Chapter 7 C — Pre-Torridonian intrusive rocks associated with the Lewisian Gneiss

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Ultra-basic dykes; basic dykes and sills; microcline-mica dykes; biotite-diorite dykes; granite and gneissose granite dykes and sills; pegmatites.

Dykes and sills of later date than the Fundamental Complex are extensively developed in certain regions. These belong to three periods — (1) pre-Torridonian; (2) post-Torridonian and pre-Tertiary; (3) Tertiary. The post-Torridonian intrusions are insignificant in amount. They include porphyrites and other rocks of the same age as the post-Cambrian intrusions of the Assynt district, and also Tertiary dolerites. These rocks will not be described in the present chapter.

The pre-Torridonian intrusions include ultra-basic rocks of the picrite type, dolerites (diabases), granites, pegmatites, and various schistose or massive rocks which have resulted from the modification of these types. These rocks will now be described.

I Ultra-basic dykes

A few dykes of ultra-basic composition occur in the area represented in Sheets 101 and 107. The least-altered rocks are dark in colour, massive in texture, and mainly composed of olivine and augite, together with a certain amount of reddish-brown biotite, magnetite, and a basic felspar. A specimen from a dyke occurring 1 mile N.N.E. of Little Assynt, near the outlet of Loch Assynt (S3307) [NC 160 255], (S8123) [NC 169 249], may be taken as a type. It is remarkable for the occurrence of conspicuous individuals it a green or yellowish-green pyroxene, often measuring ¼ inch across. At first sight this mineral appears to form porphyritic crystals in a dark, fine-grained matrix; but on closer examination it is seen that it occurs in irregular patches rather than as distinct idiomorphic crystals. This augite contains chromium.

Under the microscope the two chief constituents are seen to be olivine and augite. The olivine occurs in rounded grains and more or less idiomorphic crystals varying from about 0.5 to 1 mm in diameter. The actual olivine-substance is colourless or nearly so; but it frequently contains a large number of very minute inclusions which give a cloudy aspect to the mineral when viewed under low powers. In addition to these minute inclusions, there are also the usual anastomosing strings of magnetite. In the type-specimen there is no trace of serpentinisation, but wherever the olivine is in contact with felspar there is a narrow zone, about 0.02mm in width, of a pale green mineral. The nature of this mineral cannot be determined with absolute certainty, owing to the narrowness of the zone and the overlapping of the individuals, but from what is known of similar occurrences there can be little doubt that it is hornblende.

The augite is nearly colourless in thin section, showing only a faint greenish or brownish tint. When, as frequently happens, two individuals abut against each other, the boundary line is irregular; but when an individual is in contact with felspar, traces of idiomorphism may sometimes be seen. Twinning is rare. The structure is micro-poikilitic, in consequence of the presence of numerous inclusions of olivine.

The felspar is labradorite or bytownite, and frequently shows twinning on the albite and pericline plans. It is allotriomorphic with respect to olivine and angite, and therefore acts as interstitial matter with reference to the other constituents.

Biotite is present only as an accessory. It occurs as irregular plates which are frequently crowded with opaque inclusions. The colour, in the position of maximum absorption, is a deep reddish-brown. Magnetite is almost entirely confined to the olivine; but it occurs occasionally as independent idiomorphic crystals.

This rock evidently occupies a position intermediate between olivine-gabbro and peridotite. It contains more felspar than a typical picrite, but this difference seems scarcely sufficient to justify the introduction of a new term. The large amount of

olivine sharply differentiates this rock from the non-olivine-bearing dolerites or diabases, of which the basic dykes are so largely composed. The following analysis was made by Mr. Grant Wilson. It agrees with those of typical picrites so far as magnesia is concerned, but contains larger amounts of silica and alumina:

SiO_2	46.23
Al_2O_3	6.3
Fe_2O_3	4.3
FeO	7.07
MnO	0.33
CaO	6.08
MgO	25.13
K_2O	0.33
Na_2O	1.08
Loss on ignition	3.78
	100.63
Sp. gr.	3.04

Another specimen gave sp. gr. 3.13. Chromium was found to be present in the pyroxene, but only in small quantity. It was not estimated in the bulk-analysis.

Picrite dykes of the above type occur on the south side of Loch Assynt and near Brackloch, about two miles on the road from Loch Inver to Inchnadamff. But the dyke at Brackloch (S3310) [NC 119 239] is more altered: It differs principally in the fact that the place of the felspar is almost entirely taken by fibrous aggregates of a colourless or pale green fibrous hornblende. A distinct zonal arrangement of this hornblende with reference to the still comparatively fresh olivine may be seen, the axes of the fibres being arranged more or less at right angles to the surfaces of the adjacent olivines. Owing to this arrangement the intervening spaces, originally occupied by felspar, break up into fields bounded by lines due to the interference of fibres which have grown outwards from the neighbouring olivines. The narrow zones which surround the olivines, in the least-altered rocks, are still recognisable; a fact which proves that they correspond to an original zoning and do not simply represent the initial stages of the process by which the felspar substance has been replaced by secondary minerals. The olivine in this specimen shows the commencement of serpentinisation.

Another specimen (S4466) [NC 119 239], also from Brackloch, shows a further increase in the amount of alteration, accompanied by the development of carbonates; while a third (S2937) [NC 068 235] is composed entirely of secondary minerals, with the possible exception of some magnetite. This rock deserves a more detailed description. It is medium-grained, greenish-grey, and massive. The most conspicuous mineral, under the microscope, is a colourless hornblende, more or less idiomorphic in the prismatic zone, but always having ragged terminations. It is irregularly distributed in an aggregate of pilitic hornblende and chlorite. Here there is evidence of the conversion of a rock, originally composed of olivine, augite, felspar, and magnetite, into an aggregate of hornblende, chlorite, and magnetite. The original structure is not entirely lost in the process, for the forms of the olivines may occasionally be recognised in pseudomorphs of pilitic hornblende and chlorite. The fact that olivine has been replaced by pilitic hornblende and chlorite is probably due to interchange of material between that mineral and felspar.

A specimen from one of the dykes on the south side of Loch Assynt (S3048) [NC 235 233] shows the more common type of alteration into serpentine, and it is worthy of note that in this case no felspar is recognisable. A somewhat similar rock (S3947) [NC 320 134] in which the serpentinising process has been carried still further occurs as a dyke in the thrust gneiss on the south side of Sgonnan Mhor, 6½ miles south-east of Inchnadamff, Assynt (1-inch Sheet 102).

The comparatively unaltered rocks belong, with one or two doubtful exceptions, to the picrite group; but the altered rocks are often so completely changed, both in structure and composition, that it is impossible to speak confidently as to their original character. A specimen from a dyke at Loch-nan-Eun, one mile north-east of the bridge at Loch Inver (S3960) [NC 108 238], is composed of grains of olivine in a matrix of chlorite and hornblende, with magnetite as an accessory. The chlorite is nearly colourless and shows only the faintest traces of pleochroism in greenish and brownish tints. Under crossed nicols it polarises very much as felspar, and its resemblance to that mineral is still further increased by the

presence of lamellar twinning. A similar chlorite has been described by Patton<ref>*Min. u. petr. Mitth.,* 1888, v. 89.</ref> in a bronzite-tremolite-chlorite rock, associated with serpentine, near Marienbad in Bohemia.

The rocks above referred to are all massive, but the dykes to which they belong furnish examples of every gradation from massive rocks to the most perfect schists. A series taken from a dyke occurring on the sea-shore south of Loch-na-h-Irinne, about 3½ miles north-west of Loch Inver (S2938) [NC 048 263], (S2939) [NC 048 263], (S2940) [NC 048 263], (S2941) [NC 048 263], (S2942) [NC 048 263], (S2943) [NC 048 263], illustrates this passage. The northern edge of the dyke is little, if at all, foliated; but from about the centre to the extreme southern edge the alteration increases progressively.

The rocks are dark greenish-grey in colour. The massive variety (S2938) [NC 048 263] is composed of hornblende, biotite (pale brown), chlorite, carbonates (which do not effervesce with dilute acid), and iron-ores. The hornblende occurs in fibrous aggregates, or as small prisms with ragged terminations, forming, with the other constituents, a confused crystalline aggregate in which only faint traces of the original igneous structure are preserved. The most perfect schist (S2942) [NC 048 263] is composed of the same minerals, with the possible addition of talc. Under the microscope slight signs of puckering may be observed. Microscopically the rock is a fine-grained chlorite-schist. The other specimens belonging to the series show different stages in the development of schistosity which appear to have taken place after the alteration of the original rock.

A remarkable example of a schist formed from one of the ultra-basic dykes occurs in the Tombstone quarry, by the roadside near Clach-toll, about 4½ miles north-west of Loch Inver. It is a greenish, silvery schist containing numerous uniformly distributed knots of siderite. These knots measure over ■ in. in diameter, and behave, in relation to the main-mass of the rock, exactly in the same way as the lenticles of felspar in augen-gneiss, or as the garnets in many mica-schists. They consist of single crystalline individuals, notwithstanding their lenticular form. The interior portions are seen to be perfectly colourless in thin sections, but the margins are often stained brown, and the staining sometimes extends along cracks into the interior.

The main mass of the schist is composed of chlorite, talc (?), carbonate, a colourless, rhombic hornblende (anthophyllite or gedrite); and magnetite. The rhombic hornblende occurs in long, slender prisms which lie at different angles in the plane of schistosity and invariably give straight extinction.

The silvery lustre on the planes of schistosity suggests the presence of talc, and the microscopic section indicates the presence of a scaly mineral with high double-refraction. The hydrochloric acid solution contains a large amount of iron and a considerable amount of magnesia, but only traces of lime. The carbonates present must, therefore, be carbonates of iron and magnesia, which are those one would natually expect to find in an altered ultra-basic rock.

II Basic dykes and sills

Between Loch Laxford on the north and Enard Bay on the south the Lewisian gneiss is traversed by an extraordinary number of basic dykes which follow a general north-west and south-east direction. In many places the true dyke-like character of the intrusions is perfectly obvious. More or less vertical walls of black basic rock clearly cut across the gneissose banding (Plate 20). But in other places, owing to movements after or during the injection of the dykes, the dyke-like character is lost, and the rock of the dykes becomes more or less incorporated with the earlier complex.

In the southern area between Loch Maree and the islands of Rona and Raasay, the basic bands rarely, if ever, show the normal dyke-like character, although evidences of intrusion may not unfrequently be found if carefully looked for. It is not improbable that some of these masses were intruded as sills, especially those which are associated with the supposed sedimentary rocks. The rocks of which the dykes are composed vary considerably in mineralogical composition and structure, but would doubtless exhibit, if analysed, much greater uniformity in chemical composition. Three marked types, easily recognisable in the field, occur to which the general terms dolerite (diabase), epidiorite (amphibolite), and hornblende-schist have been applied. The reeks of the first group are essentially composed of labradorite, pyroxene, and magnetite with normal igneous structure; the epidiorites are plagioclase-hornblende rocks, with or without a mineral of the epidote group, and often without normal igneous structure; the hornblende-schists may be briefly described as foliated

epidiorites. All three types shade into each other and may be found in one and the same dyke. Transitions from massive epidiorite to foliated hornblende-schist may take place within the limits of a hand specimen or even a microscopic section.

The rocks to which the general term dolerite has been applied are found on microscopic examination to be more variable in composition than was at first sight supposed. They are dark, medium to moderately coarse-grained holocrystalline rocks belonging to the diabase and gabbro families of Rosenbusch. The Survey collection includes rocks to which the terms diabase, enstatite-diabase, hornblende-diabase, gabbro, hyperite and norite would be applied by that author.

The minerals entering into the composition of these rocks are olivine, enstatite, augite (including diallage), hornblende, biotite, labradorite, and iron-ores. Olivine is usually absent, but occurs in a few specimens. When present it possesses the same characters as those described in connection with the last group of rocks. It contains the same minute inclusions and the same anastomosing veins of magnetite.

Enstatite is more common, but is by no means invariably present. It usually shows a marked tendency to idiomorphism, occurring in prismatic crystals similar in form to those found in the enstatite-andesites. Cross-sections are eight-sided, and the four prismatic faces are less developed than the pinacoids. Longitudinal sections are often terminated by two faces meeting at an obtuse angle. The sections are often colourless, but pleochroism of the common type may sometimes be observed. The above characters are best seen in the rock from a dyke on the north side of Loch Assynt, about 4 miles west of Inchnadamff (S2319) [NC 20 25].

The monoclinic augite is often nearly colourless in thin sections, like the enstatite; but it occasionally shows brown tints, especially at the margins of the grains. Idiomorphism is much less prominent than is the case with the enstatite, and although the typical ophitic structure, so characteristic of the Tertiary dolerites, has never been observed, lath-shaped sections of labradorite do occasionally penetrate individuals of augite, thus giving rise to what may be termed a sub-ophitic structure. In the majority of cases the augite is free from inclusions; but it occasionally contains minute dots and rods like those occurring in the other minerals, and more rarely brown plates, like those of the well known hypersthene of St. Paul. The distinction between augite and diallage is valueless for classificatory purposes, so far as these dykes are concerned.

Green compact hornblende is found not only in the epidiorites but also in the rocks with true igneous structure. It usually occurs on the margins of the augite, and may be either idiomorphic or allotriomorphic with respect to labradorite.

Biotite is usually present, but never in any quantity. It occurs as reddish-brown scales, often in association with iron-ores.

The plagioclase-felspar may occur as broad laths, as irregular grains, or as large individuals which behave as a matrix in which the other constituents are embedded. Interstitial labradorite is especially characteristic of the rocks rich in enstatite, and lath-shaped labradorite of those which contain only monoclinic pyroxene.

When the powder of a rock is placed in a diffusion column the felspar concentrates at a level corresponding to sp. gr. 2.69. This observation was made on two specimens, in one of which the mineral was allotriomorphic, and in the other idiomorphic with respect to the pyroxenes. It agrees with the optical determinations, and proves that the dominant felspar is labradorite; but, as zonal structure may occasionally be observed, there are doubtless slight deviations from the type. In some of the specimens the felspar appears. cloudy under low powers in consequence of the presence of extremely minute dots and rods similar to those seen in the other minerals (Plate 47), Fig. 2. The presence of these inclusions in olivine, augite, and labradorite, but not in all three minerals in one and the same rock, points to the conclusion that they are original products of the magma. But if so, they must have existed only at special stages in the consolidation, and must have been liable to resorption during the later stages when they occur only in the earlier-formed minerals.

Two or three varieties of rock will now be briefly described. The most common type is represented by a specimen (S8627) [NC 265 241] from the hill-slope above the lowest Chalda Loch, about 1½ mile northeast of Inchnadamff. It is a medium-grained, black, massive rock composed of more or less lath-shaped labradorite, nearly colourless augite, and a very small amount of magnetite or ilmenite. Compact green hornblende and biotite also occur, btit only as accessories. Some of the pyroxene grains and the marginal portions of others show a kind of micrographic structure under crossed nicols, as if they were formed of an intergrowth of two minerals — possibly augite and enstatite. This rock is a dolerite or

diabase. The structure is represented in (Plate 47), Fig. 1. Closely allied rocks occur ¾ mile S.S.E. of Ben Dreavie, a hill 1¾ mile S.S.W. of Ben Stack, east of Ruadh na Moine, on the south shore of Loch Assynt, one mile north-west of Inchnadamff (S3103) [NC 235 232], north of Creag-a-Mhhail, one mile north-west of Scourie, and doubtless at many other localities in the central area. This type frequently passes over into epidiorite and hornblende-schist. In some of the rocks above-mentioned the lath-shaped form of the felspar is less marked than in the rock- selected as a type, and the augite takes on the characters of diallage. Such rocks may be called gabbros. They appear to be especially characteristic of the central portions of the broader dykes (S2944) [NC 145 458].

Another type of rock is characterised by the presence of enstatite. A good example of this type occurs near Tomore Lodge on the north shore of Loch Assynt (S3042) [NC 1 2], (S3043) [NC 1 2], (S3044) [NC 1 2].

The rock from the centre of the dyke shows lustre-mottling (macro-poikilitic structure) due , to irregular individuals of labradorite measuring half-an-inch or more across. Both enstatite and augite are colourless, except at the edges, where they are sometimes brown and pleochroic. The former is more abundant than the latter and markedly idiomorphic. In this specimen there is an entire absence of diabasic structure; but in another from the same dyke (S3044) [NC 1 2], taken between the centre and the edge, the labradorite shows a distinct tendency to take on the lath-shaped form. The interstitial character of the labradorite in the rock from the centre of the dyke, coupled with the idiomorphism of the enstatite, differentiates this rock from the norites and hyperites, but the differences are scarcely sufficient to justify the introduction of a new term. It is therefore a basic hyperite; while the rock with lath-shaped labradorite may be termed enstatite-diabase. Both rocks contain iron-ores and a very small amount of green hornblende and biotite. This dyke shows a passage into epidiorite (S3040) [NC 1 2]. Examples of hyperite or enstatite-diabase occur also on the West side of Loch-an-Ruighein (S2318) [NC 154 267], about one mile north of Little Assynt.

The rocks above referred to are either free from olivine or contain only an occasional grain; but a specimen from the dyke already cited from the north side of Loch Assynt, about 4 miles west of Inchnadamff, contains this mineral in abundance (S2319) [NC 20 25]. It is essentially composed of olivine, enstatite, and interstitial labradorite. The olivine is precisely similar to that of the picrites, and contains the whole of the magnetite present in the rock. The enstatite is colourless and idiomorphic ((Plate 48), Fig. 1). The rock may be termed olivine-norite, but the structure is not that of a typical norite, owing to the interstitial character of the felspar. Its specific gravity is 3.16. The abundance of olivine links this rock with the picrites.

The rocks which remain to be described under this head all contain green hornblende. At the one end we meet with true igneous structure in which the hornblende appears to be original (hornblende-diabase and hornblende-gabbro); at the other end the rocks show no igneous structure and pyroxenes are entirely absent (epidiorites or amphibolites).

A dyke from Loch a' Chroisg, 4½ miles S.S.W. of Inchnadamff, Assynt, which will be subsequently referred to as illustrating passage-forms between diabase and epidio'rite, furnishes a good example of hornblende-diabase ((S2745) [NC 215 159] and (Plate 47), Fig. 2). This specimen is composed of lath-shaped plagioclase, augite, enstatite, ophitic green hornblende, and iron-ores. The hornblende is compact, and does not appear to have originated from the pyroxene. The labradorite is quite fresh, but the central portions of the individuals appear turbid in consequence of the presence of minute inclusions. A similar rock occurs at Con a' Chreag, Loch Glen Coul, 1¾ miles south-east of Kylesku (S2759) [NC 26 29].

The epidiorites are essentially plagioclase-hornblende-rocks, but sometimes contain also a mineral of the epidote group, together with quartz, iron-ores, and granular sphene Often zoning the iron-ore.

They may be roughly separated into two groups according to the presence or absence of the structure characteristic of the gabbros, diabases, and hyperites. In those of the first group (*a*) the lath-shaped or interstitial character of the felspar-sections is in most cases well marked, and the characteristic inclusions so common in the felspars of the diabases are often present. The hornblende is of two types. There is the compact green hornblende, similar to that of the hornblende-diabases, and also the fine-grained and sometimes fibrous aggregates which appear to eat into and finally destroy the original augite. Cores of augite may frequently be detected in the centres of these hornblende-aggregates. A little interstitial quartz is often present.

Examples of this type occur on the north side of Scourie Bay (S2371) [NC 14 45], at Con a Chreag, Loch Glen Coul (S2760) [NC 26 29], about half-way' down the north side of Loch Assynt (S2935) [NC 213 250], and half a mile northwest of the Falls of Kirkaig, Assynt (S3907) [NC 109 186]; doubtless, also, in many other localities.

The typical rocks of the second group (b) of epidiorites are devoid of igneous structure. They are essentially composed of plagioclase and hornblende, with which some quartz and a mineral of the epidote group are often associated. The felspar occurs as irregular grains or in large ophitic patches; sometimes as granulitic aggregates. It is in general more allied to albite than the felspar of the pyroxenic rocks. Not unfrequently it is crowded with minute prisms and grains of epidote, thus forming the typical saussurite of Cathrein. Under these circumstances it is either albite (S2933) [NC 213 250] or some closely allied felspar. The hornblende may be. either pale or dark green. It occurs as spongy aggregates enclosing rounded grains of quartz, as compact irregular individuals, and as aggregates with ragged outlines from which prisms often jut out into the surrounding felspar. Detached grains and prisms often occur as inclusions in the felspar.

Biotite and iron-ores zoned with colourless granular sphene are frequently present (Plate 48), Fig. 2

Epidiorites of this type are extremely common in the central area, and may be obtained from almost any of the basic dykes. The collection of the Geological Survey contains good examples from the roadside at Loch na Bruthaich, Strath Croy, 2½ miles north-east of the village of Stoer (S3948) [NC 073 316], (S3949) [NC 073 316]; from Eas Dubh on the Ullapool River, 1■ miles north-east of Ullapool (S3067) [NH 152 954], (S3068) [NH 147 953]; and from the north side of Loch Assynt, 5¼ miles north-west of Inchnadamff Church (S3041) [NC 1 2], (S3040) [NC 1 2].

The massive epidiorites frequently pass into foliated rocks. These may be either typical hornblende-schists or rocks intermediate between epidiorites and hornblende-schists, which may be termed foliated epidiorites. Hornblende and felspar are the principal constituents. Iron-ores and granular sphene are usually present; epidote and quartz are occasionally found.The powder of one of the typical hornblende-schists from the broad dyke crossing Ben Stack, north of Achfarry (S2727) [NC 295 401], was placed in a diffusion column. The hornblende concentrated at a level corresponding to a specific gravity of 3.19–3.2; the felspar at a level corresponding to 2.69–2.7. The felspar of this rock, like that of the dolerites, is, therefore, labradorite; but its mode of occurrence is entirely different. It is present in the form of untwinned, often water-clear grains resembling quartz. In those rocks which contain epidote the felspar is albite or some closely allied variety.

Amongst the accessory constituents of the foliated rocks iron-ores and sphene deserve special mention. Where both are present the sphene takes the form of colourless granular aggregates in the centres of which one or more grains of iron-ore may be observed. Sometimes the iron-ore predominates, and the sphene merely form$_s$ a narrow zone; at other times the sphene predominates, and only one or two specks of iron-ore can be recognised. The deforming stresses by which the foliation has been produced have exercised considerable influence on the aggregates of sphene and iron-ore. They are sometimes in the form of thick lenticles; at other times they have been so dragged out as to be represented only by trains of small granules.

The distribution of hornblende and felspar in the rocks is worthy of special note. In many cases the minerals are not uniformly scattered through the rocks. Lenticular aggregates of granulitic felspar, or of felspar and epidote, alternate with others of hornblende. This is no doubt due to the coarse-grained character of the original rock. Aggregates have taken the place of large individuals; but the grains, formed at the expense of a large individual, have held together, so that the structure of the original rock has affected that of the schist, although the outlines of the folia are quite distinct from those of the original minerals. This peculiarity in the distribution of the two principal constituents is especially marked in those rocks which occupy an intermediate position between the massive epidiorites and the typical hornblende-schists. In the latter rocks it is not recognisable.

A specimen from the Ben Stack dyke, already referred to, may be selected as a type of the more perfect schists. It is a dark, medium-grained rock bounded by two more or less flat surfaces which correspond to the principal planes of schistosity. It shows a marked linear foliation. Three sections have been prepared from this specimen; one parallel to the principal planes of schistosity, another at right angles to these planes and parallel to the direction of stretching, and a third at right angles to this direction. A comparison of these sections shows that although the hornblende rarely exhibits

traces of idiomorphism the individuals are more or less elongated in the direction of their vertical axes, and roughly arranged with their longest diameters parallel to the direction of stretching. The preparation at right angles to the direction of stretching abounds in sections which show the characteristic cleavages meeting at angles of 124°, whereas such sections are rare in the other two preparations. The colour scheme for the hornblende is X greenish yellow, Y green, Z green with a tinge of blue.

The felspar (labradorite) in this rock occurs in the farm of untwinned grains, usually of equal dimensions in the different directions. It is partly water-clear and partly turbid in consequence of the development of minute overlapping scales of a micaceous mineral. Iron-ores and sphene occur as accessories.

A specimen from the dyke ¼ mile north-west of Loch a' Chroisg, 4½ miles S.S.W. of Inchnadamff, Assynt ((S2747) [NC 215 159], (Plate 48), Fig. 2), may be taken as a type of one of the less perfect schists (schistose epidiorite or amphibolite). It is a medium-grained rock, with a trace of linear foliation, composed of granulitic felspar, a mineral of the epidote-zoisite group, pale-green hornblende and granular sphene. The figure is taken from a section at right angles to the direction of linear foliation, so that the parallel structure is not strongly marked.

The principal types of rock occurring in the basic dykes have now been described at sufficient length, and it remains only to give some account of the mode of association of the different types. The transition from dolerite (diabase) to epidiorite and hornblende-schist was first observed in the case of the dykes occurring on the north side of Scourie Bay and running south-eastwards to Loch a'Bhaid Daraich.<ref>The metamorphosis of Dolerite into Hornblende-schist, by J. J. H. Teall, *Quart. Jour. Geol. Soc.,* 1885, pp. 133–145. See also *British Petrography,* Plates xix and xx.</ref> They may be picked up again on the south side of the loch and followed for a considerable distance towards the south-east.

The least-altered rock is a typical diabase with sub-ophitic structure composed of labradorite, augite, titaniferous magnetic iron-ore, apatite, and some secondary products including hornblende (scarce), chloritic minerals, and quartz. At the other extreme is a typical hornblende-schist essentially composed of hornblende, felspar, iron-ore, sphene, and apatite. The two most extreme types were analysed with the following results:

	I	II
SiO_2	47.45	49.78
TiO_2	1.47	2.22
Al_2O_3	14.83	13.13
Fe_2O_3	2.47	4.35
FeO	14.71	11.71
MnO	—	0.27
CaO	8.87	8.92
MgO	5.00	5.40
K_2O	0.99	1.05
Na_2O	2.97	2.39
CO_2	0.36	0.10
H_2O	1.00	1.14
	100.12	100.46

I — Diabase from dyke north side of Scourie Bay. P_2O_2 and S (in FeS_2) were not estimated. The P_2O_5 is therefore reckoned with the Al_2O_3. Three specific gravity determinations made on different samples gave 3.106, 3.105, and 3 086.

II — Hornblende-schist from the same dyke. The specific gravities of two specimens were found to be 3.111 and 3.122. Both analyses by Teall.

The two analyses show a very close general agreement. No general conclusions can be drawn from the slight differences which exist.

Between the two extreme types of rock, occurring in one and the same dyke, many intermediate varieties may be observed. The replacement of the pyroxene by hornblende can be followed stage by stage, and as it becomes more and

more pronounced the typical igneous structure is lost. The change first affects the peripheral portions of the pyroxene-grains and works its way inwards until no trace of the original mineral remains. The labradorite loses its lath-shaped character and takes the form of aggregates of irregular grains which are, in many cases, entirely destitute of twin lamellation. In this particular dyke the development of epidote or zoisite has not been observed, so that the felspar of the epidiorite, like that of the diabase, is labradorite. Some quartz has made its appearance in connection with the amphibolitisation of the pyroxene.

At Creag a' Mhail, the promontory on the north side of Scourie Bay, and at the small bay about ¼ mile to the east of this point, both gneiss and dyke are traversed by narrow zones of secondary disturbance (see Sheet 107). At both these localities the passage from massive epidiorite to hornblende-schist is well displayed.

The dyke which runs along the north shore of Loch Assynt ¾ ths of a mile E.S.E. of Tomore and 5¼ miles north-west of Inchnadamff Church has already been referred to. A series of specimens ((S3040) [NC 1 2]-(S3045) [NC 1 2]) has been collected from this dyke. The centre of the mass is a basic hyperite with interstitial labradorite; nearer the margin it becomes an enstatite-diabase with lath-shaped labradorite. Two other specimens ((S3040) [NC 1 2], (S3041) [NC 1 2]), probably from the central portions, are typical epidiorites or amphibolites, with saussuritic aggregates of epidote and a water-clear felspar belonging to the albite-oligoclase series. None of these specimens is foliated. This dyke is interesting as proving that the rocks with enstatite furnish epidiorites of the same type as those which arise from the alteration of the diabases.

Another series of specimens (S2741) [NC 214 157], (S2742) [NC 215 159], (S2743) [NC 215 159], (S2744) [NC 215 159], (S2745) [NC 215 159], (S2746) [NC 215 159], (S2747) [NC 215 159], (S2748) [NC 215 159], (S2749) [NC 215 159], (S2750) [NC 215 159] was collected from a dyke ¼ mile north-west of Loch a' Chroisg, Assynt. The least-altered rocks (S2742) [NC 215 159] and (S2745) [NC 215 159] are hornblende-diabases. The other specimens are either massive epidiorites or foliated rocks of the type intermediate between epidiorites and hornblende-schist. There is in this dyke a marked difference in the coarseness of the grain between the central and marginal portions; but both the coarse and the fine-grained varieties have been converted into epidiorites. Apart from variations in the grain and the frequent changes from diabase to epidiorite the dykes are, as a rule, fairly homogeneous in composition. There are no marked differences depending on variations in the relative proportions of the ferromagnesian and felspathic constituents. The central portions of this dyke do, however, show, a want of homogeneity similar to that so frequently seen in the rocks of the fundamental complex, but on a much smaller scale. This is illustrated by one of the epidiorites in the above series (S2746) [NC 215 159] in which irregular patches of black rock shade into others of a lighter colour, much richer in saussurite. Acid segregations, such as are occasionally seen in large masses of dolerite (*e.g.,* Stirling Castle Rock) appear to be extremely rare. One such case has, however, been observed by Mr. Peach. It occurs in a broad dyke about mile north-west of the Falls of Kirkaig, Assynt (S3905) [NC 109 186], (S3906) [NC 109 185], (S3907) [NC 109 186], (S3908) [NC 109 186]. The least altered rock is an enstatite-diabase (S3908) [NC 109 186]. The acid masses which occur in the centre of the dyke are coarse-grained aggregates of alkali-felspar, quartz, biotite, hornblende, and epidote.

So far, reference has been made only to the basic dykes of the central area, where the dyke-like character of the intrusion is often obvious, and where pyroxenic rocks with true igneous structures are not uncommon. In the southern area, basic igneous rocks are equally abundant, and many of these are certainly of later date than the fundamental complex; but the original character of the intrusion is often obscure: pyroxenes of the types found in the central area have not been recognised, and true igneous structures are rare.

The massive rocks are amphibolites (epidiorites), and the foliated rocks are either hornblendic or actinolitic schists.

Broad bands of basic igneous rock are associated with the supposed sedimentary beds both on the north-east and south-west sides of Loch Maree (Sheets 91 and 92). These include massive epidote-amphibolites or epidiorites similar to those occurring in the dykes of the central area (S3746) [NG 851 718], schistose varieties of the same rock (S4995) [NG 790 835], (S5491) [NG 905 769], hornblende-biotite schists (S4786) [NG 952 730], (S5489) [NG 902 770], (S5487) [NG 904 772], fine-grained platy actinolite-schists (S4996) [NG 792 822], (S3746) [NG 851 718], and chlorite-schist (S3747) [NG 808 774].

The broad belt of hornblende-schist about two miles north of Letterewe, Loch Maree, contains bands and lenticles of saussurite, composed of a mineral of the epidote-zoisite group and a turbid substance representing felspar (S4423) [NG 95 71]. The centre of one of these lenticles contains numerous crystals of blue tourmaline (S6341) [NG 95 71]. Tourmaline is a rare mineral in the Lewisian gneiss, and its occurrence in this rock is therefore of exceptional interest. Mr. Clough observed it also in pegmatite veins penetrating the hornblende-schist, and in one case it was found to be associated with quartz and axinite. This district appears to have been slightly affected by boracic acid exhalations similar to those which have so profoundly modified the rocks in certain parts of Cornwall.

In addition to the broad sill-like intrusions above referred to, there are also innumerable smaller bands associated with the true archasan gneisses. In the descriptions of the field-relations of these rocks it has been proved that they represent masses of basic igneous rock intruded into the fundamental complex, and that some of them exhibit dyke-like relations to the surrounding rocks. The majority are hornblende-schists, but they include also massive epidiorite, some of which show traces of felspar-phenocrysts (S3744) [NG 812 718], (S4193) [NG 813 640].

Near the centre of the district, south of Poole we, in which Mr. Clough has proved the existence of a kind of anticlinal structure in the arrangement of the dyke-like masses, the hornblende-schist is linearly foliated, parallel with the pitch of the folds. This is well seen in a specimen from a point ■ mile north of Meall an Spardain (S4434) [NG 856 766]. The rock is essentially composed of green hornblende and a somewhat basic oligoclase. Quartz and a few grains of colourless sphene are also present. Two sections have been prepared; one parallel to the direction of foliation, the other transverse (Plate 49), Figs. 1 and 2. A comparison of the two shows that the individuals of hornblende, though irregular in outline, are arranged with their vertical axes approximately parallel with the direction of foliation, and consequently with the pitch of the folds in the district. The grains of oligoclase are irregular in outline and of approximately equal dimensions in the different directions.

The rock has not been subjected to mechanical deformation since the formation of the existing minerals. There are no signs of cataclastic action. These facts prove that the rock was either intruded during movement and consolidated in its present form, or that a previously formed rock was entirely recrystallised under the influence of the stresses which produced the "rodded" or "mullion-structure" of the district.

III Microcline-mica dykes

In addition to the ultra-basic and basic dykes there are a few others of peculiar composition. A specimen from Creag Tombaca, Glen Dhu, 1½ mile E.S.E. of Kylesku (S2734) [NC 255 333], may be selected as a type of a group having affinities with mica-traps. It is a massive purplish rock. The rough surface shows large, irregular cleavage planes of felspar, the lustre of which is interrupted by inclusions of biotite. The constituents are microcline, biotite, hornblende, calcite, quartz, sphene, apatite, and iron-ores.

Microcline is abundant, and occurs in irregular patches which give uniform extinction over large areas. It often appears cloudy under a low power in consequence of the presence of minute inclusions, amongst which scales of hematite may be recognised. Biotite occurs in very irregular plates, and contains numerous indeterminable inclusions. The hornblende, which is rare, is pale green in colour and idiomorphic in the prismatic zone. Calcite occurs in irregular grains. Apatite is abundant, and occurs either as thick hexagonal prisms or as fairly large grains which are frequently arranged in groups. Sphene is present in the granular form. Iron-ores are represented by the inclusions of hematite in the felspar and by a few opaque grains. Both in structure and composition this rock has affinities with the mica-traps.

Another specimen (S3242) [NC 224 349] from a point half a mile north-east of Kyle Strome, near Kylesku, while agreeing in a general way with the one just described, presents some interesting points of difference. It is slightly schistose, and most of the felspar occurs in the form of untwinned grains in association with quartz. A few large individuals, often crowded with small scales of hematite, are present, and these show microcline-structure. Iron-ores in the form of irregular opaque patches are more abundant in this rock than in the one above described, and numerous green grains, which are either pyroxene or hornblende, are also present.

Two other specimens, one from Maldie, 1½ mile east of Kylesku (S3863) [NC 251 342], and another from a point two-thirds of a mile E.S.E. of Unapool (S2732) [NC 246 324], belong to this group, although the characters are not so well preserved as in the specimens above referred to.

Another specimen from Creag Tombaca (S2733) [NC 255 333] is a fine-grained, dark, purplish schist composed of alkali-felspar, quartz, biotite, calcite, apatite, and sphene. The micro-structure is that of a typical crystalline-schist.

From the foregoing descriptions it follows that the massive rocks of this group are related in composition and structure to minettes, from which they differ mainly in containing microcline instead of orthoclase. Like most of the other arcluean dykes found in the Lewisian Gneiss they are liable to pass over into crystalline-schists.

IV Biotite-diorite dykes

A remarkable variety of biotite-diorite occurs at Allt-a-Mhullin, two miles S.S.W. of Loch Inver (S3959) [NC 084 204]. The rock is black, and shows lustre-mottling or macro-poikilitic structure in a most marked manner. The mineral which forms the substratum of the rock is a glassy plagioclase belonging to the oligoclase-andesine series (sp. gr. 2.65–2.66). Cleavage faces of this mineral often measure an inch or more across. The individuals are irregular in outline, and interlock with each other in such a way that if the other constituents could be removed, a spongy mass of felspar would remain possessing the form of the original specimen. Under the microscope the felspar is seen to be quite fresh, though often crowded with extremely minute inclusions. The other minerals are hornblende, biotite, iron-ores, and apatite.

Hornblende appears in two forms — brown and green. The brown variety occurs in crystals and irregular patches, often rendered nearly opaque by inclusions of iron-ore. It is deeply coloured and strongly pleochroic. The great variety forms either compact grains or fibrous aggregates. It is probably, in part at least, a secondary mineral after pyroxene. Biotite occurs in large ragged plates. The specific gravity of the rock is 3.05.

Another variety of biotite-diorite forms a dyke at Loch an Ruighein, north of Little Assynt (S3958) [NC 15 26]. The most striking feature of this rock is the occurrence of large blade-like crystals of a glassy felspar (oligoclase-andesine), which often show fine striation on the basal plane and also twinning on the Carlsbad plan. On the fractured surface these blades sometimes measure 1½ in. in length by ■ th in. in breadth. They are not bounded by sharp outlines against the matrix, and cannot, therefore, be said to form porphyritic constituents in the ordinary sense of the term.

Under the microscope the large felspars are seen to be crowded with minute inclusions, the majority of which are colourless grains and prisms, too small for precise determination. The ground-mass is a crystalline granular aggregate of quartz, plagioclase, biotite, hornblende, calcite, epidote, and magnetite. Hornblende is scarce; biotite, in the form of small scales, is abundant. The specific gravity of the rock is 2.87.

V Granite and gneissose granite dykes and sills

Sills and dykes of granite and gneissose granite are extremely common in the neighbourhood of Laxford Bridge, and similar rocks occur in other areas of the Lewisian Gneiss. The sills are intimately connected with coarse-grained microcline-pegmatites which are often clearly intrusive in the rocks of the Fundamental Complex, and probably represent another facies of the same magma.

The specimens of granite and gneissose granite are, with one or two exceptions, medium-grained pink rocks, in which the parallel structure is due simply to the orientation of the constituents, especially the biotite, and not to a variation in the relative proportions of the different constituents in different layers. The intrusive magma was homogeneous. In this respect there is a marked contrast between the later intrusions and the Fundamental Complex, although some of the broader basic dykes do show signs of incipient differentiation. Cataclastic structures are usually absent, and the ordinary parallel structure is certainly not due to deformation since the constituents assumed their present forms.

The dominant minerals are oligoclase, microcline, and quartz, Biotite is the more common ferro-magnesian constituent; but hornblende has been observed in one or two cases. The rocks are thoroughly acid in composition (sp. gr. 2.61–2·63), and the ferromagnesian constituents are never present in any large proportion. Muscovite is not uncommon, but it occurs

rather as an aeosssory constituent. The other accessories are epidote, orthite, iron-ores, apatite and zircon.

The three principal constituents all occur in irregular grains-The felspars sometimes contain rounded inclusions of quarts, bid this is by no means a marked feature of the rocks. In one or two cases vermicular pegmatite was observed. Oligoclase has bees more often affected by alteration than microcline, which is almip perfectly fresh. Biotite occurs in small isolated plates, but is not. at any rate as a rule, idiomorphic in the prismatic zone. Of the other minerals, epidote is the only one that calls for any special reference. It occurs in irregular grains which frequently contain a core of deep brown orthite. Its relations to the other miners.* do not suggest a secondary origin.

VI Pegmatites

Pegmatites are extremely common in many portions of the Lewisian Gneiss, and their intrusive character is often clearly shown. In the neighbourhood of Laxford they are intimately associated with granites and granitic gneisses, into which they occasionally pass by imperceptible gradations.

The dominant type of pegmatite is an extremely coarse-grained rock, mainly composed of pink microcline and quartz, often intergrown so as to produce the well-known graphic granite. A white plagioclase, which may be either albite or an acid oligoclase, is also present, though, as a rule, in small quantity, and large plates of biotite (haughtonite) are occasionally found. The plagioclase may occur as independent crystals of considerable size, as a zone more or less enveloping microcline, or as perthitic and microperthitic intergrowths with microcline.

Individuals of microcline measuring several inches across are very common, and these frequently show two modes of intergrowth with plagioclase, both of which are well represented in a specimen taken from a point about 1½ miles north of Loch Stack (S6290) [NC 276 474]. In a section parallel to the brachy-pinacoid the plagioclase can be easily distinguished from the microcline by its stronger double-refraction. It extinguishes uniformly over the whole area of the section at an angle of about 19° in the positive direction as referred to the trace of the basal cleavage, and shows, with convergent polarised light, the oblique emergence of a positive bisectrix.

These facts prove that the felspar in question is albite and that the two felspars are intergrown so tliat their brachy-pinacoids are, at least, approximately parallel. The albite occurs in narrow, irregular and often branching veins which show a rude kind of parallelism over the whole of the section. The angles which these veins make with the trace of the basal cleavage vary from 50° to 70°, so that there is here no regular succession of lamellae parallel to the macro-pinacoid of the microcline. It is as if a number of more or less parallel cracks had been formed and the open spaces filled in with definitely orientated albite substance.

In addition to the phenomenon above described, there is also another and more or less distinct mode of intergrowth on a much smaller scale. When viewed with a low power the brachypinacoidal section presents a fibrous appearance which, when a higher power is used, is seen to be due to the occurrence of parallel rods or plates of a colourless mineral agreeing with albite in refractive index and direction of extinction.

The parallelism of these rods or plates, which are doubtless formed of albite, is much more marked than that of the broader veins, and their direction with reference to the trace of the basal cleavage can, therefore, be determined with considerable accuracy.

The angle is about 73°, with a possible error of about 1°. In the chapter on crypto-perthite, in the monograph on the minerals of the pegmatite-veins of southern Norway,<ref>Die Mineralien der Syenit-pegmatit-gänge der Südnorwegischen Augit and Nephelinsyenite. Zeit, f, Krys, Vol. XVI., Leipzig, 1890</ref> Prof Brögger describes a somewhat similar intergrowth in which the striation on the M-face (010) makes an angle of 72° with the trace of the basal cleavage. He concludes that the soda-orthoclase, which h agrees with this felspar in composition, is a sub- microscopic intergrowth of such a character that lamellae of albite are arranged parallel to a steep orthoclase ([overbar 8]01). This would give a striation making an angle of 72° 2½■ with the trace of the basal cleavage, if the intergrowth were coarse enough to make itself recognisable under the microscope.

In a section of the above felspar taken parallel to the basal plane the cross-hatching of the microcline is well seen, while the albite e of the veins shows only the normal lamellar twinning of plagioclase.

The veins vary considerably in width and sometimes in direction, but their general course is at right angles to the trace of the brachy-pinacoid. The inclusions which produce the fine striation in the other section are here seen end on. They appear for the most part as oval dots; but occasionally, owing to the coalescence of several dots, a rod-like form is produced.

The minute inclusions are not distributed uniformly through the section, and where they are most abundant the broad veins are least conspicuous. Prof. Brogger has suggested that the finer intergrowths with orthoclase, parallel to the steep macro- or orthodome, are original structures, and that the coarser perthitic intergrowths which are often parallel to the macro- or ortho-pinacoid have been formed by secondary processes at the expense of the finer inter-growths. The phenomena seen in the above felspar from Scotland are undoubtedly similar to those described by Prof. Brogger, and his theory may apply to them.

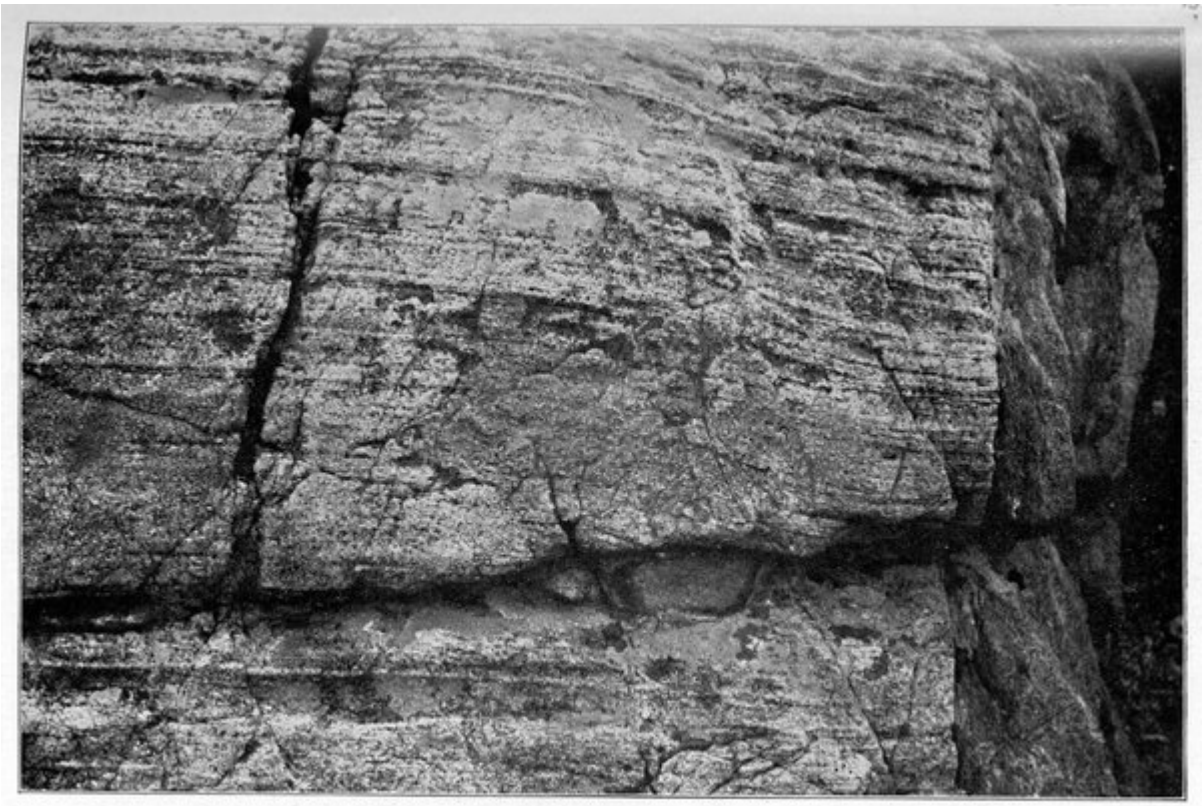
Combining the results of the observations made on the two sections, we see that the fine micro-perthitic structure is due to the occurrence of extremely minute rods or plates of albite which lie in a plane corresponding very closely with the steep orthodome of orthoclase (801), and that the coarser perthitic structure is due to veins or irregular lamellae which show a tendency to follow more closely a direction corresponding to the macro-pinacoid. The perthitic lamellae are, however, very irregular, and so frequently give off branches at different angles that the crystallographic relations of the two felspars are of a very vague and indefinite character.

Another mode of association of the felspars is represented by a specimen from a point about ¼ mile E.N.E. of Badcall Storehouse, Loch Laxford. In this case a crust of plagioclase from ■ th to ¼ inch in thickness surrounds a crystal of microcline. Flakes of the plagioclase parallel to the brachy-pinacoid give extinctions of from 5° to 7° in the positive direction. The mineral is, therefore, oligoclase. The section (S6326) [NC 231 476] which is approximately parallel to the basal plane of the microcline shows also inter-growths of plagioclase similar to those already described.

Mr. Clough found a small quantity of Amazon-stone in a pegmatite of the ordinary type, occurring near Badnabay, one mile west from Laxford Bridge. It is composed of alternating lamellae of green microcline and white albite, the former measuring about 1.5 and the latter about 0.4 mm in thickness. The boundaries of the albite lamellae are not so irregular as in the specimen of pink microcline above described. They correspond roughly with the macro-pinacoid of the microcline.

Biotite-pegmatites with pink microcline are by far the most common, and when the term pegmatite occurs in the description of the geology of the north-west of Scotland these rocks are almost always referred to. Biotite, however, is often absent. A few coarse-grained pegmatites are found in which albite or an acid oligoclase is the only felspar present. Good examples of these occur,in some lines of movement in the Laxford area (S6297) [NC 260 455], (S6293) [NC 260 455], and (S6298) [NC 260 455], where biotite is associated with the plagioclase. More or less crushed pegmatites, essentially composed of albite and muscovite (S6328) [NG 977 755], occur at a point about 5/6th mile south of Carnmore old house, four miles N.N.E., Letterewe, Loch Maree.

Microcline-pegmatites are abundant in certain parts of the northern and southern areas, but they are rare in the district occupied by the pyroxene-gneisses. They are usually massive; but very fine examples of foliated pegmatites in which the large individuals of microcline form "eyes" occur near Shieldaig on the south side of Loch Torridon (see (Plate 9))



Junction of basic dyke with banded pyroxenic or hornblendic Gneiss, ¼-mile south-west of Loch a Bhaid Daraich, Scourie, Sutherlandshire.

(Plate 20) Junction of basic dyke with banded pyroxenic or hornblendic gneiss; quarter of a mile south-west of Loch a' Bhaid Daraich, Scourie, Sutherlandshire. B6

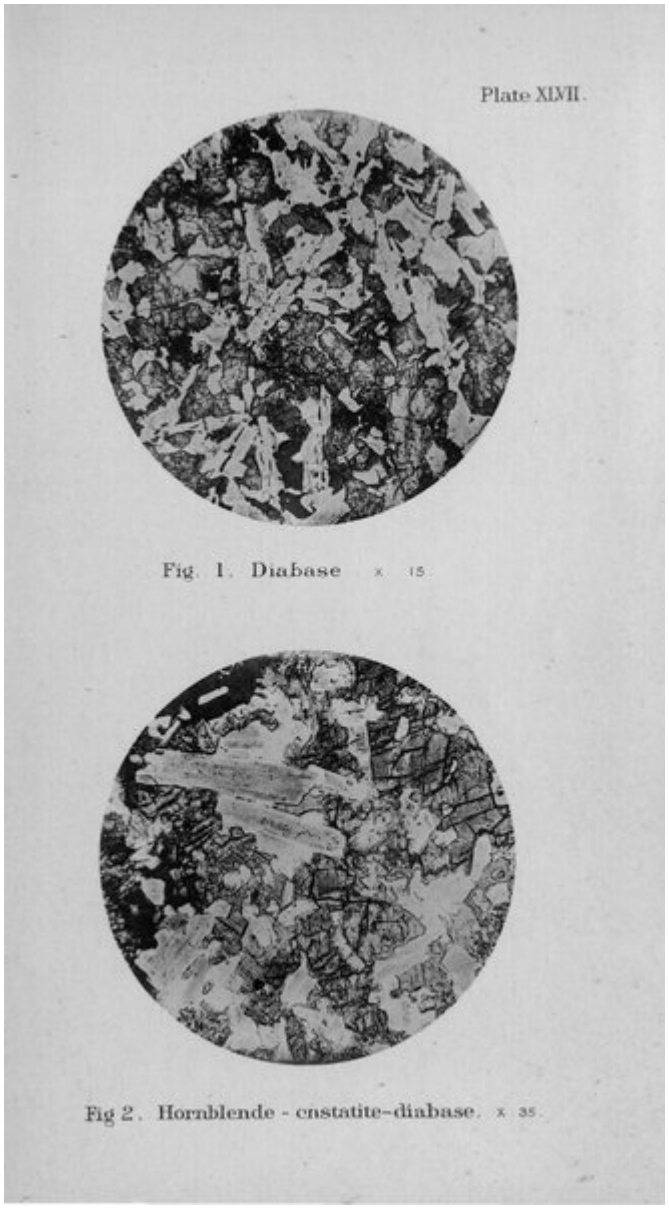


Plate XLVII.
Fig. 1. Diabase x 15.
Fig 2. Hornblende - enstatite-diabase. x 35.

(Plate 47) 1.

Plate XLVIII.

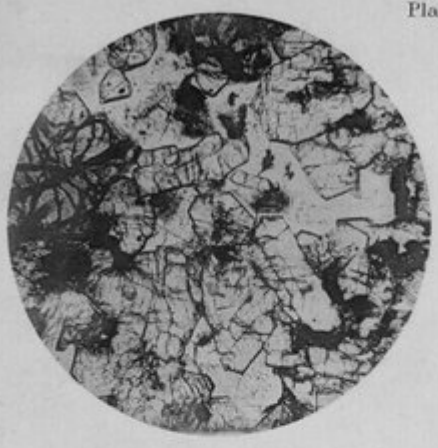


Fig. 1. Olivine-norite. × 35.

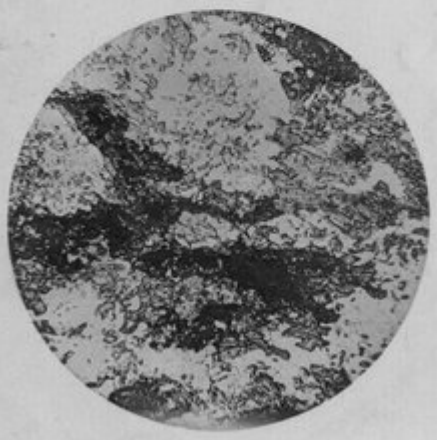


Fig. 2. Epidote-amphibolite. × 35.

(Plate 48) 1.

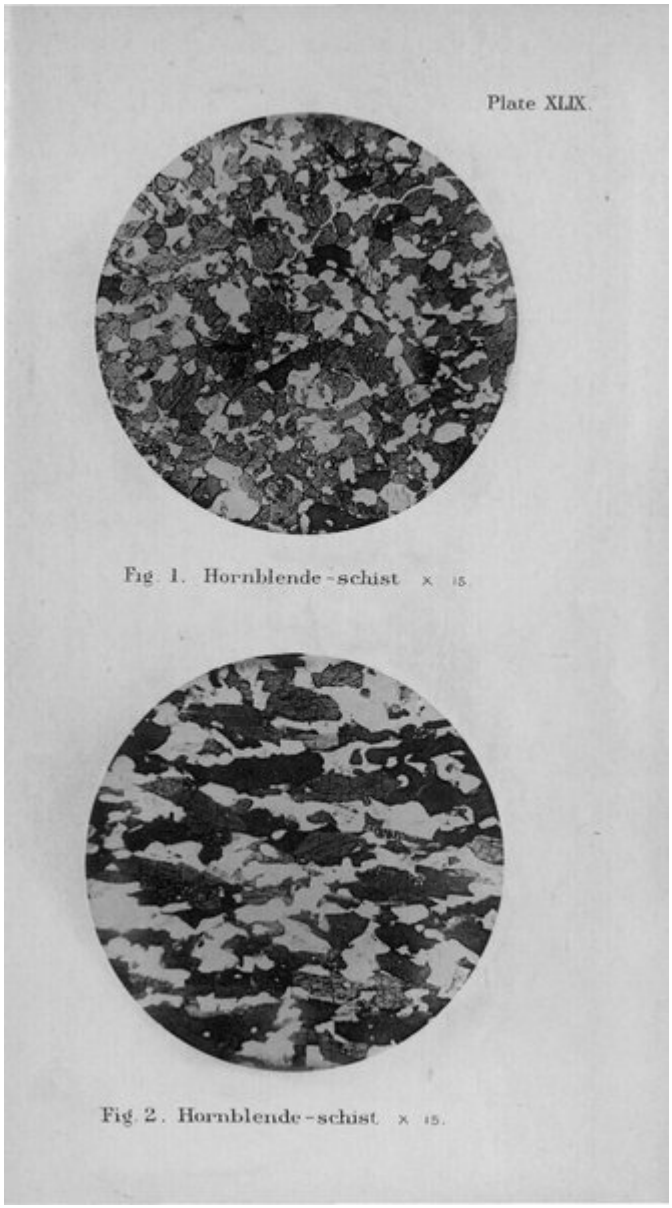


Plate XLIX.
Fig. 1. Hornblende-schist. × 15.
Fig. 2. Hornblende-schist. × 15.

(Plate 49) 1.