It has been proved in the glaucophane-epidote-schist, a rock in which there is still a little albite, and is probably much more plentiful elsewhere than is as yet known. In the clastic schists, the decomposition-products of the felspars are now largely represented by minute flakes Of a white mica, which, as the felspar is albite, may be safely regarded as paragonite. Para-gonite in this form is widely diffused throughout the Complex. Very likely much of the sericite ' may be paragonite, but the contact-micas of the hornfels must be chiefly muscovite. Brown biotite seems to be nearly confined to the Penmynydd mica-schists (where it is not abundant), the granites, the hornblende-gneisses, and the biotite-gneisses. In the last it has been shown to be haughtonite. It is often chloritised, and the great separation of leucoxene and rutile that then takes place shows that it was highly titaniferous. Its remarkable bleaching in the biotite-gneisses, where it often simulates a muscovite, has been described. A much more unusual mica is the grass-green biotite of the New Harbour Beds, of which a chemical analysis is much to be desired. It shows a tendency, in the South Stack Series, to development along with muscovite in compound encarsioblasts.

The Amphiboles — The strongly coloured amphiboles belong essentially to the Penmynydd Zone and the Gneisses, those of the gneiss having a stronger pleochroism and a broader habit. Pale green ones appear in the contact-aureoles of the Coedana granite and the serpentine, still paler ones in the schistose gabbro, and the colourless calcareous tremolite is essentially the amphibole of the ophicalcites. The great, and for Britain unique, development of glaucophane in the Penmynydd Zone is yet another product of the high sodium-content of the Complex.

Pyroxenes, doubtless plentiful in the original basic rocks, have now a restricted distribution. Augite is known only in the spilitic suite and in the sub-gabbroid sills of Caerau; enstatite and diallage only in the gabbros, pyroxenites, and some of the serpentines. A little green diopside exists in the hornblende-gneiss, and a colourless diopside is abundant in the fosterite-limestone.

Olivine has not been found unaltered, but its products, among which is talc, are abundant in the serpentine-suite. Forsterite has been identified in a cipolino of the gneiss.

Iron-ores and Titanium — Among the iron-ores; pyrite is known as a mineral of allomorphic foliation, and micaceous laumatite is quite a character of the Penmynydd Zone, both in acid and in basic schists, but the haematite of the jaspers is flocculent. Magnetite is probably not very abundant, for inspection in reflected light reveals that very much, perhaps the greater part of the opaque iron-ore has a brownish tinge, shows frequent alteration into leucoxene, and must therefore be ilmenite. Connected with this is the abundance of sphene in many rocks, especially in the green-mica-schists of Holy Isle, in parts of the Pemnynydd Zone, and in the hornblende-gneiss, where it attains to the rank of an essential and develops crystals of unusual size (Plate 12), Fig. 2. Rutile is also, locally, abundant. These facts, together with the titaniferous character of the biotites, point to a high titanium-content in the Complex as a whole, in association with its high sodium-content. Such an association has been elsewhere noticed by Thomas and Jones.<ref>*Quart. Journ. Geol. Soc.* 1912, p. 389.</ref> In the Mona Complex, however, it is not confined to igneous rocks, but is found even in some of the sediments. During the earlier stages of the deposition of the beds, the titanium was probably concentrated largely in basic igneous matter, becoming disseminated, as time went on, by means of volcanic explosions (see p. 50).

Epidotes are widely distributed, both in igneous and sedimentary material. Some are post-metamorphic, and may be quite recent, but the great majority are true minerals of anamorphism. They are abundant and well crystallised in such rocks as the New Harbour Beds and the Penmynydd mica-schists, the amphibolic schists derived from the spilitic lavas, the hornblende- and especially the glaucophane-schist, in some of the hornblende-gneisses, and in the epidote-hornfelses of the granite and the serpentine; but on a smaller scale and more poorly crystallised in the less reconstructed rocks like most of the Gwna Beds, from which their anamorphic origin is evident. Typical pistazite graduates into varieties with low bi-refringence, sometimes without loss of the lemon-yellow tint and pleochroism. The discovery of piedmontite in the Green-mica-schists is of great interest, and it is to be hoped that more and better crystals will be found. Zoisite, recognised by its uniform low bi-refringence, and characteristic interference-tints of clear indigo-blue, usually accompanies the epidotes where the rocks are well re-crystallised, whether they be sedimentary or igneous. But it is especially a mineral of the Penmynydd Zone of metamorphism, where it is abundant in some varieties of mica-schist, but still more so in the amphibolites of the Aberffraw coast and the hornblende-schists of Gwalchmai. In these it seems to be al ways a clino-zoisite with the optic-axial plane transverse to the prism.

Various acecessories— Zircon is frequent in various rocks, but in moderate quantity. Apatite is abundant in the Penmynydd Zone, and still more in the Gneisses. Spinel has been identified in a limestone of the gneiss. Axinit-e in a vein in the spilitic lava. Graphite in a thin phyllite and mica-schist of the Gwna Beds and the Penmynydd Zone. Tourmaline (an accessory in many rocks) is especially developed in the hornfels of the Coedana granite, in which andalusite also has been found. Xanthophyllite occurs in the same hornfels, and also in graphite-schist of the adjacent part of the Penmynydd Zone, always as an encarsioblast. Garnet, small and idiomorphic, is found in the Penmynydd Zone; large, allotriomorphic, and much decomposed, is often abundant io the Gneisses, accompanied sometimes by green idocrase.

Sillimanite is known for certain only in the gneiss (Plate 12), Fig. 3, Fig. 5, where it is developed on a great scale in several places.

The Carbonates calcite and dolomite, present everywhere as decomposition-products, form considerable masses of rock in the Gwna Beds, where they are often tinged with rhodochrosite. In the Penmynydd Zone and in the gneiss they are re-crystallised along with high-temperature minerals as cipolini, and the same is the case, also, in the ophicalcites.

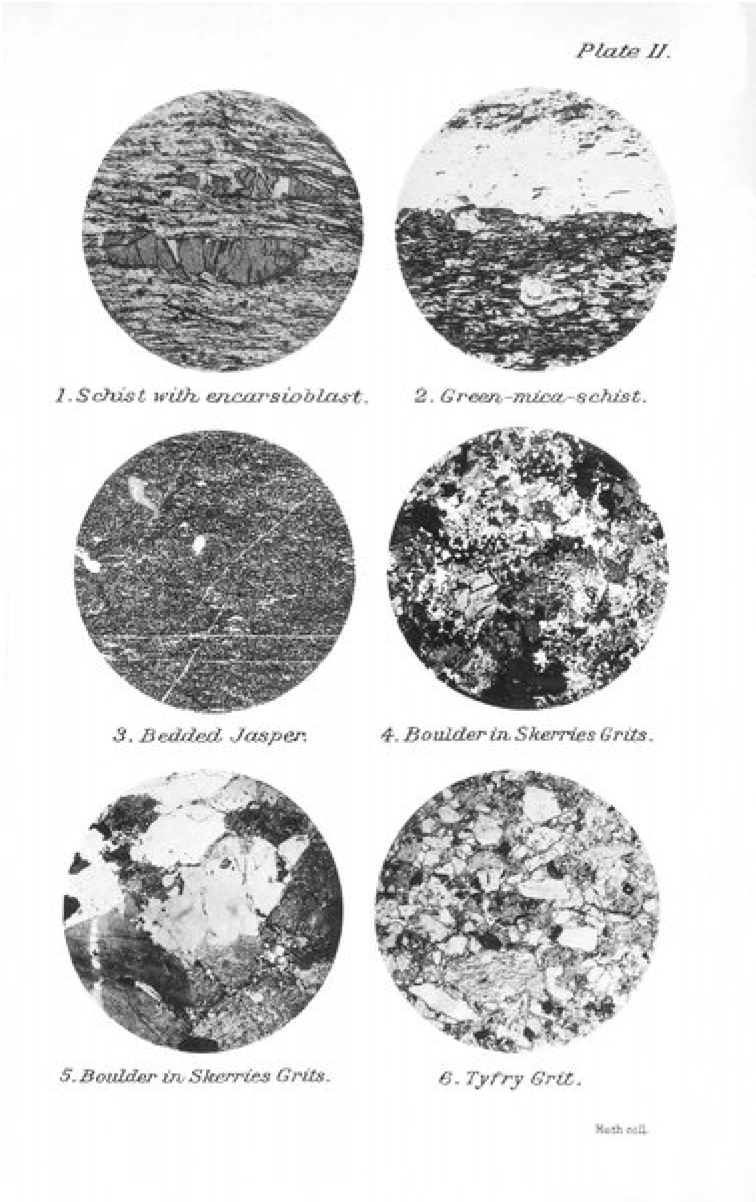
Quartz-veins are only a subordinate feature, but venous quartz in lenticular augen is developed on an enormous scale in the Gwna Green-schist and in the Penmynydd Zone.

Green Tint and the Chlorites — No character of the Mona Complex can be more striking to the most superficial observation than its persistent pale-green colour. The extensive Gwna Beds, the Church Bay Tuffs and Skerries Grits, the Amlwch Beds, the Coeden beds, the New Harbour Beds, and, to a less degree, the South Stack Series, the Penmynydd schists, the Hornfelses, and even the Gneisses and the Coedana granite, are all inure or less pervaded by this pale green colouration. Now in all these great formations, except the New Harbour Beds and the South Stack Series, which are coloured by a green biotite, the green colouring matter is a chlorite. Looked upon usually as mere decomposition products, and suffering from somewhat indefinite optical properties, chlorites are apt to receive scant attention from petrologists; but it is evident that in this complex they must have no small physical significance and be worthy of a closer study. And it soon becomes clear that they have not all been produced in the same manner. Some are decomposition products, but others are true minerals of anamorphism, and are thus respectively products of destruction and of reconstruction. They may be distinguished as 'chlorite of catamorphic dissolution' and 'chlorite of anamorphic evolution'. The first of these can be recognised in the usual way. The chlorite of the undeformed parts of the spilitic lavas is after augite, that of the Gneisses, of the granites, of the hornfels, of the parts of the Penmynydd Zone that adjoin the latter, is for the most part after biotite, partly after hornblende. These, then, are chlorites of dissolution. But consider such a rock as the Gwna Green-schist. It is in a very early stage of reconstruction, minute white mica being the only new mineral that accompanies the chlorite. There is not, nor ever can have been (for in the autoclastic mélange the almost raw material is still preserved to us), any crystalline mineral after which this chlorite can be a product of dissolution. The original ferro-magnesian matter was probably a sprinkling of pyroxenie dust or glass of spilite, which would have decomposed very soon after the deposition of the beds. This chlorite was therefore produced in the early stages of dynamic reconstruction, and is a chlorite of ana-morphic evolution. So is that of the Amlwch and other northern rocks, only the evolution has proceeded further, so that both it and the white mica are more distinctly crystallised. Consider now the passage from the Gwna Green-schist into the Penmynydd Zone, which we have already seen (pp. 124–6) to be an anamorphic evolution. In the Penmynydd mica-schist we find a chlorite in much larger, better-formed flakes (or rather plates), clear green, intergrown with the muscovite, with no sign of being a pseudo-morph after any other mineral. It is a chlorite of evolution, the most perfect known in the Complex. In the most advanced stages of the Penmynydd Zone a biotite appears. Van Elise has expressed the opinion<ref>'A Treatise on Metamorphism', p. 369.</ref> that 'the equations which represent the reactions in the zone of catamorphism are reversible in the zone of anamorphism'. We have, accordingly, a chlorite of dissolution replacing a biotite of evolution, and a chlorite of evolution replaced by a biotite of evolution.

In geological time, however, the chlorite of dissolution is vastly later than that of evolution. Some of it may possibly be as old as the later movements of the Mona Complex, some may be due to Ordovician destructive movements, some may be as late as Tertiary erosion. In the parts of the Penmynydd Zone where biotite is beginning to appear and yet (long afterwards) has become chloritised, chlorites of both origins must occur in the same rock, a conjunction that may be looked for along lines running northeast and south-west through Gaerwen Church and Porth Tre-castell respectively<ref>A slide from near Gaerwen (E9919) [SH 470 716] containing chloritised biotite, contains also a clear green chlorite that seems to be independent.</ref> Most likely these chlorites belong to different species, for certain differences between them appear to be tolerably constant. The chlorites of dissolution tend to be irregularly formed and not cleanly crystallised; to be yellowish-green in tint and rather feebly pleochroic. Their bi-refringence is low, and they frequently polarise in the well-known blue, with occasionally the lavender hues. Their axial angle is commonly very small, though hi-axial ones are not infrequent. For the most part they seem (even when flakes with intergrown muscovites, with whose optic-axial plane their own appears usually to coincide, are excluded), to be optically negative, but the reactions in convergent light are poor. The chlorites of evolution are better and more cleanly crystallised, of a clear, cool-green tint, and with much stronger pleochroism. Their bi-refringence appears to be rather higher, and they often polarise in the peculiar brownish hues. They are usually, though by no means always, distinctly biaxial, the average axial angle being in any case greater than in the other group. All those examined appear to be optically positive. The chlorites of dissolution, therefore, would appear to be partly Pennine, partly prochlorite; but the chlorites of evolution may, with some confidence, be ascribed to clinochlore. The subject, however, needs much further study.

The chief special idiosyncrasies of the Mona Complex are therefore: its high sodium-content, expressed in albite, paragonite, and glaucophane; its high titanium-content, expressed in ilmenite, sphene, leucoxene, and rutile; and its persistent green colour, due chiefly to the great abundance of chlorite of anamorphic evolution.

(Plate 16) The North Stack and the sea-cliffs of the Holyhead Quartzite From the South Stack Moor. Height seen = 582 feet. ***Note****.—The feature determined by the North Stack fault runs on, from sea-cliff, up the mountain-side, below the sky-line.*



(Plate 2) Microphotographs of the Mona Complex. 1. Schist with encarsioblast. 2. Green-mica-schist. 3. Bedded Jasper. 4. Boulder in Skerries Grits. 5. Boulder in Skerries Grits. 6. Tylry Grit. See Appendix 3.

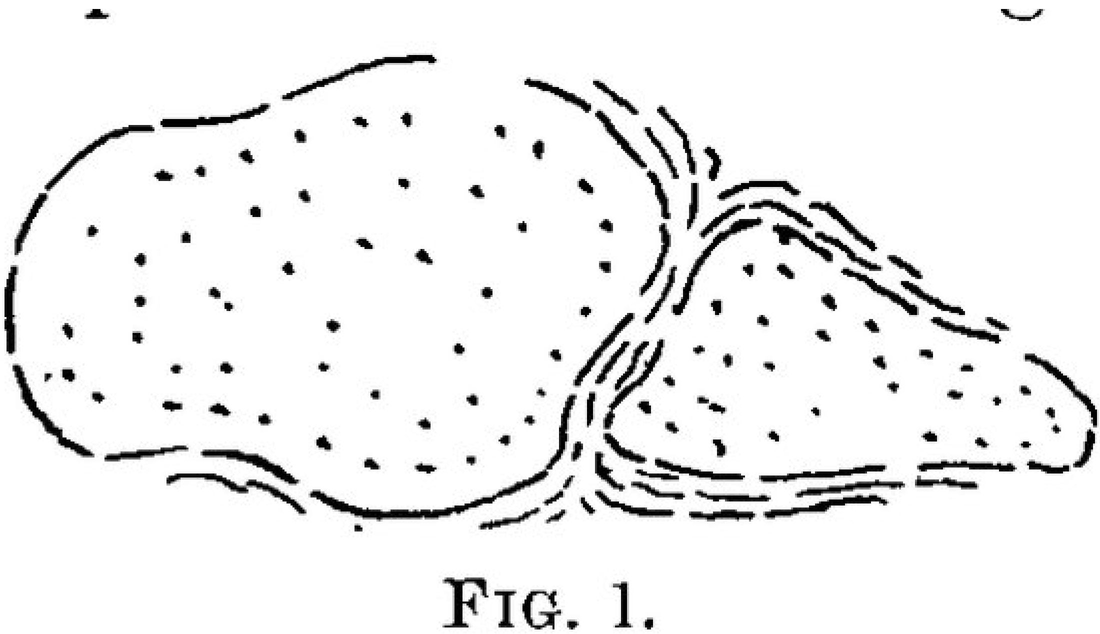


FIG. 1.

(Figure 1) Two-foot ellipsoids. Chapel, 500 yards north of Llanfwrog Church.

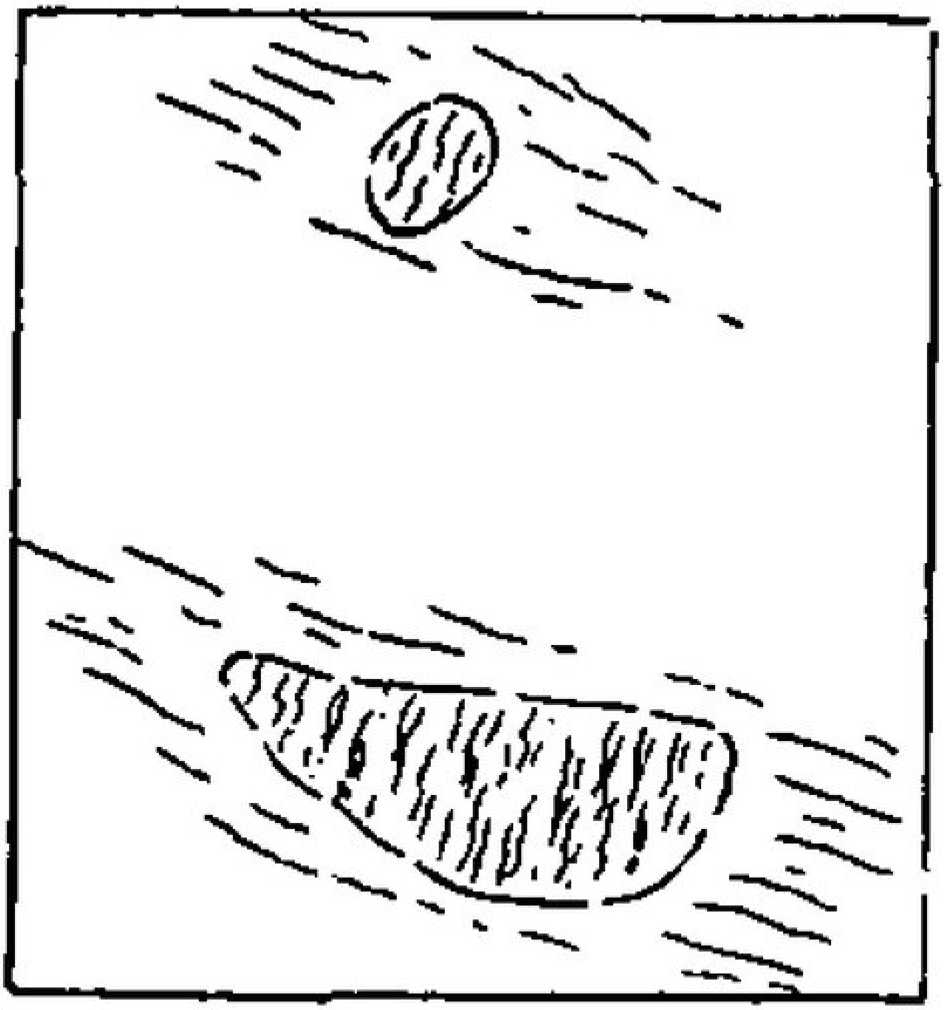


FIG. 2.

(Figure 2) Pebbles of old schist in Skerries Grits, Bwlch. Natural size

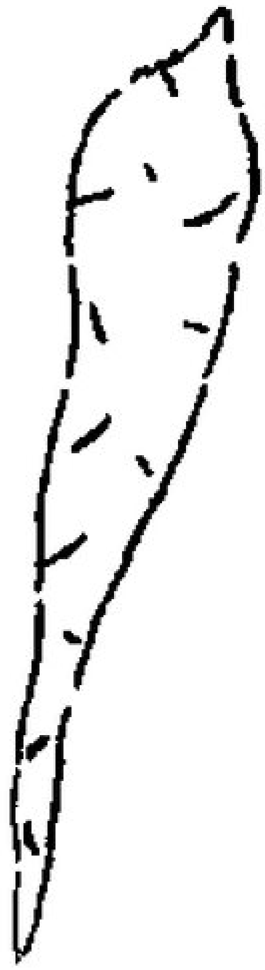


FIG. 3.

(Figure 3) Deformed boulder. 8 inches long. The Skerries.

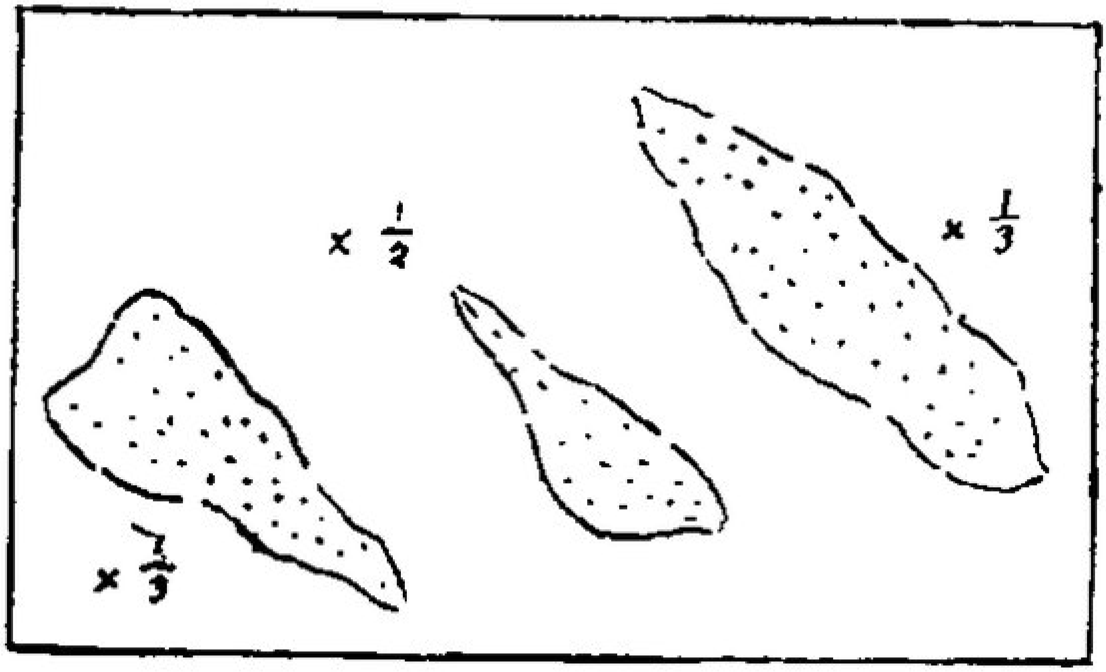


FIG. 4.

(Figure 4) Peacoids of grit in Gwna Mélange. North of Glyn-afon.

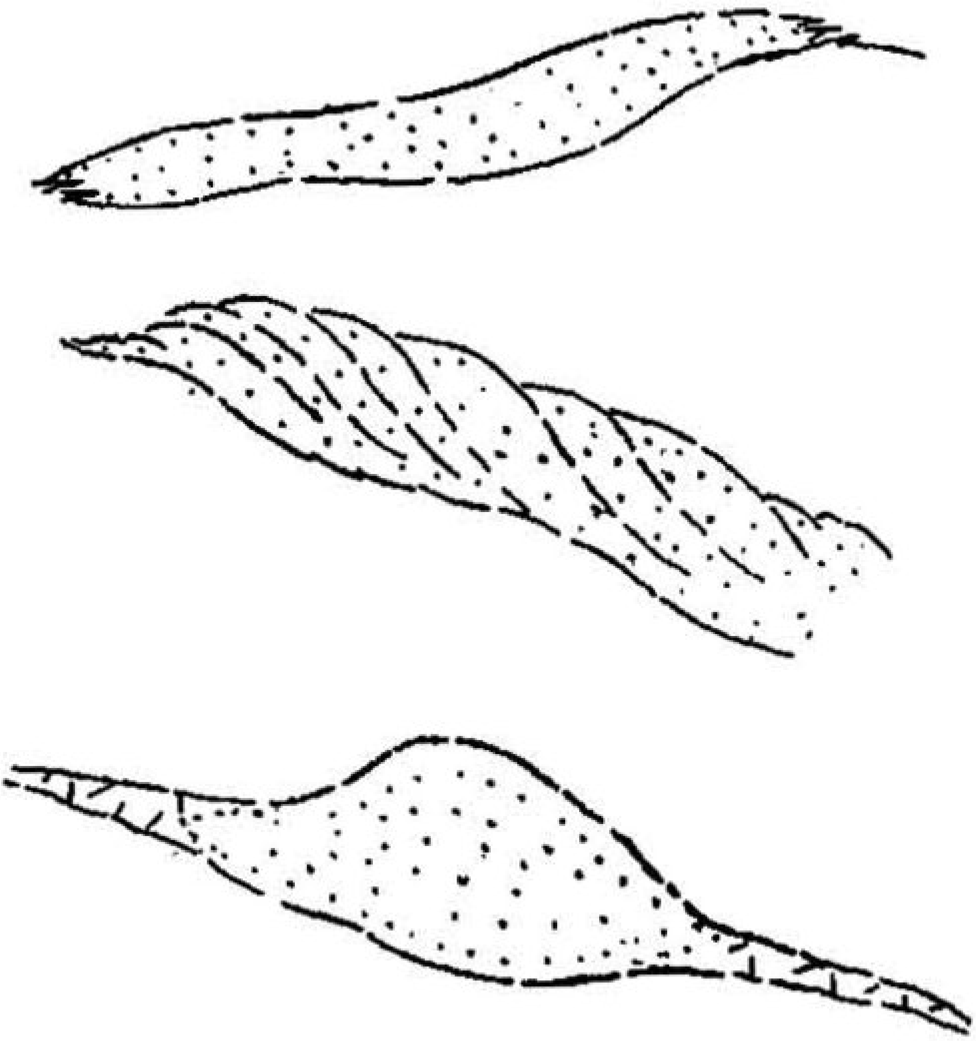
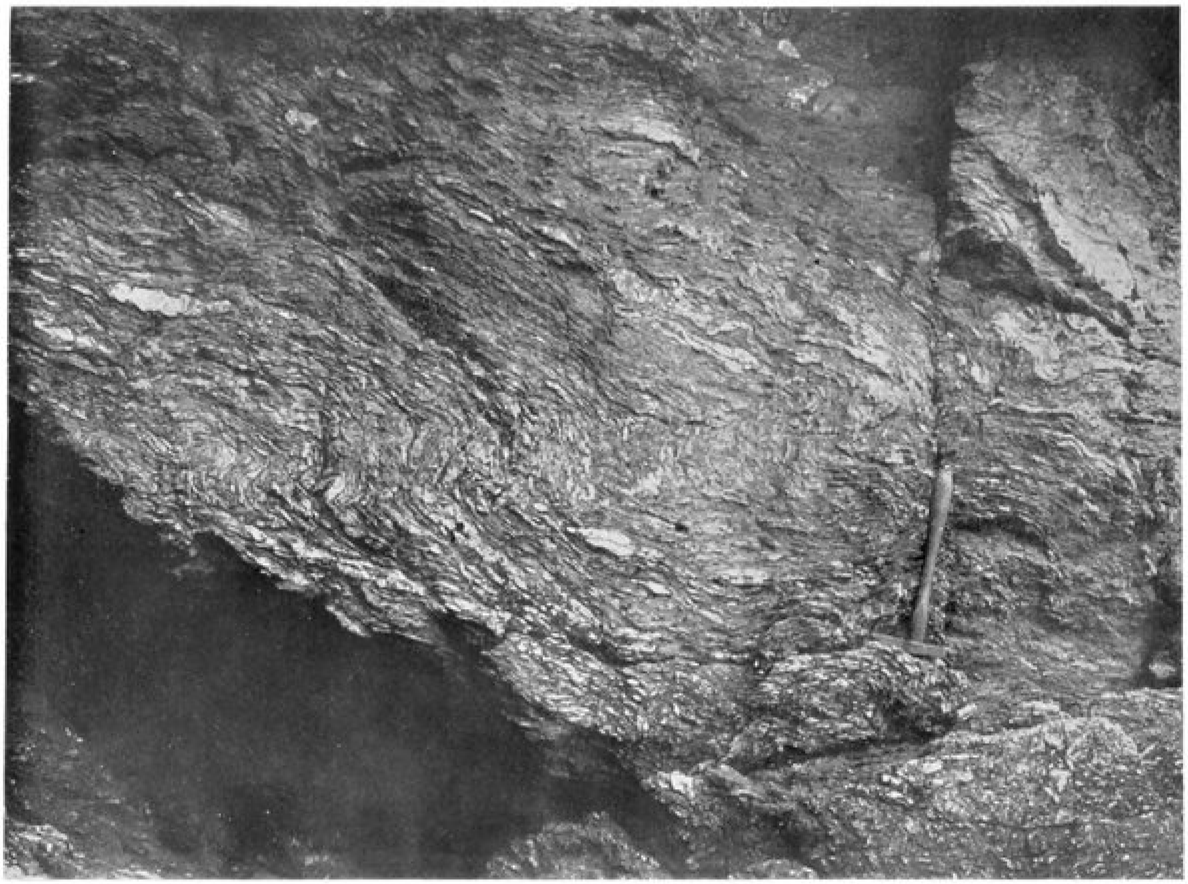


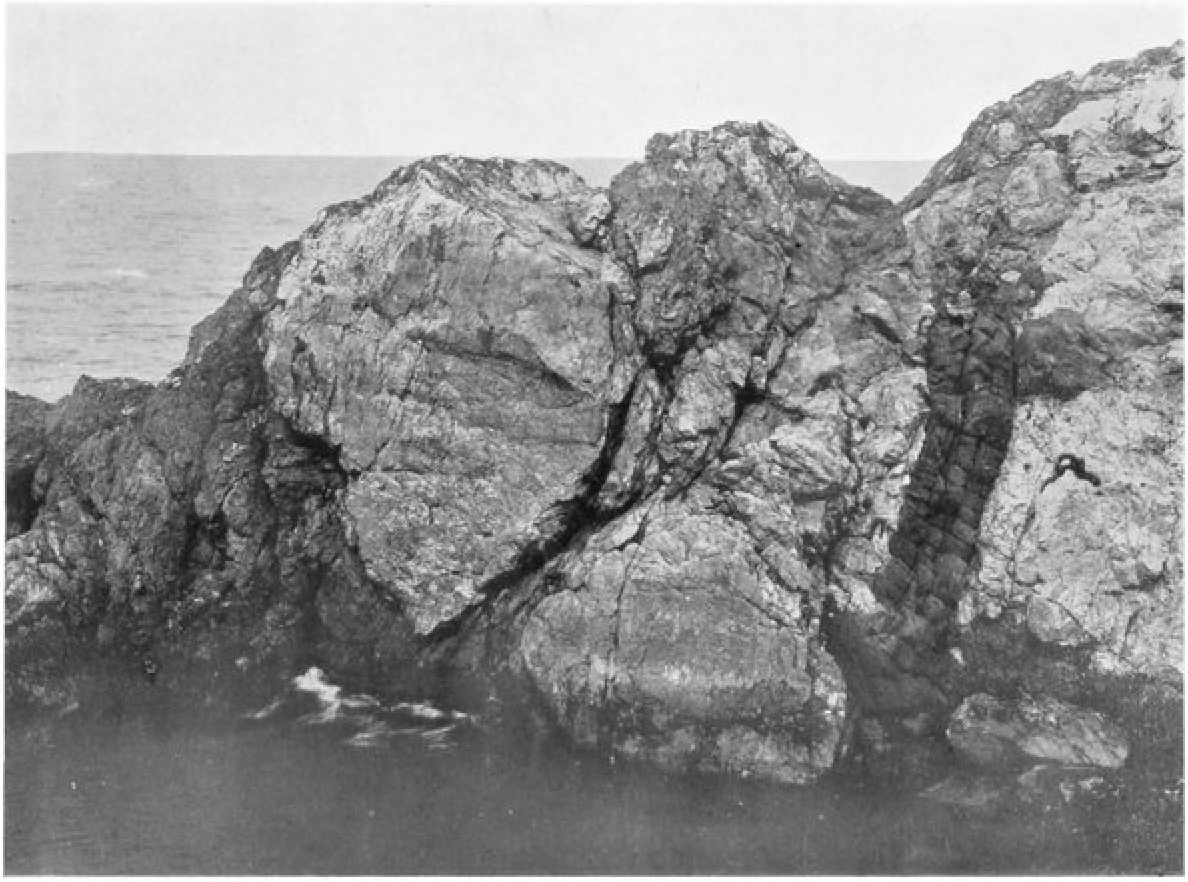
FIG. 5.

(Figure 5) Peacoids of grit in Gwna Mélange. North of Glyn-afon.

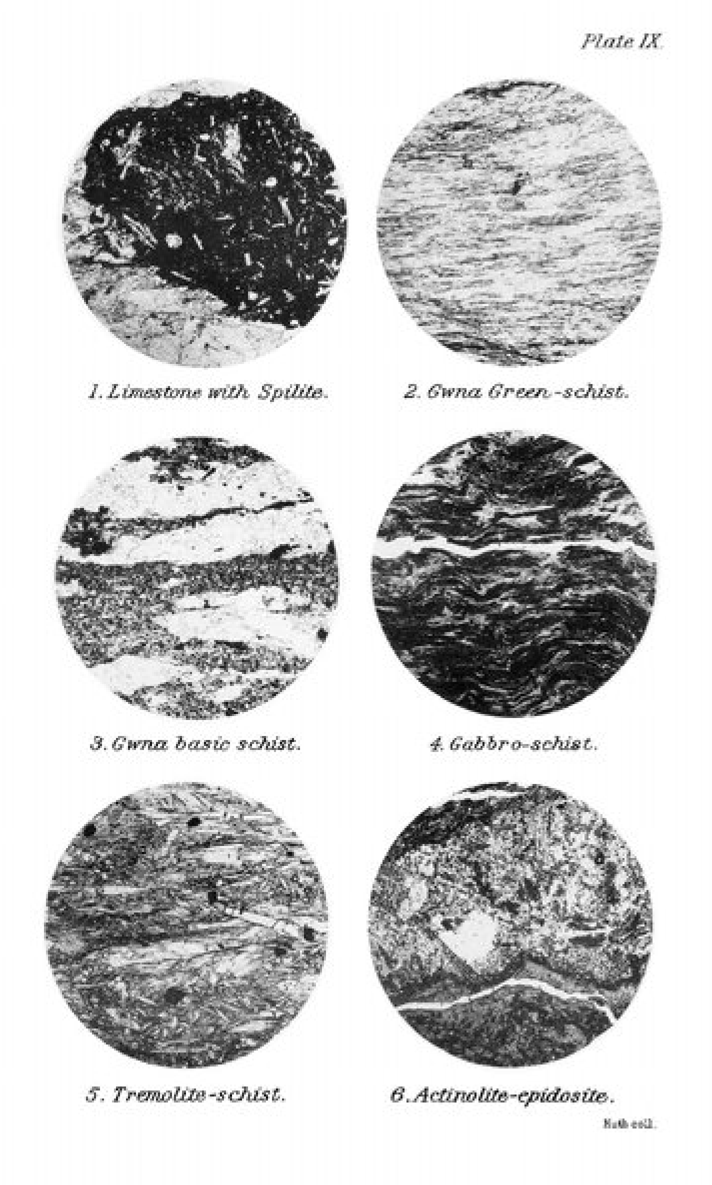
(Plate 7) Autoclastic Melange. Coast near Porth Cadwaladr, Bodorgan.



(Plate 23) Folding of Autoclastic Melange. Menai Strait.



(Plate 22) Lenticular quartzites in Autoclastic Mélange, with late basic dyke. Porth Wnol.



(Plate 9) Microphotographs of the Mona Complex. 1. Limestone with Spilite. 2. Gwna Green-schist. 3. Gwna Basic Schist. 4. Gabbro-Schist. 5. Tremolite-Schist. 6. Actinolite-Epidosite. See Appendix 3.

(Plate 8) Siliceous Gwna Green-schist with venous quartz-augen. Ynys Gaint, Menai Strait.

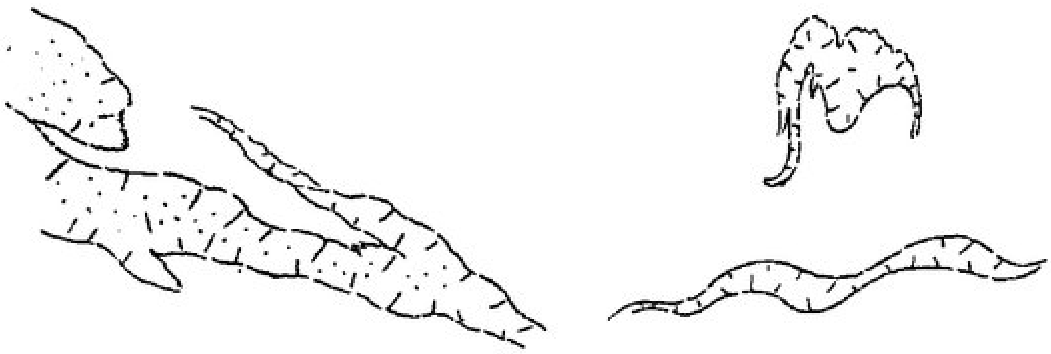
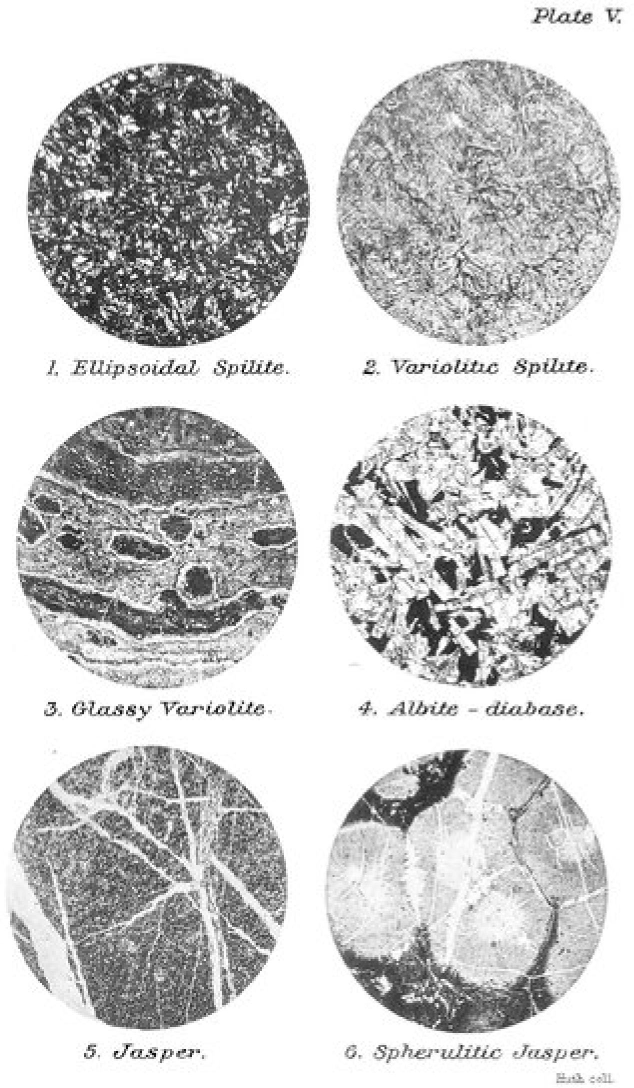


FIG. 6.—VENOUS QUARTZ PHACOIDS,
AETHWY REGION.

(Figure 6) Venous-quartz phacoids, Aethwy region.

(Plate 3) Ellipsoidal spilitic lava. Dunes of Newborough.

(Plate 4) Intersticial jasper between spilitic ellipsoids. Dunes of Newborough.



(Plate 5) Microphotographs of the Mona Complex. 1. Ellipsoidal Spilite. 2. Variolitic Spilite. 3. Glassy Variolite. 4. Albite-Diabase. 5. Jasper. 6. Spherulitic Jasper. See Appendix 3.

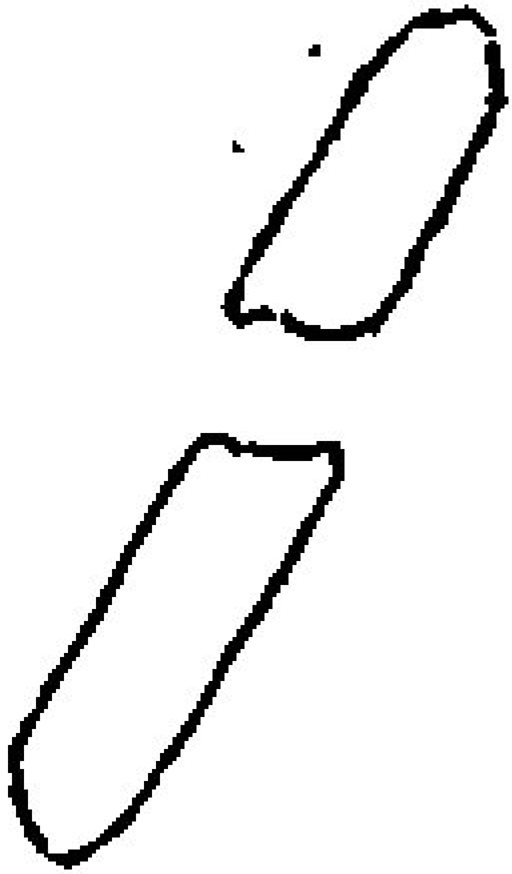


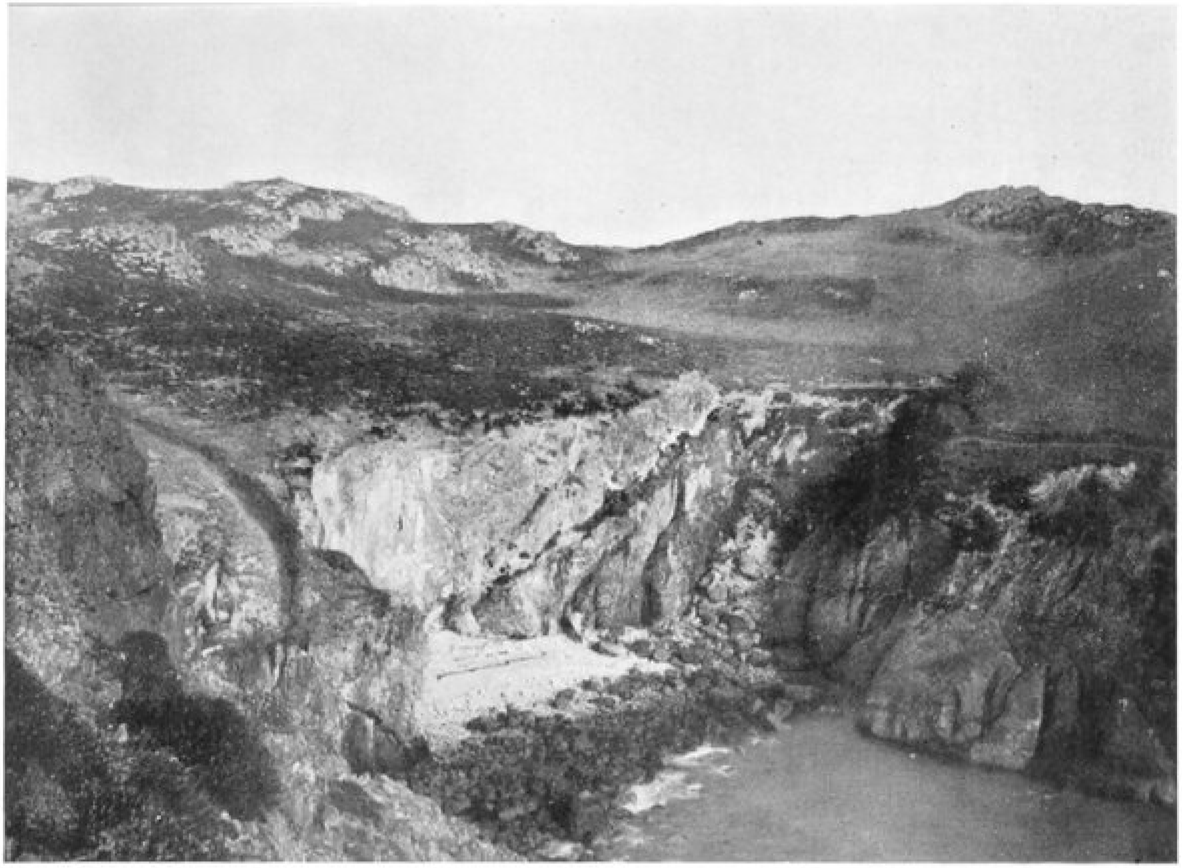
FIG. 7.

(Figure 7) Broken zircon in Bodafon quartzite. Highly magnified.

FIG. 8.

(Figure 8) Compound oolitic grain in Gwna Limestone. (E10816) [SH 375 946]

(Plate 6) Rose-Limestone with ellipsoidal structure. Dunes of Newborough.



(Plate 25) The Hwch lower thrust-plane. Porth-yr-hwch. Fydlyn Felsitic Tuff thrust over Gwana Green-schist.

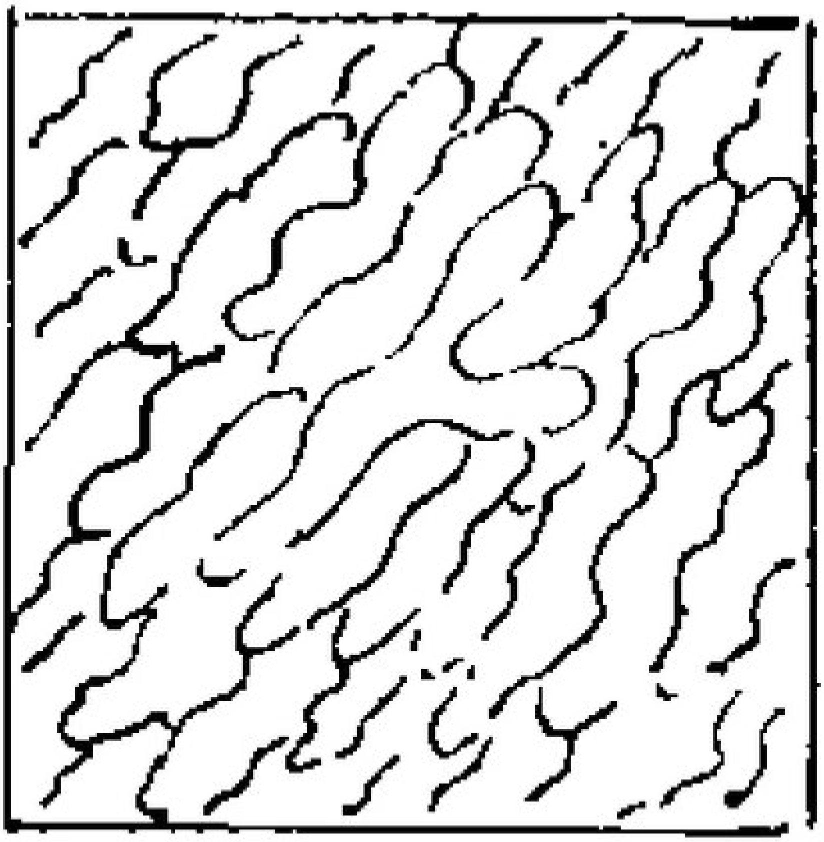


FIG. 9.

(Figure 9) Old foliation in Coedana granite West-south-wst of Coedana Church.

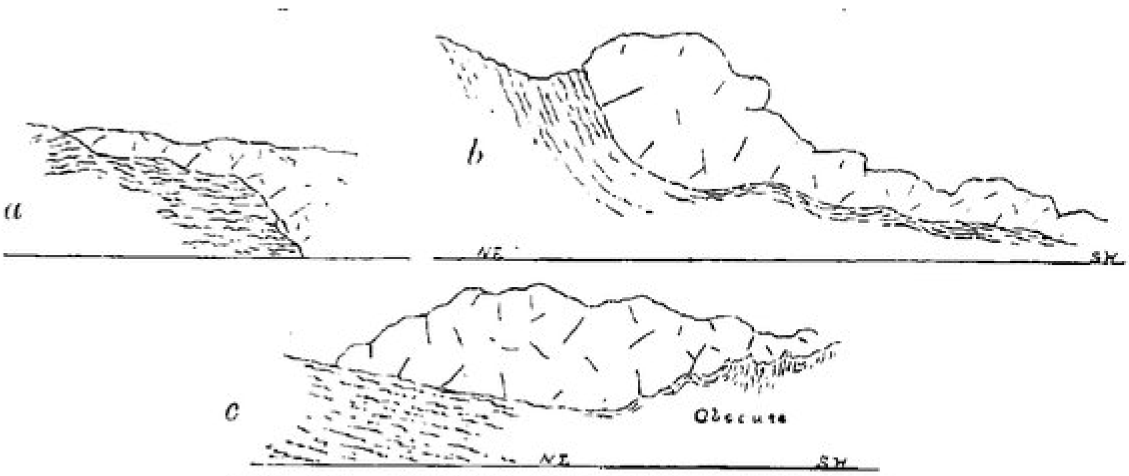


FIG. 145.—GRANITE SILLS IN MICA-HORNFELS.

(Figure 145) Granite sills in Mica-hornfels. Heights on south side of main road, quarter to half a mile west of Caer-glaw. Lengths: a. six feet ; b, c, ten feet.

FIG. 146.
FOUR-INCH GRANITE SILL
IN MICA-HORNFELS.

(Figure 146) Four-inch granite sill in Mica-hornfels. Same locality as (Figure 145).

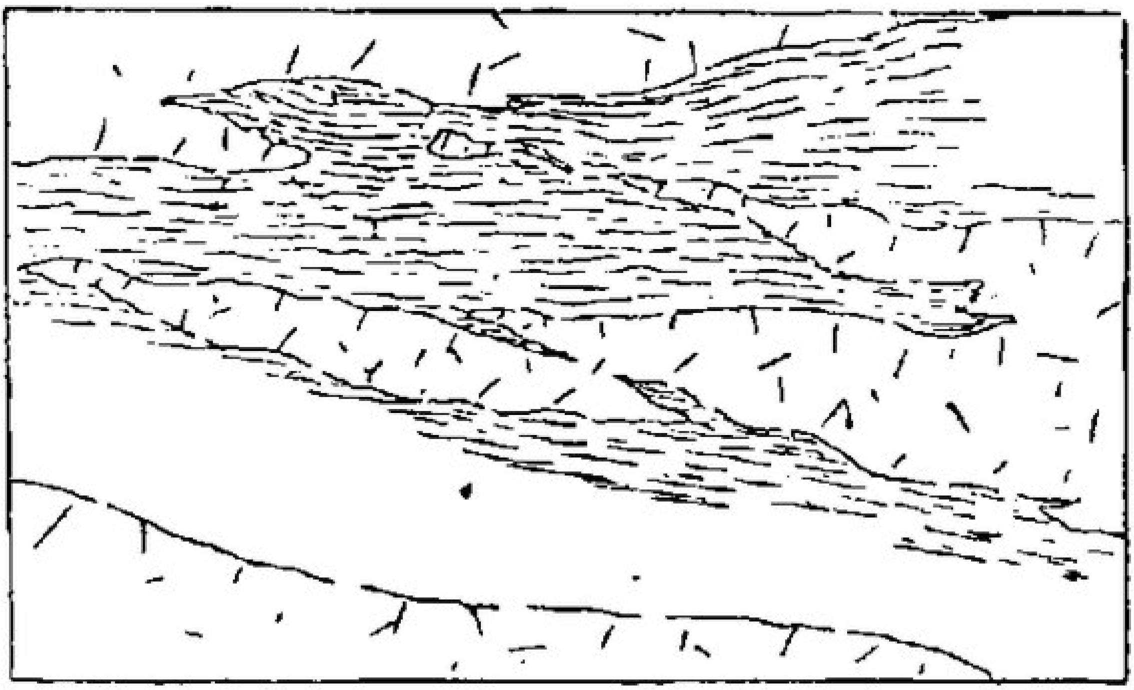


FIG. 147.
GRANITE SILLS IN AN INCLUSION OF
MICA-HORNFELS.

(Figure 147) Granite sills in an inclusion of Mica-hornfels. Length: two to three feet. Same locality as (Figure 145).

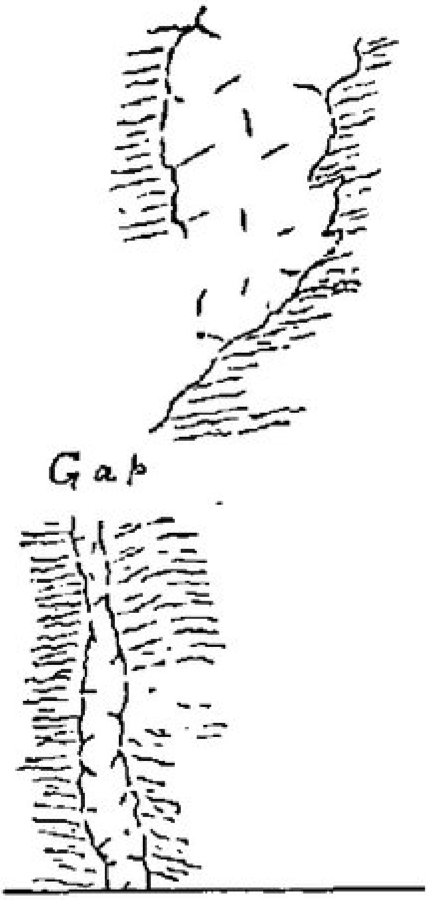


FIG. 148.
SIX FEET OF
GRANITE VEIN IN
MICA-HORNFELS.

(Figure 148) Six feet of granite vein in Mica-hornfels. Same locality as fig. 145.

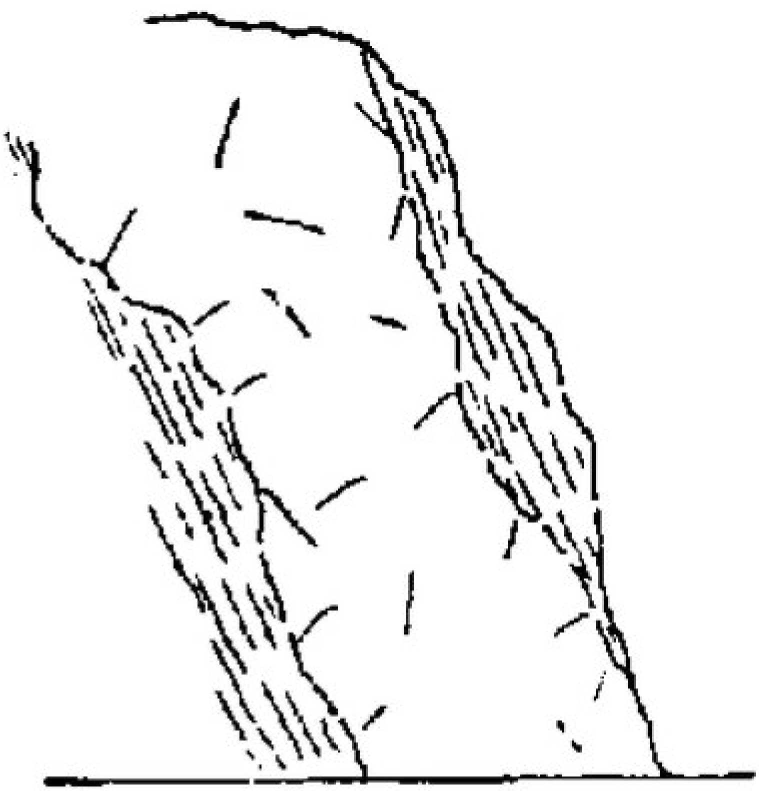


FIG. 150.
SIX-INCH GRANITE
SILL IN HORNFELS.

(Figure 150) Six-inch granite sill in hornfels. Gwalchmai, 250 yards north of inn.

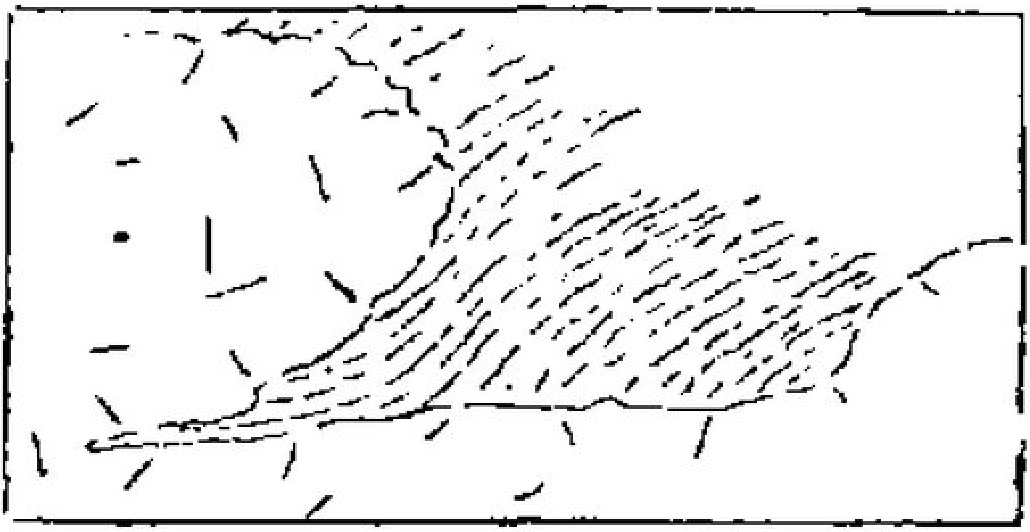


FIG. 151.

TEN INCHES OF BEDDED MICA-HORNFELS TRUNCATED BY GRANITE.

(Figure 151) Ten inches of bedded Mica-hornfels truncated by granite. Laneside, west of y-foel.

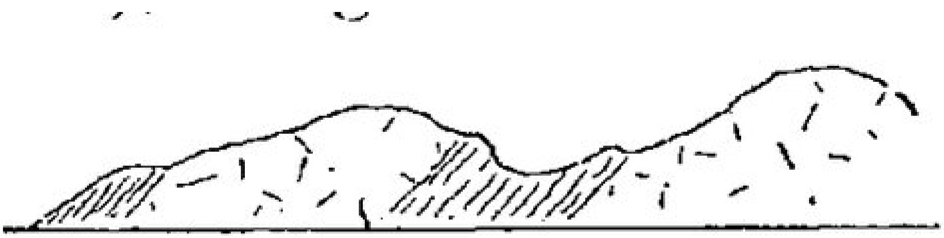
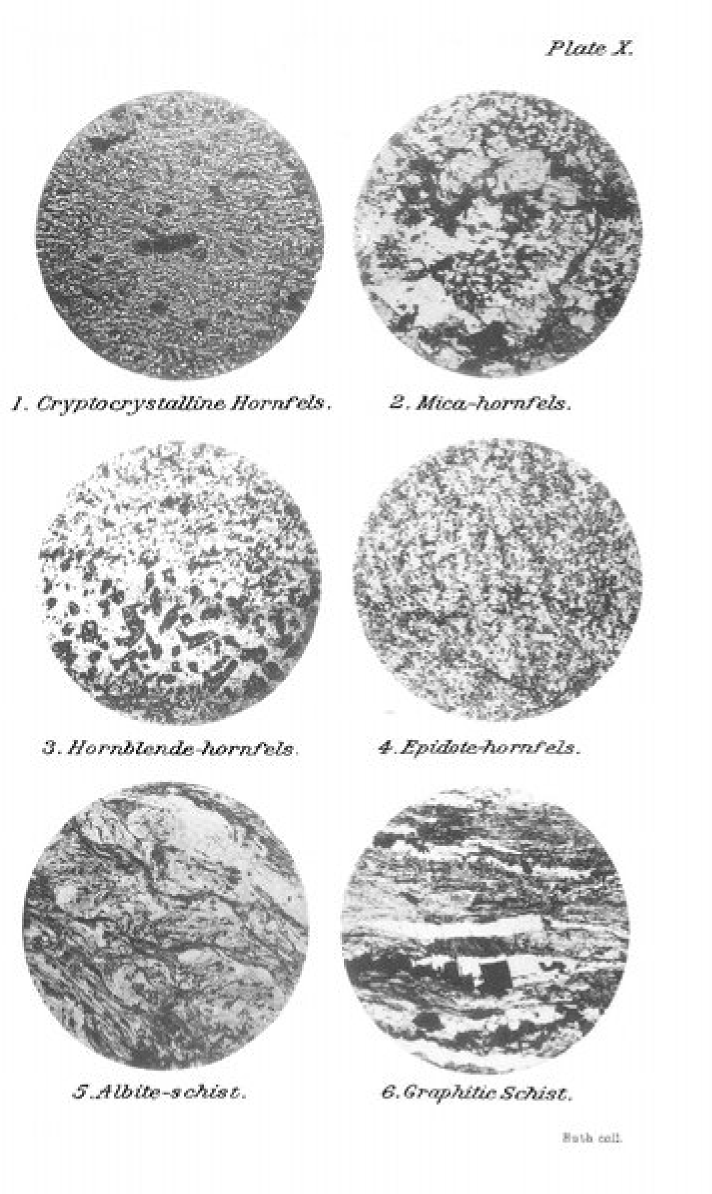


FIG. 152.
GRANITE SILLS IN HORNBLENDE-HORNFELS.

(Figure 152) Granite sills in Hornblende-hornfels. Maen-gwyn Farm, at 'oed' of 'Coedana'.

FIG. 153. TRANSGRESSIVE MARGIN OF GRANITE.

(Figure 153) Transgressive margin of granite. Maen-gwyn.



(Plate 10) Microphotographs of the Mona Complex. 1. Crypto-crystalline Hornfels. 2. Mica-Hornfels. 3. Hornblende-Hornfels. 4. Epidote-Hornfels. 5. Albite-Schist. 6. Graphitic Schist. Note to 5 and 6 — A figure of typical Penmynydd mica-schist ought perhaps to have been given. But its usual, crystalline characters can be seen in these, if we disregard the porphyroblasts and encarsioblasts. See Appendix 3.

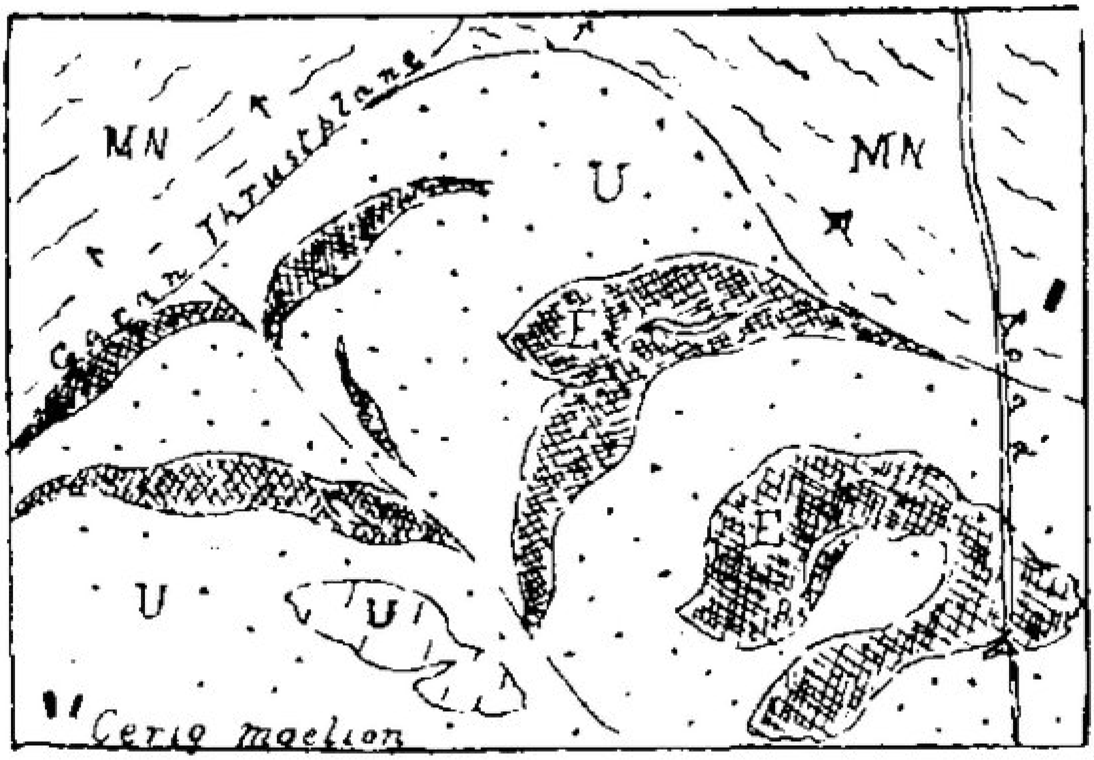


FIG. 122.

THE CERIG-MOELION INTRUSIONS AND THE GARAN THRUST-PLANE.

(Figure 122) The Cerig-Moelion intrusions and the Garan Thrust-plane. From the six-inch map. Reduced from the .0004 map. MN = New Harbour Beds. U = serpentine and ophicalcite. E = gabbro in ring dykes.

(Plate 11) Folded Penmynydd Mica-schist with quartz-augen. Graig-fawr, Holland Arms.

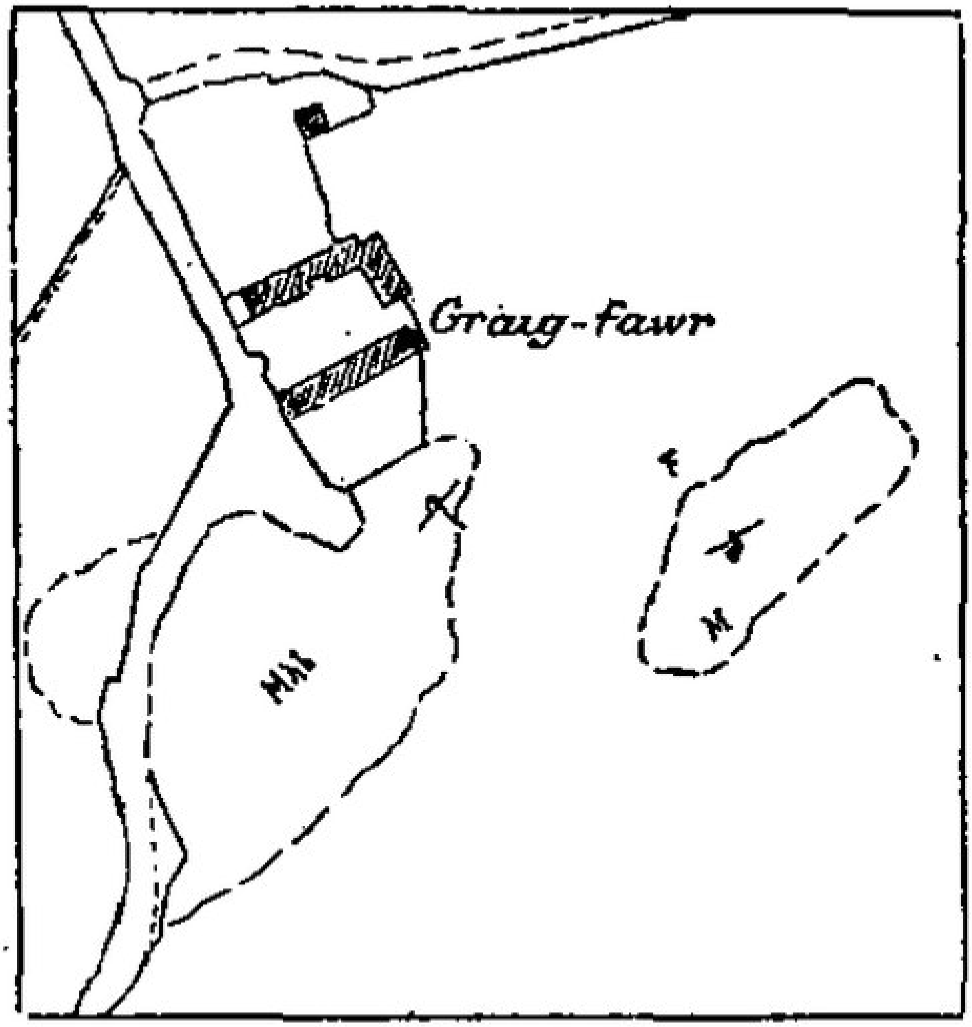


FIG. 10.

(Figure 10) The felsitic survival. Scale 1:5,000. F=Felsite, M=Mica-schist, Mhb=Hornblende-schist

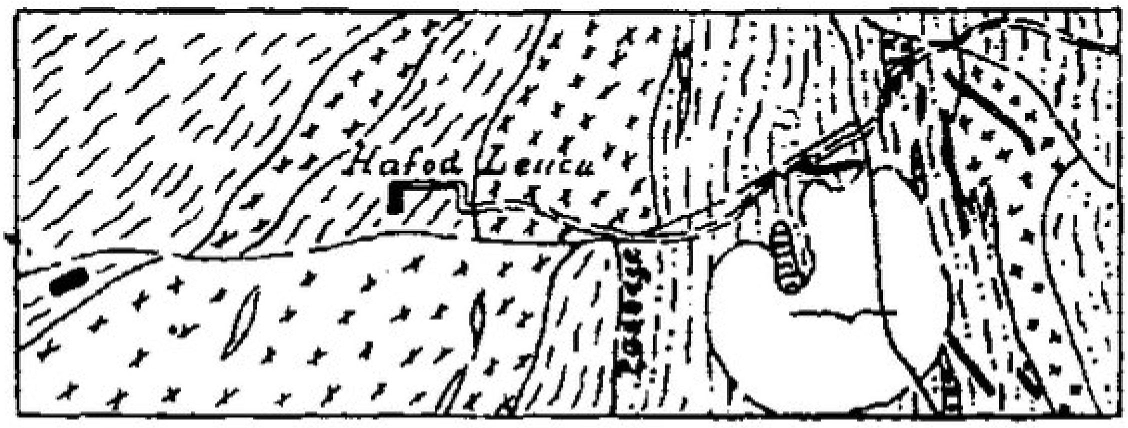
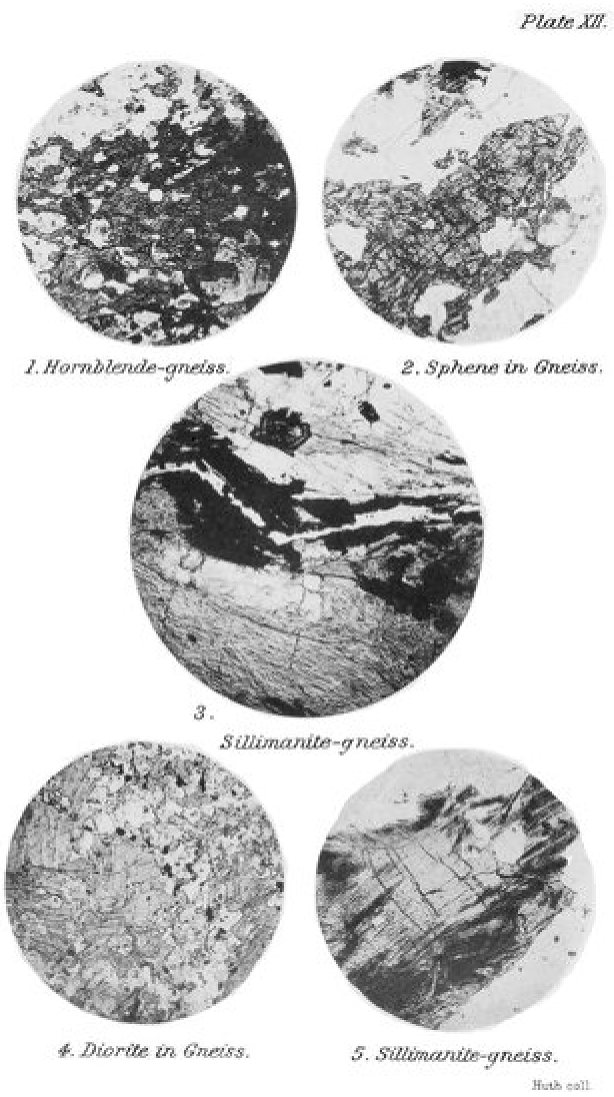
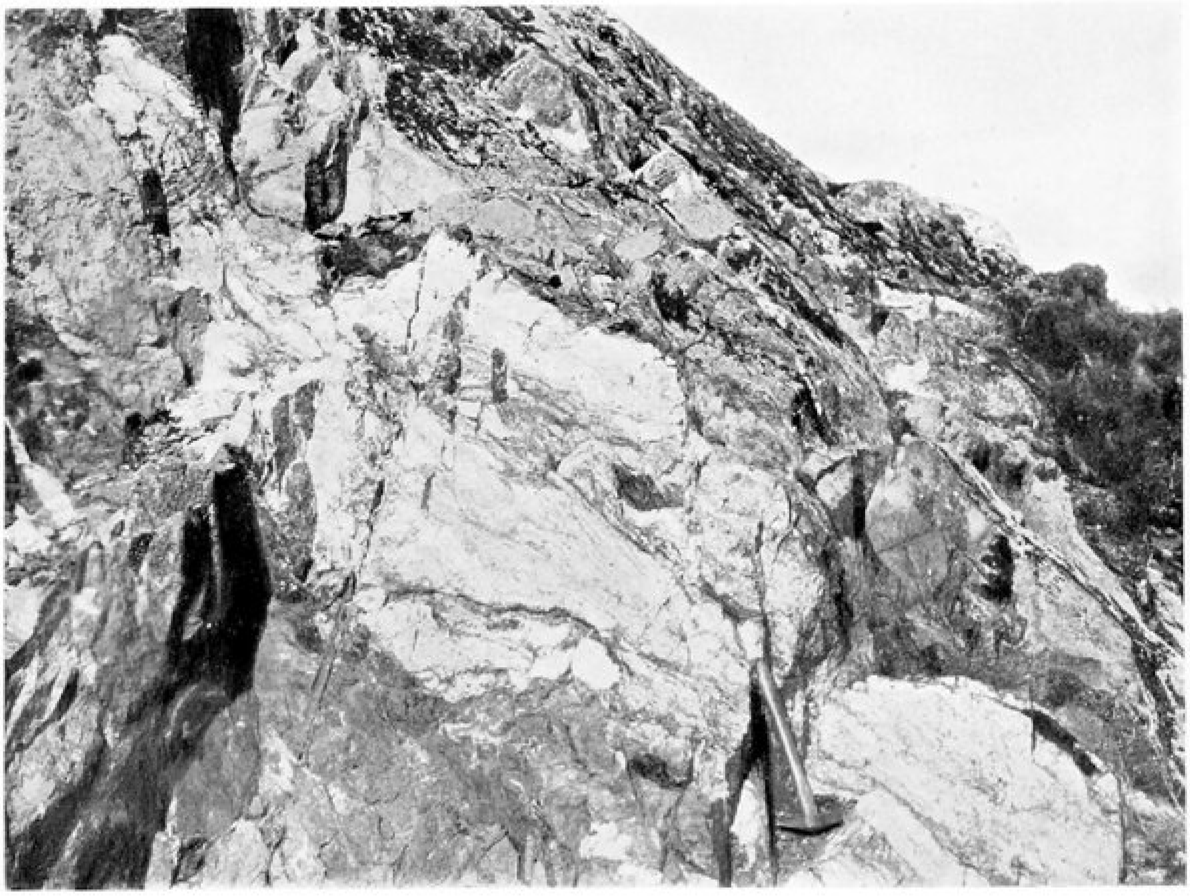


FIG. 11.

(Figure 11) Position of passage in Mynydd Llwydiarth. From the six-inch map. Dashes and dots=Gwna Green-schist. Dashes=Penmynydd Mica-schist. Crosses=Basic rocks. Dykes also shown.



(Plate 12) Microphotographs of the Mona Complex. 1. Hornblende-Gneiss. 2. Sphene in Gneiss. 3. Sillimanite-Gneiss. 4. Diorite in Gneiss. 5. Sillimanite-Gneiss. See Appendix 3.



(Plate 13) Albite-pegmatite in hornblende-gneiss. Clegir-mawr, Gwalchmai.

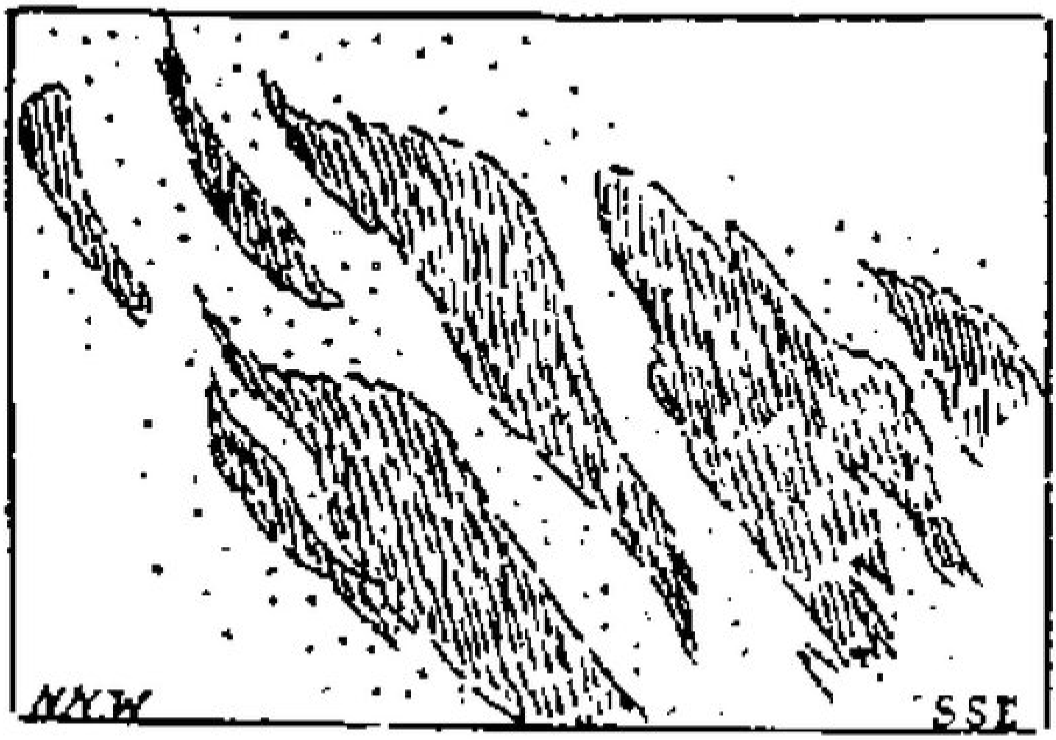


FIG. 12.

(Figure 12) Hornblende-gneiss in granular albite. North boss on east margin of Werthyr alluvium. ×1/2

FIG. 13.

(Figure 13) Six-inch knot of albite-pegmatite in hornblende-gneiss. 200 yards north-north-west of Craig-yr-allor.

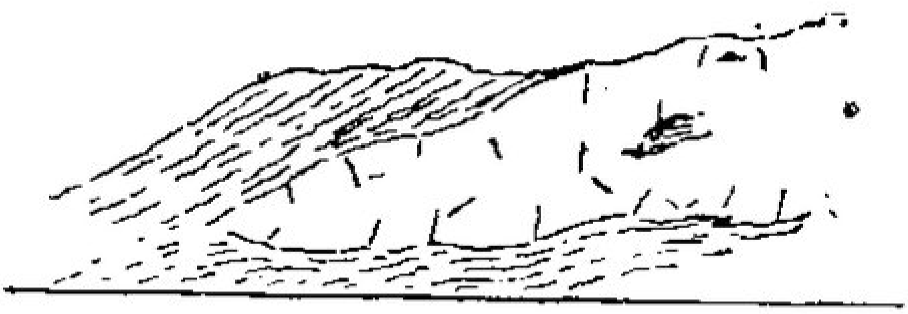


FIG. 14.

(Figure 14) Six-inch and four-foot sills of albite-pegmatite in hornblende-gneiss. West and north-west of Clegir-mawr.

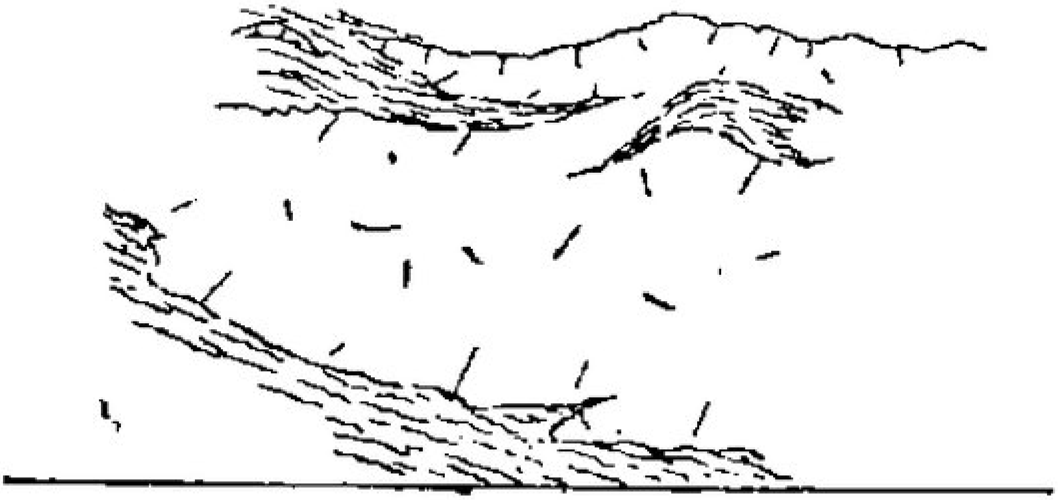


FIG. 15.

(Figure 15) Six-inch and four-foot sills of albite-pegmatite in hornblende-gneiss. West and north-west of Clegir-mawr.

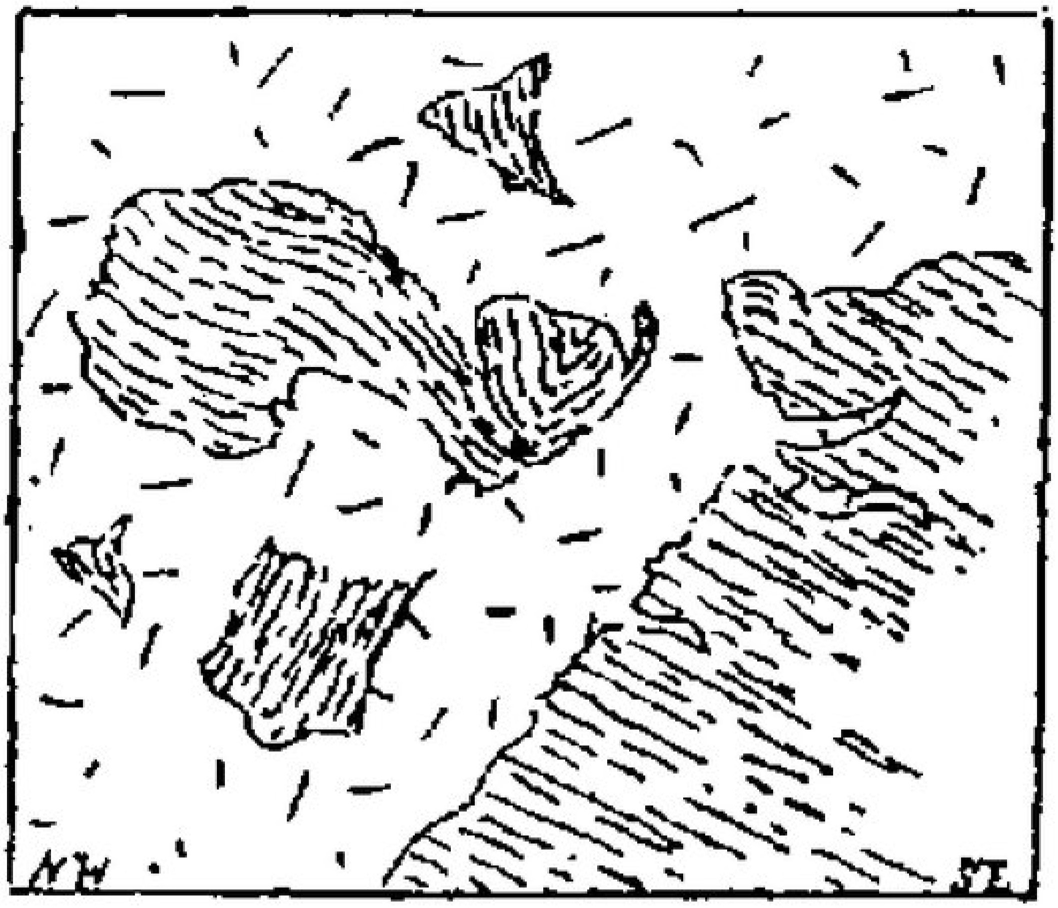


FIG. 16.

(Figure 16) Coarse albite-pegmatite isolating hornblende-gneiss. Height: 1 ft. 6 in. High boss, 200 yards north-west of road-fork at Clegir-mawr.

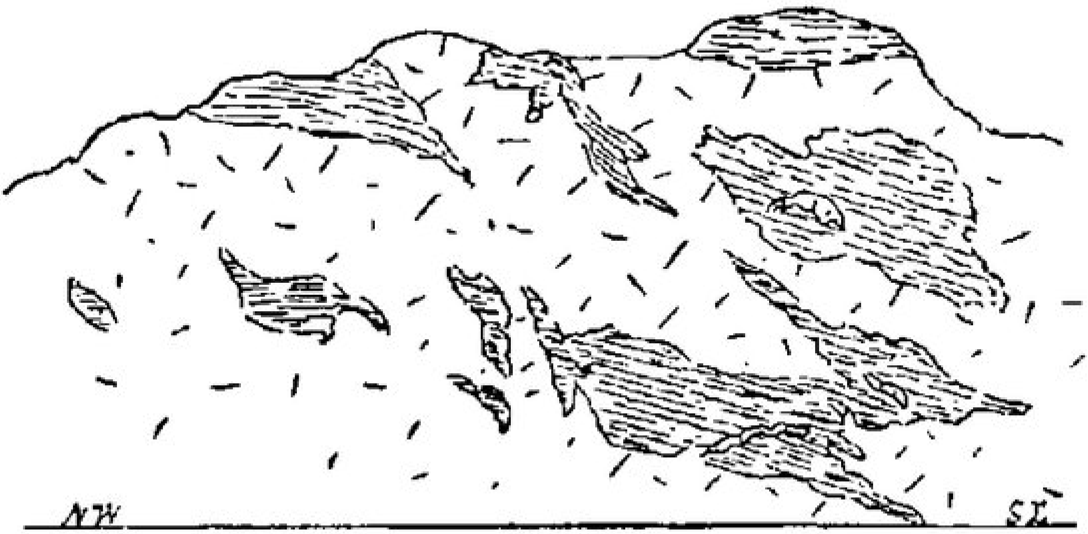


FIG. 17.

(Figure 17) Coarse albite-pegmatite isolating hornblende-gneiss. Height: 2 ft. High boss, 200 yards north-west of road-fork at Clegir-mawr.

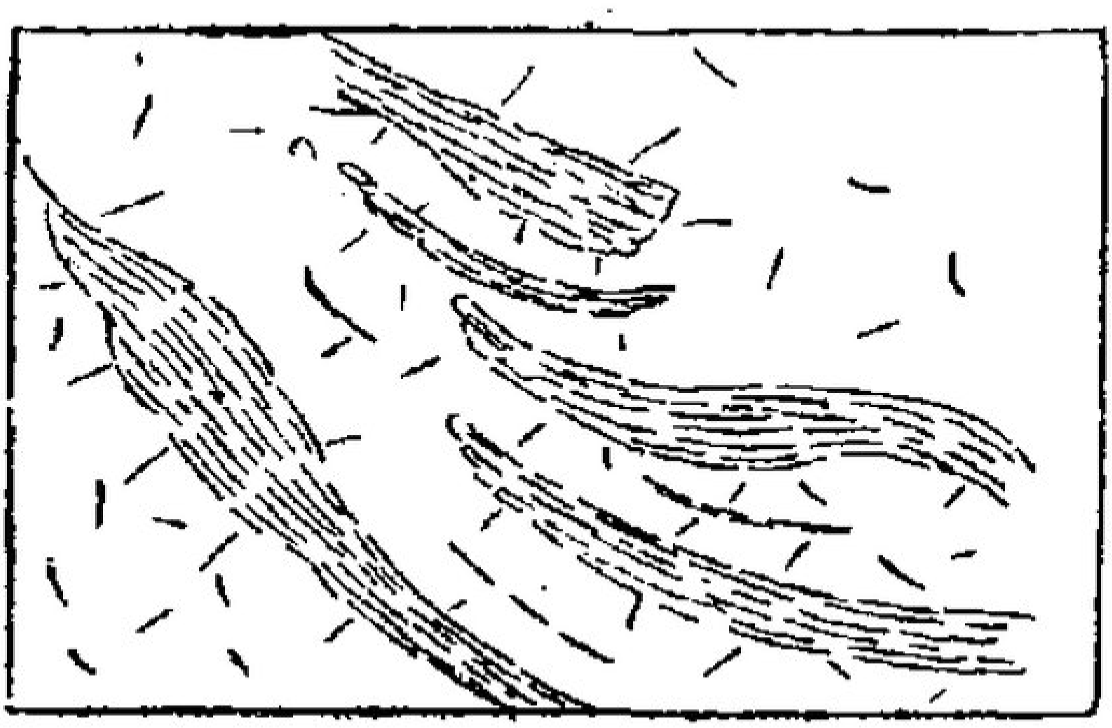
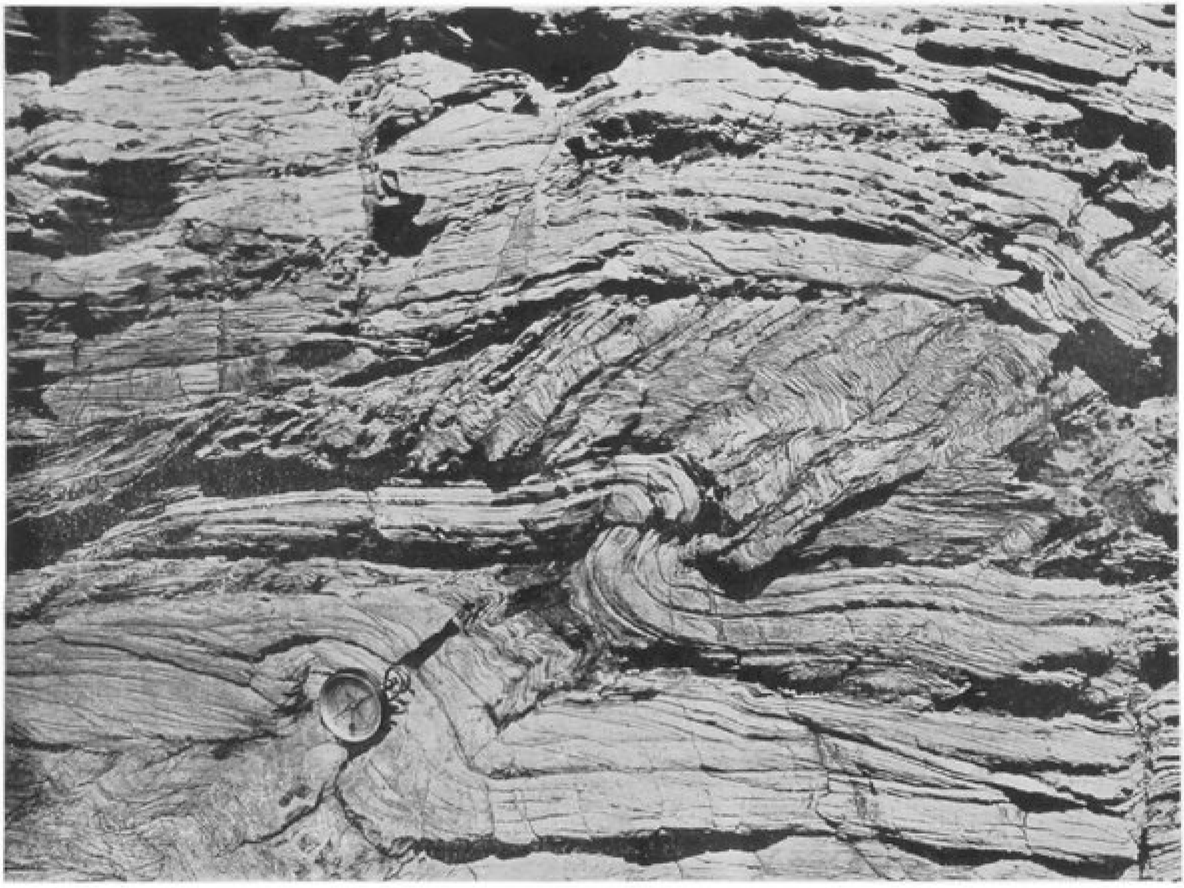


FIG. 18.

(Figure 18) Coarse albite-pegmatite isolating hornblende-gneiss. Height: 1 ft. 6 in. High boss, 200 yards north-west of road-fork at Clegir-mawr.

(Plate 42) Late olivine-dolerite Dyke. Henborth, Holy Isle.



(Plate 20) Isoclinal folding with small-scale thrusting. Salt Island, Holyhead.

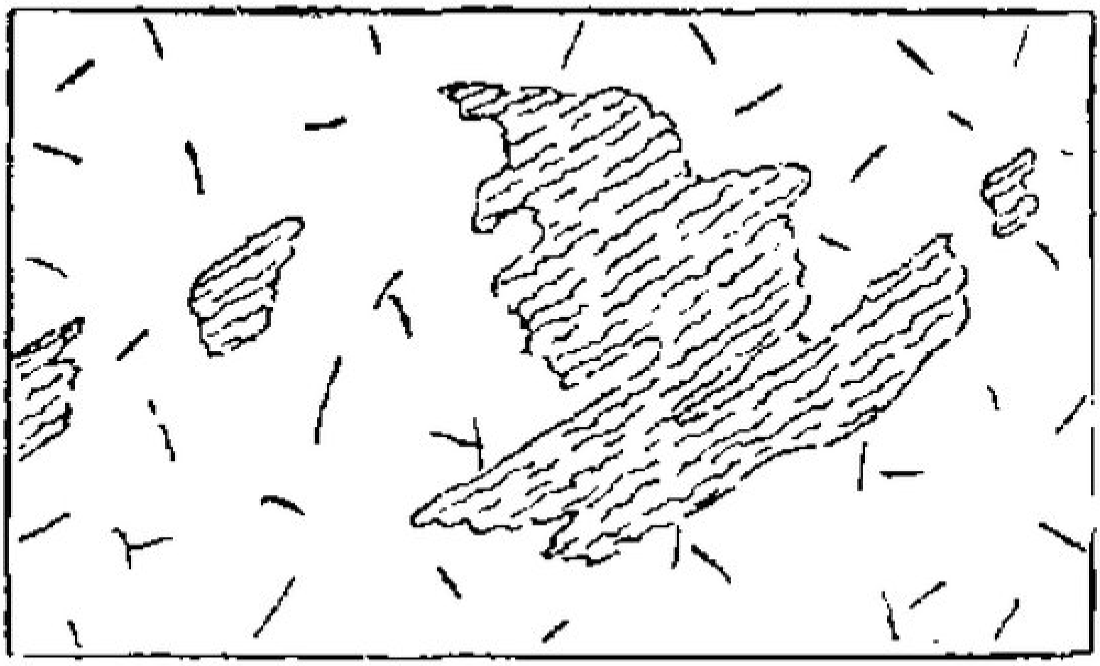


FIG. 19.

(Figure 19) Inclusions (up to two feet in length) of gneiss in albite-granite. About 330 yards east-north-east of Llandrygarn Church.

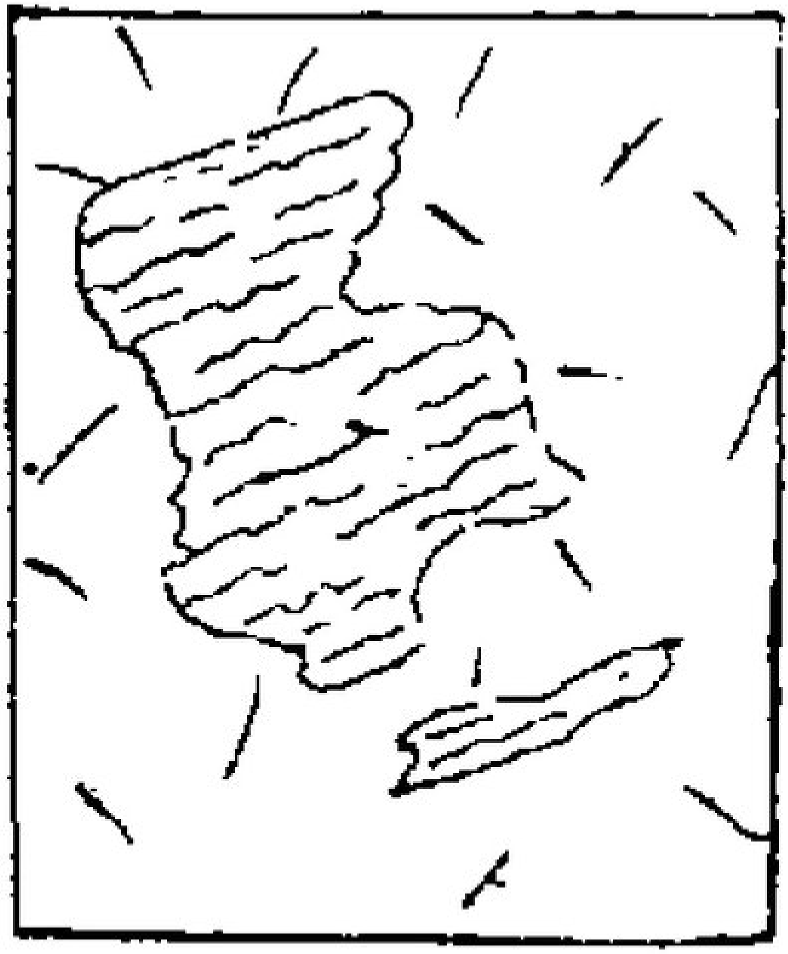


FIG. 20.

(Figure 20) Inclusions (up to two feet in length) of gneiss in albite-granite. About 330 yards east-north-east of Llandrygarn Church.

(Plate 15) The Banded Gneisses. Henblâs, Llandrygarn.

FIG. 21.

(Figure 21) One-foot granitoid band cutting thin granitoid bands North-east of Henblâs.

(Plate 14) Micaceous gneiss with knots of albite-granite. Coast of the Gader Inlier at the Fox's Den.

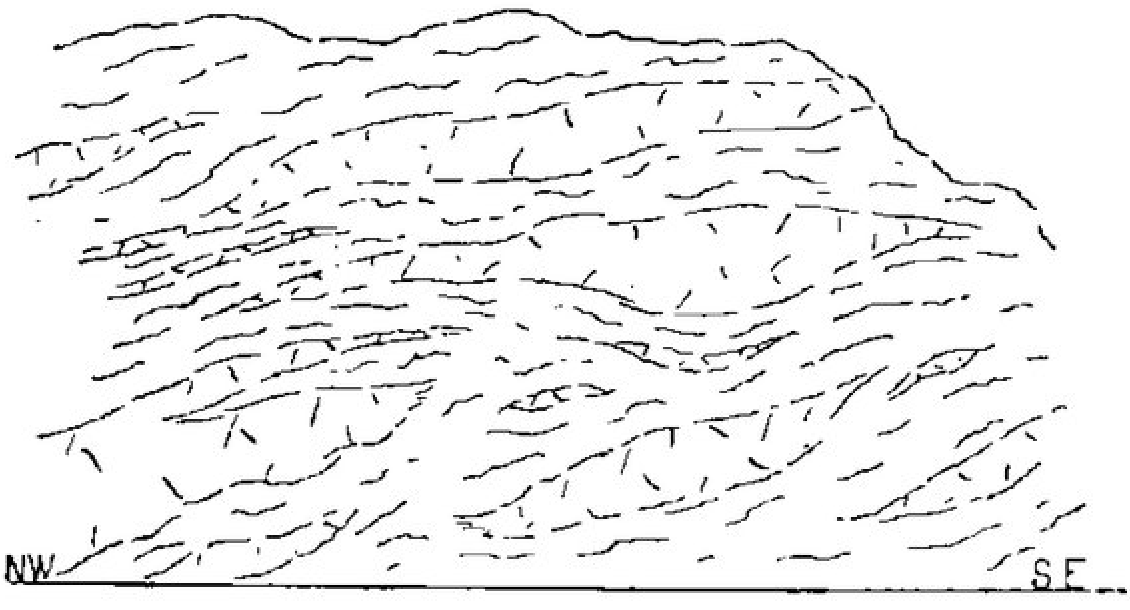


FIG. 22.

(Figure 22) Granites in gneiss. Coast of the Gader Inlier. Height, about three feet.

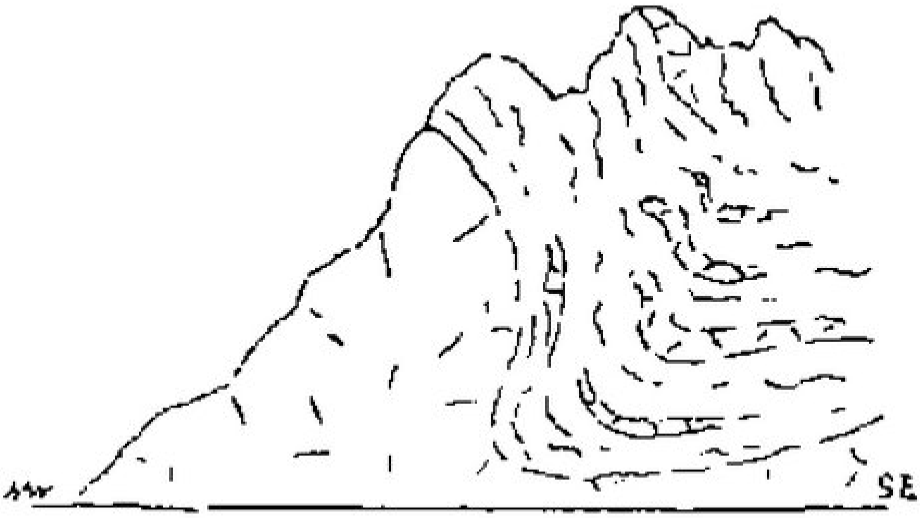


FIG. 23.

(Figure 23) Granite in gneiss. Coast of the Gader Inlier. Height, about two feet.

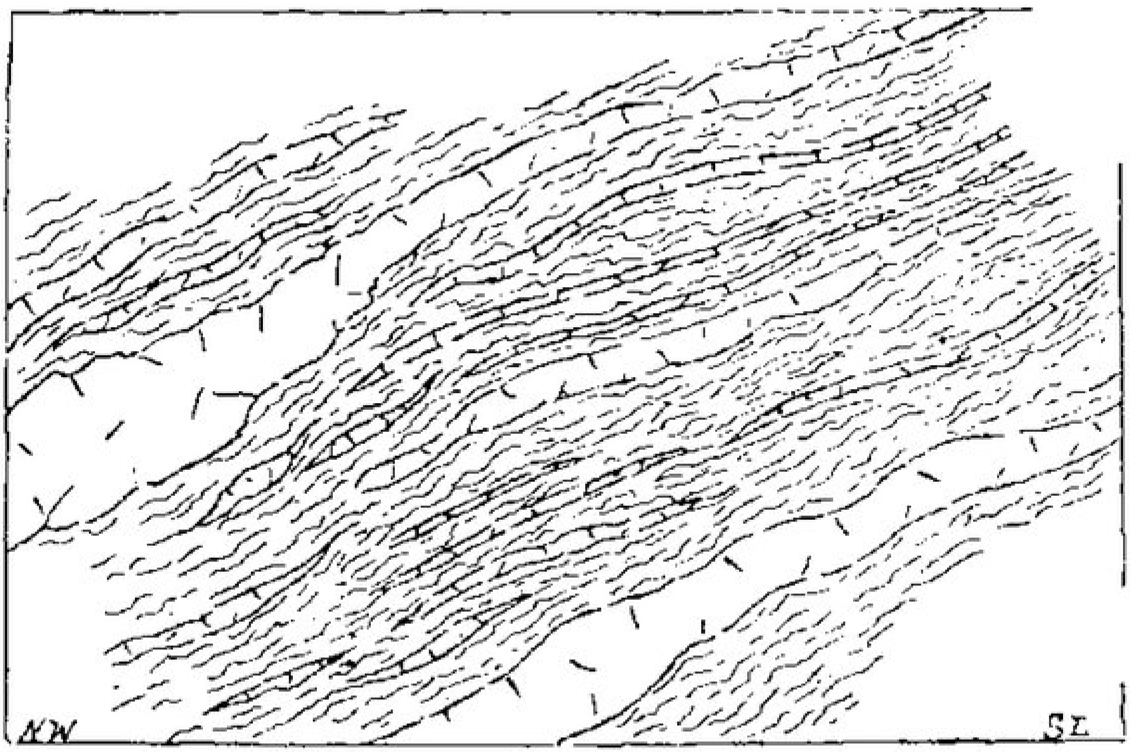


FIG. 24.

(Figure 24) Gneiss with lenticular albite-granites. Gwyndy crags. Height, two feet.

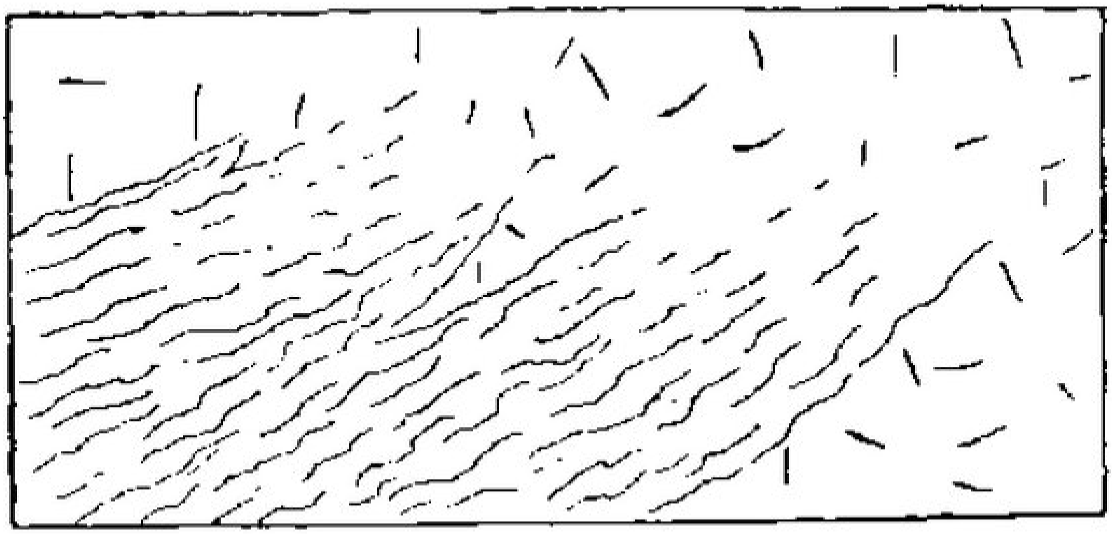


FIG. 25.

(Figure 25) Passage of gneiss into albite-granite. Gwyndy Crags.

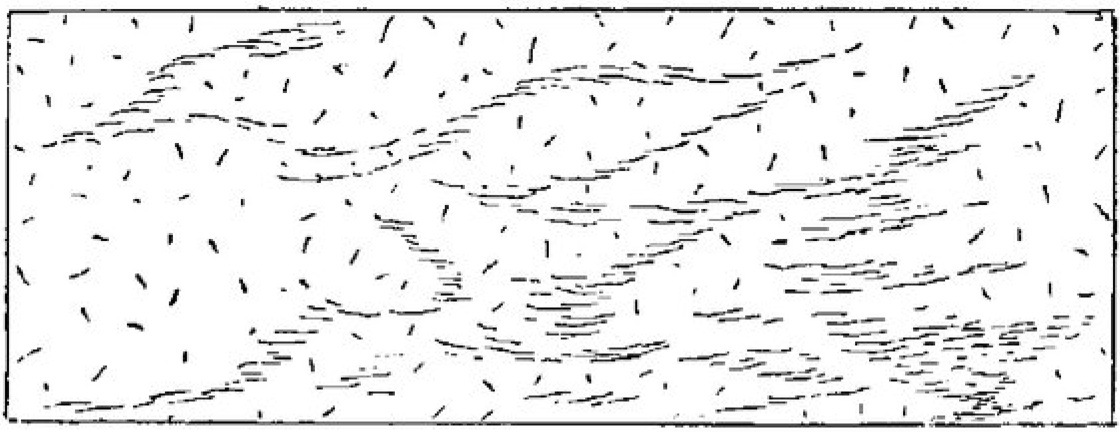


FIG. 26.—FILMS OF GNEISS IN GRANITE.

(Figure 26) films of gneiss in granite. Coast of the gader inlier. Plan 18 inches long.

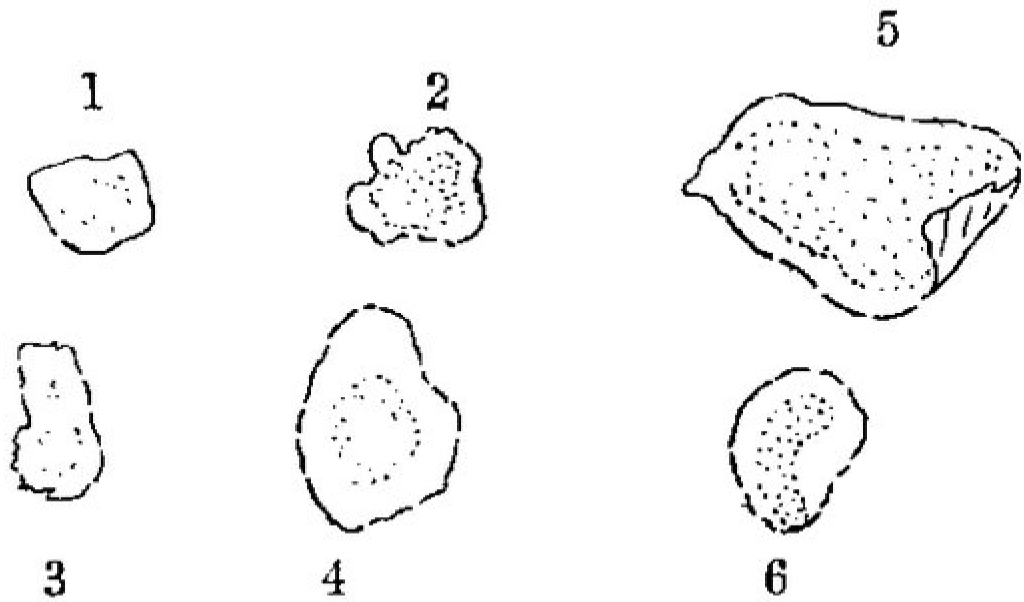


FIG. 27.

(Figure 27) Rejuvenated albites. 1, 2, 3, 4 from (E10151) [SH 241 829] 5, 6 from (E10131) [SH 217 805].