Chapter 3 Chief petrographical characters, distribution, and structure

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In presenting a general summary of the Lewisian gneisses and schists along the western seaboard of Sutherland and Ross, attention will be directed, first, to the classification and main petrographical characters of these rocks as determined by Dr. Teall, and described by him in detail in Chapters IV.-VII.; and, second, to their distribution and structural relations as worked out in the field.

General petrographical characters

The Lewisian gneiss of this region may be separated into (1) a Fundamental Complex, composed (a) mainly of gneisses that have affinities, both chemically and mineralogically, with plutonic igneous products, and (*b*) partly of crystalline schists, which may be regarded as probably of sedimentary origin; (2) a great series of igneous rocks intrusive in that complex, in the form of dykes and sills.

I. Rocks of probably plutonic origin

Those members of the complex that have affinities with plutonic rocks contain, as their chief mineral constituents, olivine, augite, including diallage, hypersthene, hornblende, biotite, plagioclase, microcline, orthoclase, and quartz, which enter into the- composition of peridotites, gabbros, diorites, and granites. The term gneiss is not strictly applicable to many of the members of this series, owing partly to their massive character and partly to the absence in places of mineral banding, but it is here adopted for the sake of convenience of description. The classification of these rocks, proposed in 1894 by Dr. Teall,<ref>Annual Report of Geological Survey for 1894, p. 280; and for 1895, p. 17 of reprint.</ref> is based mainly on their mineralogical composition, but partly on their structure. From the subjoined table it will be seen that the classification of three of the groups is determined by the nature of the ferro-magnesian constituent, while a fourth is composed of ferro-magnesian minerals without felspar or quartz, and a fifth is characterised by the presence of both muscovite and biotite.

1. Rocks composed of ferro-magnesian minerals without felspar or quartz, comprising (A) peridotites, pyroxenites and banded hornblende rocks, (B) hornblende rocks not included in the banded series.
2. Rocks in which pyroxene is the dominant ferro-magnesian constituent, felspar always and_quartz sometimes present. These include (A) rocks without quartz such as pyroxene-granulite, (B) with quartz, of which augite-gneiss is a representative type.
3. Rocks in which hornblende is the chief ferro-magnesian mineral, felspar being almost always present. These embrace (A) rocks without quartz or nearly so, and basic in composition, either massive (epidote-amphibolite or garnet-amphibolite) or schistose (hornblende-schist or -gneiss), and (B) with quartz, of which the granular hornblende-gneiss is an excellent example.
4. Rocks in which biotite is the dominant ferro-magnesian constituent, both felspar and quartz being present, comprising biotite-gneiss proper and granulitic biotite-gneiss.
5. Rocks in which biotite and muscovite occur together with quartz and felspar; muscovite-biotite-gneisses.

(I) The ultra-basic rocks of the first group have only a limited development in the Fundamental Complex and are older than the more acid gneisses that enclose them. The hornblende rocks (I. B) are always associated with those containing pyroxene (I. A).

(II) The early basic members of the Complex are more largely represented than those of the ultra-basic series, and include, among other types, pyroxene-granulite and pyroxene-rocks resembling gabbros (II. A), together with garnet-amphibolite and epidote-amphibolite (III. A). Like the rocks of the first group, the early basic members are older than the more acid gneisses that surround them, and are usually banded and folded with the latter.

The pyroxene-gneisses with quartz form an important sub-division of the second group (II. B) and have a definite geographical distribution in the North-West Highlands. One of the most characteristic features is the blue quartz which they contain, and by means of which they can be readily identified. This ingredient resembles the blue quartz found in some of the metamorphic grits of the South-Eastern Highlands and in the basal Cambrian quartzites. These gneisses pass imperceptibly into the hornblende gneisses (III. B) through the replacement of the pyroxene by hornblende.

Apart from the pyroxene gneiss, the hornblende-gneiss proper, with granular structure (III. B), is largely developed in the Fundamental Complex, and within well-defined limits. It is always banded, and the hornblende rarely shows idiomorphism, being frequently moulded on the quartz and felspar. This type often contains a green pyroxene as well as hornblende. These rocks are regarded as an intermediate series bearing the same relation to quartz-diorites that the pyroxene-gneisses do to the gabbros.

(III) The granulitic types of the third group, in which hornblende is the chief ferro-magnesian constituent, are characteristic of the pre-Torridonian lines of movement or shear zones, to which attention will be presently directed. Indeed, in certain areas, as for instance, Rona, Raasav, and Poolewe, where the later basic dykes have been foliated, it is difficult in some cases to separate them from the foliated basic rocks of the original Complex.

(IV) The biotite-gneisses embraced in the fourth group may have been formed in various ways. Some of them possibly represent altered sediments, some may be foliated granites, while others may have been derived by dynamic metamorphism from pyroxene and hornblende-gneisses. Those types in which biotite occurs in independent plates or aggregates, with a structure more or less granular, are associated with the granular hornblendegneisses in certain districts. It is possible that some of the later foliated granites, especially in the area north of Laxford, may have been classed with the biotite-gneisses of the Fundamental Complex. The quartz of the biotite-gneiss contains many minute indeterminable inclusions, but shows no trace of the minute hairlike bodies so common in the blue quartz of the pyroxene-gneiss.

(V) The muscovite-biotite-gneisses of the fifth group have also a well-defined distribution in the southern district. In some areas, as in Meall Rhiabhach, north of Loch Maree, they have undergone much dynamic metamorphism.

By means of a series of photographs of rock-structures taken in the field, the processes are illustrated in Chapter 5. whereby the original members of the Fundamental Complex may have been developed, such as various stages in the separation of the acid and basic constituents, the differentiation in place of the felspathic and hornblendic elements, and the intrusion of the residual mother liquor, the gradual passage from a brecciated condition without parallel arrangement to a banded structure, and finally the inclusion of fragments of biotite-gneiss in a mass of similar material and the compression of the various members into parallel bands. It is inferred that, after the separation of the acid and basic materials, either by differentiation during fluxion or by separate intrusion, the members of the original complex must have been subsequently affected by plastic deformation.

II The altered sediments

The crystalline schists that have affinities with altered sedimentary rocks belong to several distinct types. They include (1) dark-brown platy schist; (2) silvery mica-schist, with idiomorphic garnets; (3) dark-grey granulitic biotite-schist; (4) graphitic schists, with black carbonaceous matter distributed in parallel folia throughout and actually traversing the hornblende thus showing that the latter mineral had grown in Place before being deformed; (5) quartz-magnetite-granulites, resembling the rocks of the Penokee iron-bearing series described by Irving and Van Hise; (6), the calcareous rocks, comprising limestone, dolomite, cipoline, with tremolite, chlorite, garnet, and epidote. These presumably altered sediments are restricted mainly to the Loch Maree district, and have only a limited development, as will be shown in the sequel.

III. Later intrusions (dykes and sills)

The great series of igneous rocks intrusive in the Fundamental Complex, in the form of dykes and sills, may be arranged in four groups — (1) ultra-basic — picrites; (2) basic — comprising, among other types, hyperite, gabbro, diabase.

enstatite-diabase, and epidiorite; (3) intermediate — microcline-mica-rocks, and biotite-diorite; (4) acid — granite and pegmatites. In the areas of unmodified gneiss, particularly in the district between Scourie and Loch Broom, the ultra-basic and basic intrusions preserve their dyke-like character, showing clearly that they rose along vertical or highly inclined fissures, after the development of the early banding or foliation in the gneisses of the Fundamental Complex. The trend of the basic dykes is usually W.N.W., that of the ultra-basic group more nearly east and west, and that of the granite sills and dykes generally W.N.W. The field-evidence proves the ultra-basic dykes to be later than the basic in the Assynt region, and the granite sills and pegmatites to have been intruded into the gneisses after the eruption of the basic dykes. (Plate 2) and (Plate 21)

IV. Effects of Pre-Torridonian movements

Thedetailed mapping of the belt of country lying to the west of the post-Cambria*n* displacements has shown that, after the eruption of the ultra-basic, basic, and intermediate dykes, the whole area was in pre-Torridonian time subjected to earth movements which, affecting both the various members of the Fundamental Complex and also these later intrusions, gave rise to rapid plication of the strata and to lines of disruption or shear-zones, accompanied or followed by re-crystallisation of the original constituents, development of foliation, and occasional mylonisation of the rocks. The new planes of foliation are more or less parallel with the axial planes of folding, or with the planes of disruption.

These pre-Torridon lines of disruption and shearing generally run east and west or W.N.W., that is, approximately parallel with the dykes. Where the direction is east and west, the basic dykes are deflected, attenuated, and converted into hornblende-schist, while the original gneiss may be thrown into sharp folds, and undergo such a molecular rearrangement of its constituents as to become a granulitic gneiss. Similar effects have also been often produced in the reconstruction of the dykes and gneiss, when the trend of the movements has been toward W.N.W. the picrite dykes then passing into talcose schists. In connection with the basic intrusions it is of special importance to note that in the southern tracts, where the dykes are represented by hornblendeschists, which seem to become an integral part of the Fundamental Complex, and where intrusive junctions are only occasionally met with, biotite-gneisses and hornblende-gneisses are characteristically developed.

The granite intrusions, so well displayed north of Laxford, are likewise foliated, the parallel arrangement of the constituent minerals being chiefly marked by the orientation of the mica. In that region the field-evidence points to the conclusion that they cut the hornblende-schists, *and* that they were probably intruded before the violent plication of the gneisses. Cataclastic structures are usually absent, but the foliation may nevertheless be due to dynamic metamorphism.

V. Distribution of the fundamental complex

A brief reference may here be made to the distribution of the Fundamental Complex throughout the region between Cape Wrath and Skye, to the structural relations of the altered sediments in that complex, and to the light thrown on the history of the Lewisian Gneiss by the various modifications of the later igneous intrusions. By the detailed mapping of the Survey, the members of the Fundamental Complex have been ascertained to present a more or less definite distribution. Hence the belt has been divided into three districts: the first extending from Cape Wrath to a line drawn between Laxford and Scourie, the second from near Scourie to Loch Broom, and the third from Gruinard Bay to Loch Torridon and the island of Raasay.

In the central district, from near Scourie to Loch Broom, the characteristic feature of the complex, in the unmodified areas, is the remarkable development of grey pyroxene-gneiss with the earlier ultra-basic and basic masses (pyroxenites, hornblendites, pyroxene-granulites, and garnet-amphibolites). As these rocks had been previously thrown into more or less gentle folds, the later basic and ultra-basic dykes can be traced through them with comparative ease. The lines of pre-Torridonian movement, with their folding, disruption and structural modifications of the gneiss and dykes, are likewise clearly displayed.

But in the district between Laxford and Cape Wrath the essential features of the complex are wholly different. Granular hornblende-gneisses and biotite-gneisses here prevail, while the pyroxene-gneiss with blue quartz is absent. The basic dykes are easily traceable, though partly in a foliated form, across the belt of ground that intervenes between Scourie and

the great granite sills south of the Laxford river, but further north they appear in the form of bands of hornblende-gneiss, which can be followed only for short distances. Across the same belt also the gneisses begin to be folded on highly-inclined axes that strike north-west and south-east. The parallel lines of movement approach each other more closely until little of the pyroxenic gneiss is left unmodified. The structure of the gneisses now becomes granulitic, hornblende and biotite are the dominant ferro-magnesian minerals, and the hornblende presents a linear orientation. As the observer crosses the southern margin of the great sill-like intrusions of granite near Ben Stack, and advances northwards beyond Laxford to Loch Inchard, he finds the members of the Fundamental Complex to be either very coarsely granulitic or granular in structure; granular hornblende-gneiss, hornblende-biotite-gneiss, and biotite-gneiss proper being the chief types. Coincident with the appearance of these. varieties of gneiss there is a great development of granite sills and dykes, which have been injected mainly along the early foliation planes of the gneisses. So minute, and at the same time so extensive, has been this intrusion of acid igneous material, that the members of the complex have been isolated in lenticles, while even *lit par lit* injection is not uncommon in certain localities. Hence it is sometimes difficult to separate the foliated granites or granite-gneisses from the biotite-gneisses proper. If what have been regarded as relics of basic dykes in some instances near Laxford, and even further north, are correctly interpreted, then the linear or plane-parallel foliation, which is characteristic of the dykes in the central and southern districts, has here been replaced by the short crystallisation that forms such a striking feature of the granular hornblende-gneisses over the northern district from Laxford to Cape Wrath and Loch Eireboll. But, perhaps, the short crystallisation may be regarded as a variety of the linear type.

These types of gneiss in the Fundamental Complex between Laxford and Loch Inchard and the plexus of granite and pegmatite intrusions continue north to Cape Wrath and Durness. At intervals the gneisses are thrown into gentle folds, while in other areas they are sharply plicated along highly-inclined axial planes that strike north-west and south-east. Few shear-lines or thrust-planes have been detected north of the great granite sills at Laxford.

In the southern district that stretches from Gruinard Bay to Loch Torridon and Raasay the rocks present certain distinctive features which differentiate them from those of the central and northern districts. From the former they are distinguished by the absence or comparative absence of the pyroxene-gneiss with blue quartz, and by the presence of biotite-gneiss, hornblende-biotite-gneiss, and granular hornblende-gneiss, resembling in certain areas the Laxford and Cape Wrath types. The rocks differ from those of the northern district in the abundance of the basic dyke-intrusions, which there appear either in the massive form or as hornblende-schists. Further, they differ from the rocks of the central and northern districts in the abundance of augen-gneisses, with biotite as the dominant Ferro-magnesian constituent.

In the Gruinard part of the district, the Fundamental Complex is characterised by ultra-basic rocks (peridotites, pyroxenites, and hornblendites) and early basic masses, comprising diorites, garnet-amphibolites, and hornblende-pyroxene-granulites, which have only a limited development. The dominant type of gneiss, which is a grey acid rock with biotite and sometimes muscovite, invades and isolates the older ultra-basic and basic members. In this area the acid biotite-gneiss plays the same part as, in the Lochinver tract, the pyroxene-gneiss with blue quartz does to the older basic gneisses. In the northern portion of the district the banding of the grey gneiss is crude and irregular, and the basic dykes are then massive, though in the form of epidiorites, their intrusive character being well defined. It is noteworthy that the sequence of the later basic and ultra-basic intrusions that prevail in the central district (Assynt) seems here to be reversed; for the Fundamental Complex is intersected by some irregular dyke-like masses of ultra-basic material, while these are in turn cut by the basic dykes.

Southwards, from Gruinard, and to the west of the Fionn Loch, the basic dykes and acid biotite-gneiss are thrown into a great anticline, the axis of which runs north-west and south-east in the direction of Dubh Loch, near Carnmore. Along this arch the foliation of the gneiss is usually well-defined, and the dykes, now mostly in the form of hornblende-schist can be traced round the end of the arch. Advancing southwards from the Fionn Loch towards Loch Maree, we find the same type of acid biotite-gneiss, with its early basic masses and later dyke-intrusions arranged in a great compound syncline, which encloses one of the belts of altered sedimentary rocks above referred to. But even in certain areas beyond Loch Maree, as, for instance, in a triangular patch south-east of Creag Mhor Thollie, along the shore of that loch, and between Bad an Sgalaig and a point two miles north of Loch Torridon, it is still possible to separate with ease the augen-biotite-gneiss with the early basic masses from the later dykes. South of these limits, in Loch Torridon, in Rona, and in the north part of Raasay intrusive junctions are rare, and the later basic dykes appear as bands of hornblende-schist, which may be said

to form now an integral part of the Fundamental Complex. Allusion may here be made to an example of the development of linear foliation and plane-parallel foliation alike in dykes and gneiss between Loch Maree and Gairloch, which is, perhaps, the finest instance along the whole belt from Cape Wrath to Skye.

South of Poolewe the members of the Fundamental Complex and the later basic dykes are thrown into a broad arch, the axis of which runs north-west and south-east, as is well shown on the map (Sheet 91). Before this anticlinal arrangement was developed the dykes and gneiss had been plicated on more or less highly-inclined vertical axes, the dykes being rendered schistose in part. The later system of folding, however. produced a complete rearrangement of the constituents both in dykes and gneiss.

The latter rock consists there of augen-biotite gneiss, with ultrabasic and basic masses, traversed by basic dykes which show types of foliation that differ according as they have been developed on the crest or limbs of the arch. Iii the former case, where the basic dykes are nearly flat and still show intrusive junctions as they curve round the end of the anticline, linear foliation or "rodding" is developed, which is parallel with the pitch of the flexures. In the limbs of the fold, on the other hand, plane-parallel foliation appears alike in the dykes and gneiss, the planes common to both rocks dipping away from the anticlinal axis, that is, to the north-east and south-west. It would thus appear that differential movement of the constituents may be superinduced by folding, which may lead to partial or complete reconstruction of the dykes and gneiss, and to the development in them of common planes of schistosity.

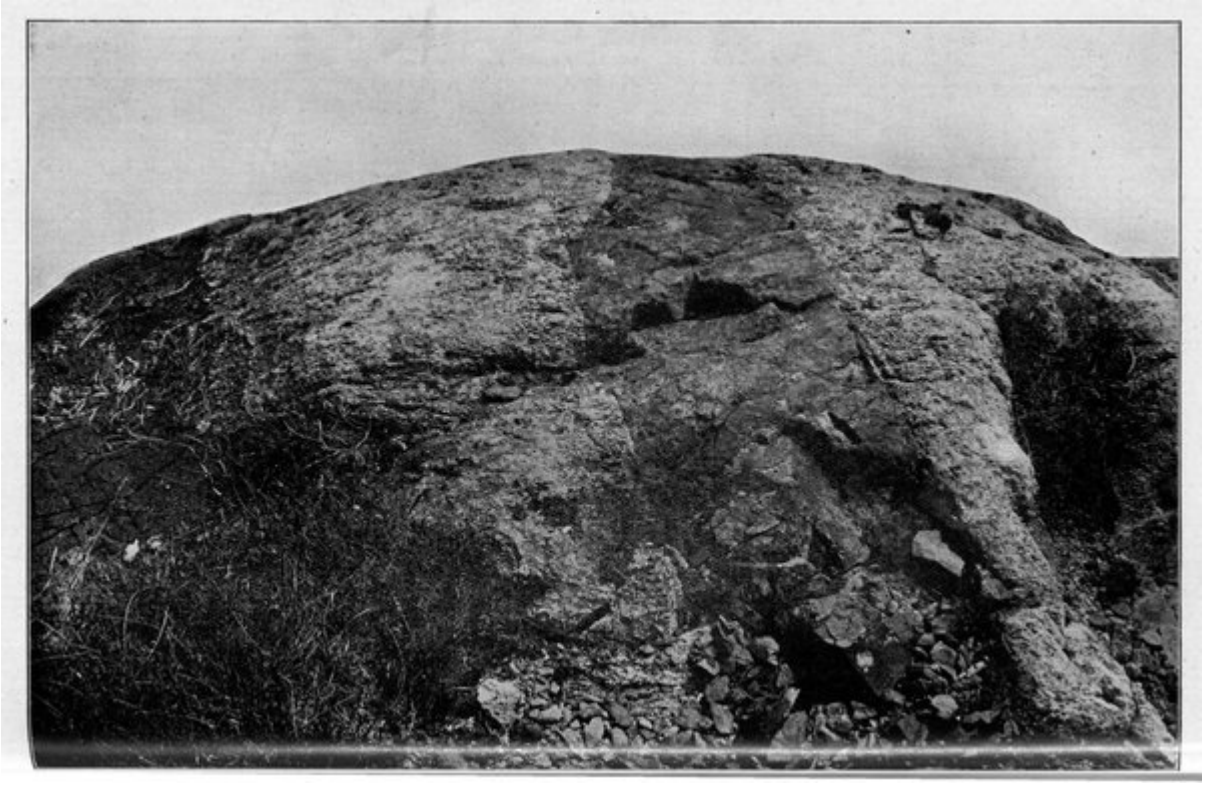
On the shores of Loch Torridon and on both sides of Loch Shieldaig, biotite-gneisses, with some early basic masses, prevail, both being traversed by bands of hornblende-schist, representing the basic dykes. A large portion of the gneiss is there composed of a highly acid rock composed of quartz and felspar, like a foliated pegmatite. The members of the complex are folded on more or less highly-inclined axial planes striking north-west and south-east.

Again, in Rona and Raasay, the dominant member of the complex is biotite-gneiss with microcline, while hornblende-gneiss is not uncommon. The latter rock, where relative age is determinable, is the older of the two. Dark bands of hornblende-schist likewise occur, and are the only portions that can be separately mapped. Obviously they represent basic dykes, although they now appear as, apparently, an integral part of the complex. Pink and white pegmatites are there associated with the Lewisian gneiss, microcline being the characteristic felspar of the former and oligoclase of the latter.

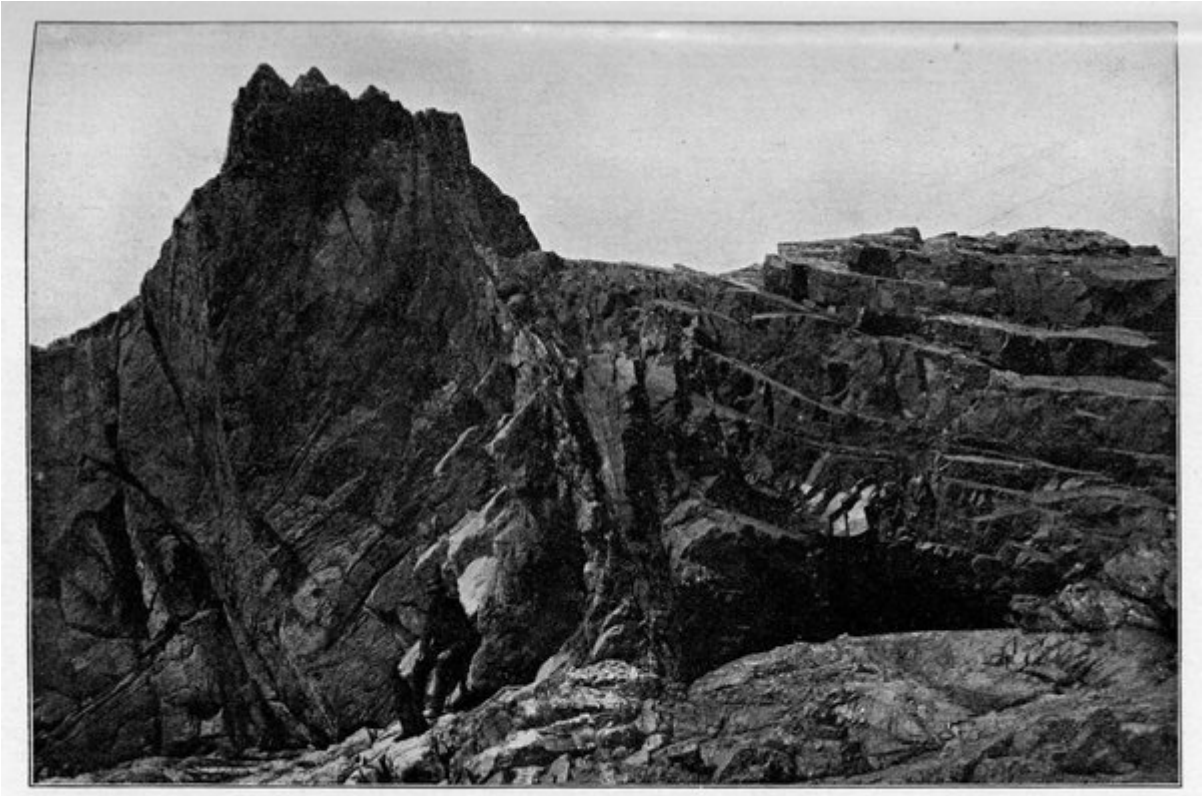
VI. — Distribution and structural relations of the altered sediments

Brief reference may now be made to the distribution and the structural relations of the altered sediments in regard to the members of the Fundamental Complex. Besides minor bands, two well-marked belts of these rocks stretch along the valley of Loch Maree, one on each side of the lake. They lie in compound synclinal folds of the Lewisian gneiss (Plate 30), and are traversed by a great sheet of hornblende-schist. (Ben Lair, near Letterewe, Sithean Mor, near Gairloch). The long axes of these compound synclines run north-west and south-east. The detailed mapping of this region has not furnished any clear evidence to show that the gneiss is intrusive in the altered sediments, but, in certain places, the two are so intimately associated as to suggest that such may have been the case. North of Loch Maree these sediments undoubtedly rest on a platform of acid biotite-gneiss with basic dykes, and are locally overlain by a part of the Fundamental Complex, consisting of biotite-gneiss with basic dykes in the form of hornblende-schists (Meall Riabhach). This overlying cake of gneiss reveals, under the microscope, cataclastic structures due to dynamic movement, and near its line of junction with the underlying sediments there are bands of mylonised rock. The superposition of the gneiss on the sediments is here due to folding and thrusting. It is obvious, therefore, that, whaLover may have been the original relations of the sediments to the Lewisian gneiss, these have been modified by subsequent earth stresses, and that both have been affected by a common system of folding.

Along the line of complication between Eireboll and Skye over whelming evidence has been obtained that slices of Lewisian gneiss were displaced and driven westwards by the post-Cambrian movement, as fully described in Chapter 32. That these isolated masses are in reality portions of the Archaean floor does not admit of doubt, for they include representatives of many of the characteristic types of gneiss to the west, with the later ultra-basic, basic, and acid intrusions, and in many cases are covered unconformably by the Torridon Sandstone and Cambrian strata.

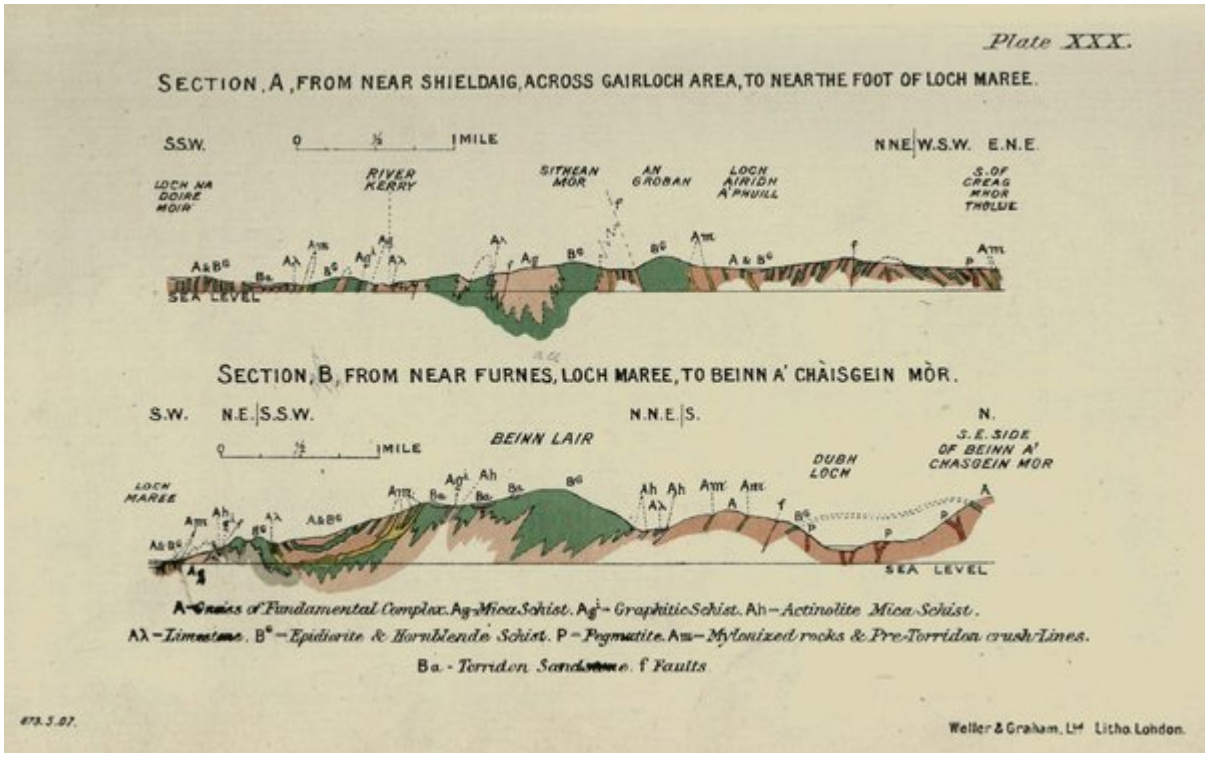


(Plate 2) Epidiorite dykes in thrust Lewisian gneiss, Heights of Kinlochewe, Ross-shire. B62.



Junction of Gneiss and dyke ; dyke on the right, Gneiss on the left. Secondary movement has taken place along the nearly vertical junction plane. Creag a' Mhail, north side of Scourie Bay, Sutherlandshire.

(Plate 21) Junction of gneiss and dyke — dyke on the right, gneiss on the left. Secondary movement has taken place along the nearly vertical junction plane. Creag a' Mhail, north side of Scourie Bay, Sutherland-shire. B10



(Plate 30) Coloured sections acrogs Lewisian series; Loch Maree and Gairloch.