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## Chapter 9 The District from Loch Laxford To Kylesku

This district is represented in Sheets 107, 108, and 113 of the Geological Survey Map of Scotland on the scale of 1:63360, one-inch to a mile. The present chapter is by C. T. Clough, with notes by the late W. Gunn and L. W. Hinxman.

In this district, which extends from Loch Laxford and Loch Stack on the north to Loch a' Chairn Bhain, Loch Glencoul and the north-east slopes of Glas Bheinn and Beinn Uidhe on the south, various types of Lewisian gneiss are well displayed. These rocks are covered unconformably along the eastern margin by a narrow belt of Cambrian strata that runs southward from Loch More by Loch an Leathaid Bhuain and Loch Glencoul to the western slopes of Glas Bheinn. The Lewisian gneisses reappear among the displaced masses affected by the post-Cambrian movements and cover extensive tracts between Loch More and Glas Bheinn. The greatest width from north-west to south-east of the unthrust area is nearly eleven miles, and of the displaced masses, composed chiefly of Lewisian rocks on the north side of Loch Glendhu, about three miles.

Throughout the undisturbed tract the Lewisian gneisses form an undulating rocky plateau of no great elevation, save near the great Cambrian escarpment, where they give rise to conspicuous hills (Ben Stack 2364 feet, Ben Dreavie over 1400 feet, Ben Strome 1374 feet), which decrease in height in a south-west direction. The rocks are but little concealed by drift except near the quartzite between Loch More and Loch Glendhu, and in Strath an Staca, and over large tracts they are almost bare of vegetation.

The district furnishes good examples of the numerous small rock-features and valleys, which run along lines of fault and crush, and frequently cross one another so as to cut the gneiss into irregular blocks. Another characteristic aspect of the gneiss is well displayed here in the abundant small freshwater lochs dotted over the surface. Some of these present very irregular shapes, and many lie in rock-basins with their long axes running along lines of fault. Between Loch Laxford on the north-east and Loch a' Bhaid Daraich and Scourie Bay on the south-west, at least 61 lochans may be seen in a tract of about eleven square miles. On the north-east and south-west sides of the district the region is penetrated by long sea-lochs such as the Laxford (Lax Fjord = Salmon Firth) and Loch a' Chairn Bhain, which branches into Loch Glendhu and Loch Glencoul.

The region west of the post-Cambrian thrusts may be divided into three belts, which are not sharply separated from one another, and whose long axes run in a W.N.W. and E.S.E. direction. In the north-eastern belt, varying from half a mile to a mile and a half in width, most of the gneisses of the fundamental complex are granular in structure and strike W.N.W. with a steep dip towards the S.S.W. They are traversed by intrusions of granite-gneiss and pegmatite which are so numerous that, taken together, they probably exceed in bulk the rocks of the complex. The south-west boundary of this belt runs from the south side of Rudha Ruadh, near the southern headland of Loch Laxford, by Creag na Fiondalach to a point about  $\frac{1}{2}$ -mile north of Loch na Claise Fearna, where it is shifted southwards for a distance of 200 yards by a N.N.E. fault. Thence it trends E.S.E. by the north slope of Ben Stack to the Cambrian escarpment. This boundary line, over part of its course, crosses the foliation planes of the gneiss. The middle belt, averaging two miles in width, has its south-west margin defined by a line extending from the south side of Ben Dreavie, by Clar Loch More, Cnoc na Glaic Moire, and the northeast side of Cnoc Michie to a point on the coast about half a mile S.S.W. of Tarbat. This boundary also crosses the foliation of the gneiss. Here the petrographical character of the gneisses is more or less granulitic, although not sharply marked off from those to the north, and their strike is similar. They are pierced by basic dykes now generally occurring as hornblende schists and by subordinate intrusions of granite-gneiss and pegmatite. Lines of disruption traverse the area which have deformed the gneiss and dykes.

The south-west belt, from four to five miles in breadth, stretches south to Loch a' Chairn Bhain and Loch Glencoul. Here the rocks of the fundamental complex consist largely of pyroxene-gneisses with a variable strike; indeed, their foliation planes often dip at gentle angles and sometimes are almost flat. They are intersected by numerous basic dykes, which in many cases are either free from foliation or only slightly deformed. It was in this area that Dr. Teall, when examining one of these dykes near Scourie, obtained evidence of the metamorphosis of dolerite into hornblende-schist. Pegmatites are comparatively rare, and the existence of rocks that represent the granite-gneisses of the other belts is uncertain. This

tract is characterised by numerous shear lines or thrusts, whereby the dykes have been deflected, displaced and deformed, and new petrographical characters have been developed alike in the dykes and gneiss. Near these lines of disruption and contortion both the dykes and gneisses lithologically resemble those in the middle belt, though near some of the thrusts they are more finely foliated and granulitised.

In the middle belt the alteration of the rocks has been accompanied by many sharp contortions, with axial planes striking W.N.W. and dipping steeply towards S.S.W. Near the boundary between the middle and south-west belts there is usually an area, from a quarter to half a mile broad, in which the contortions with axialplanes striking W.N.W. gradually increase in intensity and number in a N.N.E. direction. But on the coast half a mile S.S.W. of Tarbat the boundary between the two is tolerably sharp, perhaps because on the north-east side of the boundary the lines of thrust and contortion, which probably produce the granulitisation of the gneisses, are close together, while on the south-east they are separated by wide spaces in which the gneiss is almost flat or dips north-west.

In certain tracts of the middle belt the gneisses have largely escaped the influence of the pre-Torridonian movements, and resemble lithologically the original types so common in the south-western area of the district. Such an area occurs a little north-east of Clar Loch Mor. It is probable that many of the gneisses and dykes in the central part of the district have been derived from the alteration of rocks like the less altered types in the southwestern area. In regard to the origin of the granular gneisses in the north-eastern belt the difficulties in coming to a conclusion are greater, for under the microscope these gneisses show no structures which prove them to have been at any time in a less altered condition than now. The belt is, however, so permeated by foliated granite and pegmatites that it does not seem likely that the gneisses of the fundamental complex can have escaped alteration. The field-evidence would rather lead us to suppose that they are even more altered than the gneisses in the other belts. For it can be shown that in the south-western belt the gneisses are always more altered in the areas where the dykes are foliated. Now, in the north-eastern belt the granitic intrusions are always foliated, and this foliation can hardly be considered to represent flow-structure, for in many places it crosses the sides of the intrusions for great distances and at considerable angles. Some of the granitic intrusions occur also within basic dykes and the foliation-planes in the one rock continue into the other.

In the south-western belt the granulitic micaceous gneisses have for the most part been formed not from granular biotite gneisses, but from pyroxene gneisses or from pyroxene hornblende gneisses, and the granulitisation is accompanied with a diminution, or disappearance, of the opalescence of the quartz streaks. In the middle belt quartz streaks with distinct opalescence are rare, and in the north-eastern, perhaps, they never occur.

Strains induced during folding determined the direction of the foliation in the granite-gneisses and the second foliation in the gneisses of the fundamental complex. But in the north-eastern belt the folds are not accompanied by distinct granulitisation. The absence of definite thrusts and zones of granulitic gneiss suggests that at the time the thrusts were being formed in the other belts the gneisses in the north-eastern belt may have been comparatively plastic. The absence of granulitisation and the abundance of Pegmatites in this belt may possibly be connected with the great thickness of cover under which the rocks there may once have lain. The axial plains of the folds in both the middle and north-eastern belt constantly bade S.S.W., and as we proceed from Laxford in a S.S.W. direction we cross from lower to higher planes of second foliation.

It seems probable that at a certain pressure, or depth, definite lines of fracture could not be formed, any fissure that might be commenced being at once filled by inflow of material from the sides.<ref>See Van Hise, Principles of North American Geology. Sixteenth Annual Report of the United States Geological Survey, p. 593.</ref> Perhaps this may explain why definite thrusts have not been recognised in the north-eastern belt. The supposition that the rocks of the middle belt may once have been under a thicker cover than those of the south-western may also account for the chief differences between them, the folding in the former being general, while in the latter it is chiefly confined to the neighbourhood of certain thrusts.

## **Rocks of the Fundamental Complex**

### **Ultrabasic Group**

In the north-eastern belt the most conspicuous ultrabasic rocks- consist of thin bands and lenticles of hornblende mixed with biotite in varying proportion. In some examples biotite occurs in excess of hornblende, or alone. The hornblende is black in hand-specimens, and occurs in large stout prisms. The biotite, when fresh, has the same tint and forms large flakes. Near the margins of the lenticles biotite is most abundant; indeed, these may consist wholly of that mineral, while the interior portion is entirely of hornblende. In some bands, strings of biotite traverse the more hornblendic, central portions. Such phenomena are seen in lenticles close to the road half a mile north-west of Airdachuilinn. These bands of ultrabasic rock, though in some places several yards wide, usually do not exceed a few feet. Even where thin they often give rise to conspicuous topographical features, forming the under parts of scars or deep trenches, as for instance on the south side of Laxford Bay, near high-water mark about 250 yards south-west of the storehouse, and within a distance of 80 yards further to the south-west. Others occur along the strike of these in an E.S.E. direction, between the bridge and the bend of the river, and continue past Caol Loch a' Mhin Ath and Caol Lochan.

That movements have taken place along most of these bands is shown by the contorted condition of their folia, while the gneiss at their sides is free from contortion. A band which appears half a mile slightly north-west of the foot of Caol Loch a' Mhin Ath shows rapid isoclinal folding with axial planes striking at angles of about 45° against the adjacent gneiss. The folds are best shown by thin, hard, pale gray folia which occur within the biotite hornblende rock, but also by the biotite flakes in the rock itself. From the position and inclination of the axial planes it would appear that the rocks on the south-west side of the band had been moved in a north-west direction past those on the north-east.

In the middle belt, particularly in the north-eastern part where they are numerous, these hornblende-biotite bands are well exposed on the coast a third of a mile south of Rudha Ruadh, 350 yards north of the foot of Loch Dubh (one mile south-west of Loch Laxford), and on the roadside 200 yards below Loch na Claise Fearnna (1½ miles south-west of Loch Laxford Bay), and rather less than half a mile south-west of Badnabay. Thin bands weathering with a rough brown surface are common, particularly within or close to the garnetiferous basic rocks, the roughness being chiefly due to projecting crystals of pyroxene and hornblende.

A specimen from an exposure ■-mile N.N.W. of Tarbat proved to be a banded hornblende-pyroxenite with a little olivine passing into serpentine, and containing parallel seams of hornblende from one to six inches thick.

Ultrabasic rocks weathering partly with an orange crust and containing many specks of serpentine have been traced for considerable distances between Achfarry (one mile south of Loch Stack) and Loch Eileanach. The serpentinous portions sometimes pass along the strike into rocks resembling pyroxenites, and may also be associated with others consisting chiefly of interlacing colourless needles of anthophyllite. Hand-specimens of some of the serpentinous parts show no indication of foliation, but others are finely fissile and lustrous with white mica or talc. An acid gneiss which occurs half a mile north-west of Loch na Gualainne contains lumps, from a few inches to several feet long, chiefly composed of hornblende, the crystals of which are arranged in layers parallel to the long axis of each lump. These layers, however, do not continue quite to the sides, there being a peripheral zone, perhaps half an inch thick, which on weathered surfaces projects somewhat from the interior, and in which the hornblende crystals are disposed at right angles to the sides. This disposition suggests that the peripheral zones have been melted and recrystallized after the lumps had been caught up by an igneous rock which is now represented by the acid gneiss.

In the south-west belt hornblende-pyroxenites are seen in the following among other places: Close to the north-west side of the road west of Cnoc na Glaic Moire (1½ miles E.N.E. of Scourie); the path ■-mile E.S.E. of the top of Ben Strome; the hill half a mile slightly south of east of Ben Strome, and the south-west side of the great area of garnetiferous basic rock between Ben Strome and Loch na Leathaid Bhuaín, both localities being north of Loch Glendhu. Outcrops of hornblendite and pyroxenite are also numerous in the neighbourhood of Scourie, usually associated with, or surrounded by, basic rocks containing abundant garnets. The larger ultrabasic masses contain for the most part both varieties of rock, but the proportions between the different constituents vary much in the different outcrops. The mode of occurrence is also variable. In some instances, as in the mass forming the island in Scourie Bay. much of the rock is a granular aggregate of pale green diallage and hornblende, while in other cases, as in the remarkable banded rock described by Dr. Teall (p. 47), the hornblendite and pyroxenite form more or less separate bands. The rocks are generally coarse in grain and dark green or black in colour. Olivine is not a common constituent of these rocks, having only been found in one specimen from the mass to the north-west of Paire a' Chladaich, north side of Scourie Bay, but pleonaste or spinelle

seems to be a common accessory in the ultra-basic masses on the north side of that bay. The largest of these masses occurs on the north of Scourie House, where it shows a breadth in one place of about 130 yards, but it cannot be traced for more than a quarter of a mile. Like all the other bands under description, its strike coincides in the main with that of the adjacent gneiss. It is not entirely made up of ultrabasic material. A part of it is beautifully banded like the case described by Dr. Teall. Other examples of these ultrabasic rocks occur about a quarter of a mile north-west of Scourie House, where they dip north-west at angles from 40° to 50°.

Nearly a mile south of Scourie, in the neighbourhood of Lochan Daimh Mor, one of the largest ultrabasic masses in the district is to be seen. Its boundaries are not well defined, but it stretches from the south end of the loch in a S.S.E. direction for about a quarter of a mile, and it has apparently a breadth of from 70 to 100 yards. It appears to be mainly composed of serpentine and peridotite which is bordered on the west by a garnetiferous hornblende rock, but one specimen from this area ([S4893](#)) [NC 158 430] is described as a crystalline granular aggregate of enstatite (hypersthene rock). Fifty yards south of the main mass of serpentine an oval-shaped mass of the same rock about 100 yards in width may be observed. Its greatest length runs nearly parallel to the general strike of the foliation in the adjacent gneiss, while that of the main mass crosses the general strike nearly at right angles. Two narrow bands of gneiss appear in the ultrabasic mass near the loch, their strike being parallel to the length of the mass, so that probably a local variation of the strike of the gneiss takes place here round the borders of this ultrabasic mass.

About a quarter of a mile S.S.W. of Lochan nam Breac, Geisgeil, another patch of ultrabasic material presents a somewhat varied character. While the greater part of it is composed of an aggregate of anthophyllite and carbonate, it includes a massive rock of uniformly fine texture and dark green colour made up of olivine, which has been slightly serpentinised along cracks, and has the usual branching strings of iron-ore. This is the most typical dunite which Dr. Teall has met with in the British Isles. Only one small grain in the microscopic slide is not referable to olivine, and is probably enstatite. The aggregate of anthophyllite and carbonate forms a grey rock weathering brown from the oxidation of the iron in the carbonate. The anthophyllite is colourless and fibrous, without definite terminations. About three-quarters of a mile north of this locality another outcrop of anthophyllite-rock has been noted similar to that here described, but less decomposed. The interlacing prisms of anthophyllite are conspicuous on the surface where the carbonates have been removed by weathering.

A few small lenticular masses and thin bands of rock that resemble peridotite occur along the north shore of Loch a' Chairn Bhain and on the island of Calbha Beag. One of these, at the west end of Duartmore Bay, is affected by a line of thrust and sheared into an unctuous schist.

On the south shore of Loch Glendhu, about a mile and 300 yards E.S.E. of Kylesku Inn, a mica-anthophyllite rock ([S2955](#)) [NC 246 332], containing grains of dolomite and specks of pyrites, wraps round several nodules which are much more calcareous than itself, and consist chiefly of magnetite, spathic iron, and dolomite, but contain also abundant films of white mica, or talc, brown biotite in small nests, a little green hornblende and secondary quartz. One of the nodules is six feet long and two broad. On the island 300 yards S.S.W. of Kylestroma other calcareous lentils were also noticed, in which anthophyllite has not been detected.

## Early basic rocks

In most parts of the fundamental complex of this district rocks containing felspar, and for the most part without quartz, except in scattered strings, are abundant, and vary greatly in character, as is shown by the abundance or paucity of garnets and of strings and irregular folia rich in quartz. Save in the north-eastern belt these rocks and the basic dykes can generally be distinguished here, even when the junctions with neighbouring rocks are not visible. Almost every good exposure of the basic type shows garnets in some part or other, also strings with opalescent quartz, but only a few basic dykes are garnetiferous. In these latter cases the garnets are small and rare, while quartz veins also are not common save when the rocks have been foliated, and then the quartz is less opalescent than in the early basic group. There is no doubt that in this district the great development of garnet preceded the intrusion of the dykes.

Most of the early basic rocks may perhaps be classed either as pyroxene-granulites or garnet-amphibolites ([S3391](#)) [NC 114 328]. Mr. Harker has described a specimen from about three miles south of Laxford Bay. *Geol. Mag.*, 1891, p.

171.</ref> These rocks frequently project in the landscape. They also form knots, sometimes in groups, surrounded by the acid gneisses, and are well developed in areas where the basic dykes are not foliated. These knots must have been formed before the intrusion of the dykes. Their longer axes are generally parallel to the strike of the adjacent gneiss, but not always.

In the north-east belt the members of this group do not form large areas. Perhaps the chief exposure is that on the hill rather more than ■-mile S.S.E. of Badnabay, which is folded along north-west axes, and traceable for about 600 yards, its maximum width being about 60 yards. It is much traversed by veins of granite-gneiss. In the middle belt the early basic rocks are widespread, and perhaps form half the area of the north-east portion. Near Loch na Gualainne and the north end of Loch nan Breac, south of Loch Laxford, garnetiferous rocks are intimately mixed with pale gneisses. Again, ■-mile E.S.E. of Fanigmore, south of Loch Laxford, masses of basic rock are traversed in all directions by thin strings of acid pale grey or reddish gneiss, so that portions of the former are isolated by the latter. The veins are often only an inch or two thick, but so numerous that they almost equal the dark rock in bulk. No acid strings penetrate the basic dyke near the north-east ends of Loch na Gualainne and Loch nan Breac, from which it may be inferred that they are older than this dyke and not of the age of the granite-gneisses of Laxford.

That the acid gneisses of the early complex have in some places invaded and surrounded a basic rock, which, if not already completely solidified, at least possessed a banded structure, is shown by the occurrence in them of banded basic inclusions, which are truncated by the surrounding folia of acid gneiss. Bands of unusually acid character are so frequently found at the edge of, or within, masses of basic or ultrabasic rock as to suggest that the two rocks may have been segregated from one magma, the rock next the basic mass becoming more acid in consequence of the abstraction of the more basic minerals.

As the development of garnets mainly preceded the intrusion of the dykes, it must also have been anterior to the thrusts and contortions by which the dykes and pale gneisses have been so greatly modified, yet the garnets and the rocks containing them appear for the most part to have escaped alteration. The rocks in most of the large basic exposures are hard and massive, and not well banded, and the thrusts have often proceeded round their sides instead of crossing them. The garnets in the basic rocks on the north-west side of Loch na Gualainne vary in abundance and size in different bands. They are of a port wine colour and of great brilliancy, but never show good idiomorphic outlines, being usually aggregated into lumps and intergrown with hornblende, felspar, or ilmenite. One such lump measured six inches in breadth and six and a half in length.

In the south-west belt the largest exposures of early basic rock occur on the north-west side of the south-west portion of Loch an Leathaid Bhuain, north of Loch Glendhu, where they are much mixed with pale gneiss, but over an area of perhaps a square mile the basic rock is considerably in excess of the acid. The north boundary of the main basic area is clearly defined for about half a mile east of the path, and, though curved, has a general east and west direction; west of Maldie Burn the south boundary is also tolerably clear for nearly a mile. In a large part of the rock no banding can be perceived. The garnet aggregates are numerous and sometimes three or four inches long, and intergrown with ilmenite. There are many irregular, pale grey streaks consisting chiefly of opalescent quartz.

The hypersthene-augite-plagioclase rocks which are garnetiferous in the Scourie district seem always to occur in close connection with the hornblendites and pyroxenites. They are generally almost black, and form a border to the ultrabasic masses, but may sometimes occur independently. Here, again, the garnets, often as large as one's fist, are always cracked or broken. Those portions of the rock which are free from garnets belong to the Baltimore gabbro type, and occasionally (as in No. [\(S2990\)](#) [NC 146 448] from the shore north-west of Scourie Mor) a rock which contains garnets, but without hypersthene, is a gabbro in structure and composition. In addition to the minerals mentioned above, hornblende is often present, and is sometimes as important a constituent as any of the others. The other early basic rocks near Scourie which occur as knots in the gneiss are probably more hornblendic than augitic in character. None of these masses is of great size except that which occurs four miles south of Scourie and about half a mile east of Loch a Mhuilinn. Much basic material is enclosed in the gneiss to the west of the north end of Clar Loch Cnoc Thormaid, about three miles E.S.E. of Scourie, and along the strike of the gneiss W.N.W. It is noticeable, too, between the south end of Clar Loch Cnoc Thormaid and Loch nan Uidh, and on the north side of the eastermost bay of Loch Crocach.

## Pyroxene-gneisses, pyroxene-hornblende gneisses, and gneisses with biotite in aggregates

Gneisses in which the pyroxenes are not associated with hornblende are probably rare, but the pyroxene-hornblende-gneisses in which hornblende occurs in aggregates and has apparently replaced pyroxene are common in the south-west belt, and perhaps cover a larger surface there than any other rock. They closely resemble the pyroxene-gneisses proper, and occur with them in those places where the basic dykes are most free from foliation, and in which there have been no great pre-Torridonian movements since the intrusion of these dykes. The same areas display gneisses with aggregates of small scales of biotite, but these gneisses appear to occur sporadically, and are connected by imperceptible gradations with the pyroxene-hornblende-gneisses.

The dip of the gneisses belonging to these three types is usually towards W.N.W. — a direction which prevails over most of the area between the Sound of Handa and Loch na h-Airdh Sleibhe, in many places south of Scourie, on the coast near Kylestrome, and on Loch Glendhu. Along the shore from Scourie Bay to Badcall, and again from the south side of Badcall Bay to Allt an Strathain the general dip is west or north-west. Some miles inland, however, it becomes irregular. The gneisses between Loch na h-Airdh Sleibhe and Loch Crocach, for example, have been thrown into a series of folds, the axes of which run W.N.W. or northwest, the gneiss being sometimes horizontal, sometimes undulating gently, and in places vertical, with a strike parallel to the axes of fold. A fold of this kind on a somewhat large scale crosses the whole district from Badcall Bay in a south-east direction through Geisgeil to near the north end of Loch Crocach. Near the east end of Loch na, h-Airdh Sleibhe, on the south-west and southeast sides of Cnoc Odhar (a hill three miles N.N.W. of Kylesku) and on the south-east side of Druim na h-Imrich (north of Loch a' Chairn Bhain), the banding of the gneiss is nearly flat. Between Ben Auskaird and Loch Clach a' Chinn Duibh, 2½ miles N.N.E. of Kylesku, it generally dips north between 10° and 30°. Between Druim na h-Imrich and Cnoc Chalba, 4 miles north-west of Kylesku, the gneisses, save near the pre-Torridon shear lines, usually undulate at low angles and are often thrown into low domes and basins. (See (Plate 14)) The direction of dip is consequently very variable, but the general direction of strike is W.S.W.

The banding of these gneisses is one of their characteristic features. The individual bands are broader than those in the granulitic types, being often an inch or two in breadth. This structure is chiefly due to variations in the proportion of the dark constituents in the different layers, and to the presence of layers and lenticles of basic material. Most of the quartz occurs in parallel lenticles, or rods, connected at short intervals in such a way that on weathered faces it stands out as a complex network. It is opalescent and sometimes of a pale blue colour.

A very acid kind of augite-gneiss which occurs on the north side of Scourie Bay, about ¼-mile N.W. of Scourie House, is coarse grained, grey, and chiefly composed of quartz and felspar. Its pale green pyroxene is changed in places to aggregates of fibrous hornblende ([S4889](#)) [NC 152 451]. At Scourie Mor a considerable exposure of a somewhat different variety of pyroxene-gneiss may be seen. This rock, mainly composed of felspar, is dark grey in colour, with many reddish patches in which ferric oxide has been deposited along cracks in the quartz and felspar. ([S4890](#)) [NC 14 44]

These gneisses enclose frequent lenticles and lumps entirely composed of hornblende or pyroxene. The bands of the gneiss partly end off against these masses and partly bend round them, as may be well seen near the top of a scar on the north side of the road at the south-east end of Loch a' Bhaid Daraich at Scourie. Many of the lenticles are banded, and their folia terminate abruptly at their margins against the enclosing rock, as shown near the west end of Loch na h-Airdh Sleibhe. A much larger basic mass is exposed about half a mile south of Cnoc Mhichie, where in one place the bands in the lenticle are cut by the pale gneiss, but in another lie parallel to those in the adjacent gneiss and to the junction line. In the last-named exposure the gneiss immediately surrounding the lenticle is more acid than that which lies further away — a feature suggestive perhaps of segregation from one magma, the darker ingredients having separated first. The banded structure may conceivably have arisen in consequence of a movement of the magma simultaneously with the segregation, when some portions of the basic material had become sufficiently solid to act as "eyes". The more liquid portions may have thinned out at the sides of the lenticles, or bent round them or cut across them. In some basic lenticles the bands near the ends rapidly diminish in breadth and combine to form streaks which may be traced long distances in the surrounding pale gneiss. These streaks run parallel to other bands in the gneiss and seem similar lithologically to many of them. A case of this kind is seen 300 yards north of Loch a' Bhaid Daraich.

In various places, for instance on the east side of Lochan an Freagairt, gneisses with basic knots and confused banding are overlain or underlain by more even banded gneisses. In a section on the shore at Bagh Leathan, south of Duartbeg, a gneiss with basic lentils is cut across diagonally near the top of the section by an overlying paler gneiss; several of the basic lentils are cut by the overlying gneiss, and the rocks near the junction do not seem granulitic.

Lines of transgression or discordance are well seen in the area between Creag a' Mhail on the north side of Scourie Bay and the road on the south-east — an area in which the gneiss dips almost constantly north-west and cannot have been much altered since the intrusion of the dykes. Lines of discordance sometimes run in the direction of the general strike of the gneiss, at other times they cut it at considerable angles, but in either case they are unaccompanied by granulitisation, and differ thus from the thrusts that came after the intrusion of the dykes. The absence of granulitisation and of a distinct second foliation parallel to these lines of discordance perhaps indicates that these lines were caused by movements in the mass when in a viscous condition. This inference is supported by the fact that many of the lines, including some which cut the banding almost at right angles, are filled with streaks of opalescent quartz and felspar which are coarser in grain than the adjacent gneiss.

In a few places within the pyroxene-gneiss an acid rock occurs which presents but little indication of banding, and consists chiefly of rather coarse granules of opalescent quartz and white felspar. It resembles a fine-grained granite in which mica is scarce. An example of this type covers a considerable area on the south-west side of Creag a' Bhaid Daraich.

### **The granular and granulitic hornblende-gneisses**

The hornblende-gneisses proper, containing hornblende in compact forms, together with both quartz and felspar, and possessing a granular structure, accompany the granular biotite-gneisses and are often associated with them in subparallel layers. The proportions of hornblende and biotite vary greatly in different bands. No sharp distinction can be drawn between the hornblende-gneisses and the biotite-gneisses.

In the north-east belt the hornblende-gneisses are common and, as far as observed, all possess a granular structure. They may be studied in Fanigmore Bay, on the east side of Eilean Mhadaidh; in the river below Laxford bridge, and a quarter of a mile north-east of Airdachuilinn, Loch Stack. The hornblende in these rocks is generally fresh and black in hand-specimens: the granules of quartz and felspar are larger than in the granulitic-gneisses, and the quartz is never distinctly opalescent. Where the early banding is folded, a second foliation is often indicated by an elongation of the hornblende crystals, as may be seen near the east side of the path three-quarters of a mile slightly south-east of Loch Stack Lodge, and also 300 yards south-west of Laxford bridge.

In the middle belt, banded gneisses, in which the chief ferromagnesian constituent seems to be hornblende, are seen at the following places: a quarter of a mile S.S.W. of the outlet of Loch nan Breac, on the west side of Loch na Claise Fearn, on the south-east slope of Ben Stack, and on the north-east and east declivities of Ben Dreavie. It is uncertain to what extent the structure of these gneisses is granulitic, but it is known that hornblende gneisses with a granular structure extend as far southwest as Tarbat, three miles north of Scourie.

In the south-west belt, flaggy hornblende-gneisses are met with in which the quartz and felspar are thoroughly granulitic, but these are confined to the neighbourhood of the pre-Torridonian thrusts, and are commonly associated with the granulitic biotite-gneisses in areas which have been subjected to these movements. Granulitic hornblende gneiss occurs in a shear zone, running slightly north of west, on the coast a mile and 300 yards N.N.E. of Creag a' Mhail, near a thrust on the north-east side of Cnoc Odhar (three miles N.N.W. of Kylesku), and in one near the west end of Loch na h' Airdh Sleibhe (1¼ miles E S.E. of Scourie). Many of the granulitic gneisses to the south and south-east of Scourie contain both hornblende and biotite, and the granulitic hornblende-gneisses merge imperceptibly into the granulitic biotite-gneisses.

### **Muscovite-biotite-gneisses**

In this district some of the gneisses, with biotite as their chief ferro-magnesian constituent contain also muscovite; other types occur in which muscovite is more abundant than, or even prevails to the exclusion of, biotite. Granulitic gneisses

with predominating muscovite are seen half a mile south of Fiondail Bay, and by the path nearly ■-mile southeast of Ben Strome. The biotite-gneisses of the early complex usually contain streaks and lenticles of hornblende and biotite, which help to distinguish them from the later intrusive granite-gneisses. In the biotite gneisses the colour is generally pale grey, and the quartz granules are more elongated than in the granitic gneisses. On the other hand, the biotite gneisses of the fundamental complex are sometimes difficult to separate from those of the later granitic intrusions; indeed, it is possible that some of the streaks in the former may be due to *lit par lit* injection.

The biotite-gneisses proper chiefly occur in the north-east belt, where the later granite-gneisses and pegmatites are specially abundant, as, for example, on the coast W.S.W. of Badcall Quay, in the Laxford river ■ mile and half a mile above the foot of Allt an Rabhail, a tributary of the river Laxford, and in the little glen south-west of Badnabay. The section exposed in the last of these localities crosses the junction of the north-east and the middle belts, and notwithstanding the number of pegmatites and granitegneisses, a gradual passage seems clearly traceable here between the two types of biotite-gneiss which respectively characterise these two areas. The average size of the granules of quartz and felspar in the early gneisses gradually increases down this burn in a north-east direction, and at the same time the quartz streaks become more clear and transparent. Specimens ([S3471](#)) [NC 225 461], ([S3469](#)) [NC 236 454], and ([S3472](#)) [NC 236 454], all from this stream, have been examined under the microscope: the first is classed as a biotite-gneiss proper, while in the other two, obtained from higher up the section, the structure is partly granulitic, thus resembling all the biotite-gneisses from the middle belt which have been examined.

In the north-east belt second foliation has not been observed so often as in the middle belt, and the planes of this foliation are there not generally very close.

In the middle belt the biotite-gneisses are not always so thoroughly granulitic as those near many of the thrusts in the south-west belt. They are found at many places in the tract which extends from the coast near Acarseid Mhic Mhurcaidh Oig and Rudh' an Tiompain to Lochan an Fheidh, south-west of Loch Laxford; also on the east side of Clar Loch Mor, the south-east side of Loch na Mnatha, the east side of Loch Eileanach, and on Meall nam Breac — all south-east of Scourie. It is worthy of note that the bands of gneiss are frequently thinner and the component granules of quartz and felspar are usually smaller in the limbs of sharp folds than near the axes. Indeed, near the south-east side of Loch na Adh this attenuation is so marked that the thickness of individual bands is six times less in the limb than near the axes.

The biotite-gneisses of the early complex in the south-west belt which have been examined under the microscope are classed N.E. a. S.W. partly with those in which the biotite is in aggregates of small scales and partly with those in which the structure is granulitic. The granulitic gneisses occur along the thrusts near which the basic dykes have been converted into hornblende-schist. The gneisses with aggregates of small scales of biotite, on the other hand, have no close connection with, and sometimes occur far away from, these lines of disruption: they appear to be altered forms of pyroxene-gneisses and have been described with them. Granulitic biotite-gneiss is perhaps the commonest rock near the thrusts in the southwest belt, where it forms bands, with subordinate granulitic hornblende-gneiss and hornblende-schist, which are sometimes more than 100 yards wide. Some of the bands of granulitic gneiss are bounded by distinct lines of fracture, but more generally their sides are illdefined, the intensity of the folds and the degree of alteration gradually decreasing as we recede from their centres.

The granulitic gneisses usually weather with smoother outlines than the contiguous gneisses of the fundamental complex, and sometimes form lines of depression or the under parts of scars, which can be traced for long distances. Examples of these topographical features are seen on the east side of Cnoc na Glaic Moire (two miles E.N.E. of Scourie), the north side of Ben Auskaird (four miles N.N.W. of Ben Auskaird), and on Cnoc Mhichie, one and a half miles N.N.E. of Scourie. Most of the granulitic gneisses contain a larger proportion of mica than the adjacent less altered gneisses; indeed, the greater part of their mica must be of secondary origin, derived from minerals that occur in the other gneisses. As already indicated, the less altered gneisses near most of the pre-Torridonian thrusts are chiefly those with pyroxene or with aggregates of hornblende and biotite, which have probably replaced the pyroxene, and from these most of the granulitic biotite gneisses have evidently been derived. The biotite must have been chiefly formed from pyroxene or hornblende, and the white mica from felspar. The secondary origin of the micas is often evident from their arrangement along later foliation planes. The amount of pyroxene, or of pyroxene and hornblende, varies considerably in different bands of the less altered gneiss, and so, too, does the amount of biotite in different bands of the granulitic gneiss. The



thicker streaks of biotite in the granulitic gneiss perhaps represent dark hornblendic streaks which have been converted entirely into biotite.

The minerals on the foliation planes of the granulitic gneisses are often arranged with their long axes parallel. The direction of elongation, or stretching, varies in different localities, but near the same thrust it is generally persistent for long distances. Over the greater part of the district, when the observer looks north towards the foliation planes, the lines of elongation appear diagonal, about half way between the directions of strike and dip of the planes, and with their lower ends on his right hand.

Near the north-west side of the lower half of Loch an Leathaid Bhuain (north of Loch Glendhu) a pale grey or pink gneiss is extensively exposed. It has a massive character, strikes nearly east and west, and contains both biotite and hornblende, but in feeble quantity. Its foliation is often indistinct, but generally parallel to the boundaries of the rock. Similar gneisses spread over a considerable area between a quarter of a mile north-west and north of Ben Strome (two miles N.N.E. of Kylesku).

## Basic dykes

The basic intrusions of pre-Torridonian age in this district nearly always appear in the form of dykes, many of which can be traced in straight lines for miles. Their general direction is northwest or between north-west and W.N.W., save where deflected by later movements.

Sometimes two dykes unite, thereby forming a broader intrusion; sometimes those of larger size give off branches which either end abruptly or rejoin the parent dyke within a short distance. Others split into thin strings or follow the planes of original banding of the contiguous gneiss, at low angles, like sills. An example of this last feature occurs about 700 yards north-east and three-quarters of a mile E.N.E. of Glencoul House. Yet again a dyke may be seen to taper off and disappear, while another, or perhaps the same intrusion, may begin not far off, and follow a parallel course, as, for instance, on the shore west of Scourie More, on a small peninsula named Cleib Mhor. In a few places, one dyke can be observed to cross another of much the same composition — a feature displayed in the peninsula west of Badcall, and between 100 and 200 yards south-east of Lochain Bealach an Eilein (one mile north of Scourie). Finally, some dykes run in groups across the gneiss-plateau, as between the shore south of Badcall Bay and the Cambrian escarpment north of Loch Glendhu — a distance of seven miles.

The breadth of some dykes is remarkable. The example which appears ■-mile north-east of Loch an Leathaid Bhuain measures 140 yards across — perhaps the broadest instance in this area. Others are about 100 yards in width. In the lines of pre-Torridonian thrust and contortion the average breadth of the dykes is much smaller than in the less altered areas; some which in these areas measured 40 yards across have been deflected as they approach the shear-zones, changed into hornblende-schist, and attenuated to a few feet. In the middle belt, a great part of each dyke has taken the form of hornblende-schist, and its original thickness has probably been diminished by the contortions to which the rocks have there been subjected. These contortions are, however, not so intense as those near most of the thrust lines in the south-west belt.

In the case of the broad dykes the margin is finer grained than the interior, and resembles that of the thin intrusions. No vesicular cavities or amygdules have been detected.

The intrusive character of the dykes in the tract south of Scourie is very apparent, as the majority of them cross the foliation of the gneiss nearly at right angles. An excellent example of an intrusive junction is displayed by the dyke about a quarter of a mile south-west of the east end of Loch a' Bhaid Daraich, Scourie — one of those which supplied Dr. Teall with proofs of the alteration of a massive basic rock into hornblende-schist. (See (Plate 20))

The shore north-west of Badcall shows a dyke which seems to have nearly reached its upward limit of protrusion, at what is now the surface of the ground. Rather more than half a mile W.S.W. from Cnoc na Baineire, two small dykes run in a north-west direction and approach the sea-coast. The more westerly one ends off upward, being plainly overlain for a short distance by the gneiss, beyond which it reappears at the surface on the same line.

Regarding the surface features produced by these intrusions, it is observable that many of the undeformed dykes frequently make ridges and crags; others nearly always give rise to hollows and show few rock exposures. It is to be remarked, however, that the same unfoliated dyke may form a ridge at one part of its course and a hollow at another, though no important differences may be observable either in the characters of the intrusion or of the contiguous gneiss. (See (Plate 19))

South of Scourie nearly all the dykes are massive epidiorites, comparatively few having been converted into hornblende-schist throughout their whole breadth. Other interesting types appear to the north of that village. Thus, in one of the least altered portions of the Fanigmore dyke, south-west of Loch Laxford, the plagioclase and pyroxene are related to one another as in many unaltered igneous rocks. Nevertheless a considerable quantity of biotite is here intimately intergrown with the pyroxene. This type may be termed hyperite, as it contains apparently a little enstatite, as well as augite. About half a mile north-west of Cnoc an Fhir Bhreige, the Fanigmore dyke is cut by another of the common type. Again, south-east of Loch Bad an t -Seasgaich, which lies to the south-east of Loch na h' Airdh Sleibhe, two dykes of coarse rock, containing large crystals of felspar, have not been much foliated, but they show abundant large plates of yellow mica on certain planes. They weather with a bluish-black colour, and remind one of the Fanigmore dyke. The adjacent dykes are of a different type, being fine grained and well foliated, but there is no evidence to prove their age with respect to the coarse dykes. The dykes, which have been deflected along thrusts for great distances out of their usual course, are generally finely foliated. The one running nearly east and west for more than a mile along the east part of the Ben Strome Thrust, and that which can be traced for nearly a mile from the coast, half a mile N.N.E. of Creag a' Mhail, are both unusually finely foliated, and contain abundant flakes of biotite on their foliation planes. In the first-named, the biotite is clearly of secondary origin, for that mineral does not occur in the less-altered portions of the dyke. Most of the other dykes in which biotite is conspicuous are also unusually finely foliated.

Another peculiar type — a biotite hornblende-dolerite — which contains biotite even when it shows little or no foliation, has been traced from near the north-west end of Loch a' Bhaid Daraich, Scourie, to a place about one-third mile slightly east of south of the top of Cnoc Mhichie, and thence to the north end of Loch na Mnatha. This example differs from the dykes near it, in its greater proportion of felspar and in its mode of weathering.

Between Loch a' Bhaid Daraich and Cnoc Mhichie — a distance of about a mile — its general direction is N.N.E., nearly at right angles to the normal course of these intrusions; between Cnoc Mhichie and Loch na Mnatha its trend differs less from that of the other dykes. The evidence in the field renders it probable that it is older than the other dyke-intrusions in the neighbourhood.

In some dykes there is an original broad banding which is crossed by, and must be older than the fine foliation. In the broad dyke two-thirds of a mile slightly north of west of the outlet of Loch na h-Adh there are alternating pale and dark bands which are rather more steeply inclined than the fine foliation planes.

The hornblende in the dykes is never in prominent "augen" forms, but usually occurs in small needle-like prisms lying on the foliation planes and parallel to the direction of stretching. The prisms are, as a rule, less stout than those in the early basic rocks. In the dyke at the head of the glen south-west of Badnabay and the one running north-west from the north end of Loch na Gualainne — both of them near the area in which the granite gneisses are abundant — the hornblende is, in places, in rather stouter forms than usual.

Garnets have hardly ever been observed in the dykes, save in some instances near the north-east side of the middle belt. They are smaller and less numerous, but generally display more idiomorphism than those in the early basic rocks, and they have no rims of felspar like those in the latter group.

At the close of the present chapter fuller reference will be made to the pre-Torridonian lines of movement in this district (whereby new structures have been developed both in the dykes and gneiss), and also to the flinty crush-lines. Brief allusion may, however, be made here to certain points. In the sheared dykes, lenticles of unfoliated, or slightly foliated, rock are common, resembling "augen" structure on a large scale, as shown on the north-east side of Aird da Loch, near the foot of Loch a' Mhuirt (two and a half miles east of Scourie), about 700 yards north-east of Cnoc Mhichie, and a quarter of a mile south of the south end of Loch nam Breac. Again, in some dykes black flinty strings, that might be

mistaken for tachylite, are exposed at various localities. They may be seen on the south side of the large irregular intrusion between the shear-lines half a mile south of Ben Strome, and in the broad dyke three-quarters of a mile S.S.E. of Loch Poll an Achaidh. A dyke crossing the Scourie road 250 yards north of Duartmore bridge is also fringed with a narrow band of black flinty rock, and the crushed rock in the thrust, 350 yards south of Loch Allt nan Reath (one mile southeast of Duartmore bridge), is crossed by fine-grained splintery strings.

Reference may be made to the apparent absence of basic dykes in the north-east belt adjoining Loch Laxford and Loch Stack. They possibly occur there also, but may have escaped recognition owing partly to the veins of pegmatite and granite-gneiss which traverse them, and partly to changes in lithological character induced by these acid intrusions. Such metamorphism resulting from the injection of granite and pegmatite may have led to a recrystallisation of both the early basic materials and the basic dykes into much the same types of rock. As already indicated, some slight evidence may be adduced to show that the foliated basic dykes change their character as the area of granite gneisses is approached, and hence still more marked changes might be expected within the granite gneiss belt. It is possible that thrusts exist in the north-east belt, though they have not been recognised.

In the area affected by the post-Cambrian thrusts, the most north-easterly basic intrusions that have been recognised run from a little south of Lochan Feith an Leothaid in a W.N.W. direction north of Glencoul river. South-west of Loch Beag, at the head of Loch Glencoul, basic dykes are numerous, and as far north-west as the margin of the Cambrian quartzite on Glas Bheinn. It seems probable that in the displaced gneiss north of that hill and between Loch Gainmhich and the Lochan a' Choire Ghuirm, dykes have been sharply folded on an extensive scale, so as to cause the same dyke to be represented by several more or less parallel outcrops. The outcrop of the broad dyke, which runs north-west from near the north end of Lochan a' Choire Ghuirm is such as might be produced by a repetition of folds with axial planes striking north-west. These supposed folds seem independent of the post-Cambrian movements, though they affect rocks which have also been displaced by the Glencoul thrust.

### **Ultra-basic dykes**

In this district only a few dykes of ultra-basic composition have been noticed. The best example is a picrite which occurs near Geisgeil, about two and a half miles south of Scourie. It is about 20 yards in width, and may be followed south-east for more than a mile, in or near the burn called Allt Crom Geisgeil. Narrow dyke intrusions like peridotite are exposed at the following localities: about 350 yards south-east of the east end of Loch na h-Airdh Sleibhe, north-west of Loch Crocach (one mile north of Duartmore Bridge), between the Ordnance Station 794 and the large dyke north-east of it, and about 30 yards to the south-west of the latter locality.

Dykes which seem to consist chiefly of small needles of hornblende, and which generally form trench-like depressions, occur half a mile south of Loch na h-Adh (three miles west of Loch Stack), and a mile and a quarter E.S.E. of Ben Auskaird. The rock at the latter place is unfoliated, and its course is more nearly east and west than that of the basic dykes.

### **Microcline-mica dykes**

The microcline-mica dykes occur in the neighbourhood of Kylestrome and Aird da Loch (between Lochs Glendhu and Glencoul). Where least deformed and unaltered, the rock of which they consist is of purple-brown colour, and shows faces, sometimes half an inch broad, of red felspar containing many inclusions of dark mica. Indeed, felspar forms a considerable proportion of the whole mass, and in the thin slices [\(S3242\)](#) [NC 224 349] and [\(S2734\)](#) [NC 255 333] it presents microcline structure. The rock is often much decomposed and weathers with an ochreous surface. The direction of some of the least altered of these dykes is north-east, but one of them runs north and south. In one case, to the west of the post-Cambrian thrusts, there are traces of foliation, which may be assumed to indicate that the dyke possessing this structure is of pre-Torridon age. Another dyke which seems to cross several basic dykes runs in a south-westerly direction from the south shore of Loch Glendhu (where it is about six feet thick and shows no distinct foliation), through Aird da Loch, to Loch Glencoul, and is accompanied by a fault that displaces the basic dykes. About 80 yards further east near Loch Glendhu, on the face of a crag called in the six-inch maps " Creag an Tombaca", various thin, vertical strips of dark micaceous schist, from two to six inches thick, cut the gneiss and run nearly east and west. They probably represent

finely foliated portions of the six-foot dyke, which have been twisted and altered along an east and west thrust. Their foliation planes have a general direction parallel to the sides, but they are considerably bent in places. Under the microscope the structure is seen to be that of a typical crystalline schist.

Another microcline-mica dyke, which is vertical, about four feet thick, and traceable for 60 yards in a north and south direction, occurs near the south side of the path half a mile N.E. of Kylestrome. At the-road it is deflected westwards by one of the pre-Torridonian thrusts. A specimen of this rock, analysed by Mr Barrow, gave the following result:

SiO <sub>2</sub>	57.30
TiO, Al <sub>2</sub> O <sub>3</sub> , P <sub>2</sub> O <sub>5</sub>	17.13
Fe <sub>2</sub> O <sub>3</sub>	5.31
CaO	4.25
MgO	4.44
K <sub>2</sub> O	9.05
NaO	0.40
Loss on ignition	0.53
	98.41

The total iron is reckoned as Fe<sub>2</sub>O<sub>3</sub>.

## The later granite gneisses

As already indicated, intrusions of granite-gneiss, later than the basic dykes, are extremely abundant in the north-east belt of the district. This belt gradually increases in breadth in an E.S.E. direction towards the scar of Cambrian quartzite. While near the entrance to Loch Laxford it is about half a mile broad, near Loch Stack it widens out to about a mile and a half; indeed, it is probable that the granite-gneisses continue to increme in development in an E.S.E. direction under the Cambrian rocks, for the thrust granite-gneiss between Loch More and Loch na Creige Duibhe is much wider than any single band of this rock west of the post-Cambrian displacements. Most of these gneisses take the form of sills, but some of them occur as dykes which strike more. nearly E. and W. than the neighbouring rocks. The intrusions of gneiss gradually disappear south-westwards; in the south-west belt a few thin bands may possibly belong to the same series.

The south-west limit of the area in which the granite-gneisses are specially abundant is defined by a broad sill, or series of sills, passing rather more than 400 yards north-west of Loch na Seilge, near Loch Stack (Sheet 107). This boundary is not, however, very definite, for a close set of parallel sills runs for a little distance on either side of the line taken on the map. The inclusions of older gneiss in this Loch na Seilge sill become more numerous north-westwards from Badnabay, until they finally surpass in bulk the granitic-gneisses associated with them. On the south side of Loch Bad an t-Seabhaig (three-quarters of a mile S.S.W. of Laxford Bridge), the sill dips on the average 45° or 50°, and the outcrop is about a third of a mile wide. North-eastwards for about a quarter of a mile, the earlier gneisses alternate with thin bands of granite-gneiss and pegmatite, followed by another broad sill which, near Loch Bad an t-Seabhaig, dips at about 50° and has a width of about 250 yards, which decreases towards W.N.W., and increases in the opposite direction.

Many of the sills are so nearly parallel to the bands of gneiss of the fundamental complex that evidence of their intrusion is not readily obtained. Their intrusive nature, however, is well seen on the hill one-third mile S.E. of Loch Bad an t-Seabhaig. The dyke at the road 40 yards south of Laxford Bridge, and the two on the south-west side of Loch Stack, a little south-west of the great sills, are unusually long and straight. The first continues for at least a mile and a quarter in a W.N.W. direction, and is from 15 to 35 feet wide. The sills at Rudha Ruadh and Loch na Seilge generally form lower and less craggy ground than the earlier gneisses. Their rock-exposures weather with rounded outlines, and are frequently crossed with gently-inclined parallel joints, which are in many localities nearly at right angles to the foliation. On the north-east side of Loch Stack, about a mile from the Lodge, both the granite-gneisses and the others are crossed by strong vertical joints striking about 18° east of north.

Most of the granite-gneisses are of a pale pink colour and contain many grains of felspar, often from 1–20 to 1–10 inch in breadth, which have either a red colour or a pale-bluish chatoyant lustre. In thin slices many of the grains show

microcline structure, but oligoclase is also abundant. In many of the thin bands and dykes, the felspar when fresh is almost colourless and the rock is pale-gray. The quartz grains, generally distinct on the weathered faces, sometimes, particularly near the outsides, have a reddish colour, and contain small inclusions of haematite. Many of the quartz streaks are distinctly elongated along the foliation planes, but the foliation is chiefly marked by the distribution of the dark ferro-magnesian constituents, of which biotite is generally the most abundant, appearing in small parallel flakes. Hornblende also is seen in abundance in the massive sills in the following places: Rudha Ruadh (a promontory at the mouth of Loch Laxford); half a mile S.S.W. of Laxford Bridge; a third of a mile E.S.E. of Loch Bad an t-Seabhaig; the northeast side of Loch Stack; and a third of a mile E.N.E. of Airdachuilinn. White mica rarely appears in the thick sills.

The granitic gneisses are seldom, if ever, thoroughly granulitic, but a mylonised structure, accompanied with some granulitisation, is common among them. Cataclastic action has affected the gneiss after it was already foliated, as will be referred to subsequently<ref>See sec, on pre-Torridonian movements, page 152.</ref>. A few thoroughly granulitic dykes occur within the south-west belt, and possibly represent intrusions of the same age as the granite-gneisses.

The Rudha Ruadh sill sometimes assumes a banded structure, from the occurrence of dark stripes which contain hornblende in more abundance than the rest of the rock. Such stripes are seen in the following localities: a third of a mile slightly east of north of Cnoc an Fhir Bhreige (south-west side of Loch Laxford), about 700 yards E.S.E. of Badnabay, near Allt na Suileig (about one mile S.S.E. of Laxford Bridge), and on the north-east side of Loch Stack, two-thirds of a mile from the Lodge. In the Loch na Seilge sill a banded structure has been noted in one place, about a third of a mile S.S.E. of the outlet of Loch Bad an t-Seabhaig.

The gneiss composing the broad intrusions is generally coarser than that in the thin sills and dykes, but in some localities within the former, and running generally parallel to their margins, some bands occur which are much finer in grain than the rest. Perhaps the latter differ in age from the others.

Broad bands of pegmatite are common in the massive intrusions. Thin pegmatites, from a quarter of an inch to six inches thick, are also abundant, running for the most part parallel to the foliation, and only an inch or two apart; on weathered surfaces they usually project slightly above the rest of the rock, and are of a paler colour. Some of the granite dykes never seem to be crossed by broad pegmatites, and it is probable, as will shortly be shown, that they are of later age.

Throughout this district the granitic rocks, excluding the pegmatites, are never free from foliation, which in the sills, in some of the dykes, and in most of the irregularly-shaped masses, is parallel either to the broad bands in the earlier gneiss, or to a second foliation which crosses these bands.

In certain dykes the foliation is parallel to the sides, and a parallel second foliation is sometimes visible in the earlier gneisses. Where the latter has not been developed, it is probable that the dykes may have formed lines of weakness along which movements proceeded without having much effect on the surrounding gneiss. Dykes, foliated parallel to the sides, may be seen in the headland E.S.E. of Eilean Port a' Choit (at the head of Loch Laxford), and half a mile north of Badcall Quay.

About 50 yards south of the south-east end of Loch a' Chain Altain (1 mile north-east of Loch Stack Lodge) a fine-grained granite-gneiss appears which sometimes behaves as a sill and sometimes as a dyke. The sill portion is for the most part foliated Parallel to its side, but in one place where both the gneissose granite and the earlier gneiss are bent and make an angle of 30° with their usual direction, there is a departure from this rule. At the bend the foliation in the granite-gneiss is not deflected but continues its normal direction, appearing as second foliation planes in the gneiss of the fundamental complex.

Thin bands of granite-gneiss are not uncommon in the basic dykes in the north-east part of the middle belt. They are met with, for example, in the broad dyke at the north-east side of Loch na Claise Fearna (one and a half miles W.S.W. of Laxford Bridge); a quarter of a mile east of the outlet of Loch an t-Seana Phuill; and rather more than half a mile W.N.W. of Loch na Seilge (one and a half miles west of Loch Stack Lodge). At each of these localities the foliation in the granitic intrusion is in the same direction, and about as well marked as that in the basic rock. In the last-mentioned locality the foliation planes make an angle with the sides of the granitic band, and can be traced from the one rock into the other.

All the granite-gneisses are not quite of the same age. Near the top of a scar 100 yards from Loch Stack, and rather more than three-quarters of a mile slightly west of north of Airdachulinn, a fine-grained granite-gneiss with short pegmatitic streaks overlies and apparently truncates a coarse granite-gneiss in which no such streaks occur: it seems also to truncate a nearly vertical pegmatite in the coarse rock. Another example occurs north-east of the terrace nearly a mile slightly south of east of Loch Stack Lodge, where a dyke of fine red foliated granite with thin parallel pegmatite streaks comes in contact with a sill of coarse granite-gneiss containing some thick pegmatites. The line of junction, visible for eight or nine yards, is approximately straight, and the foliation, both in the dyke and the sill, is in the same direction, and makes a small angle with the junction.

In the area west of the post-Cambrian thrusts the granite-gneisses which occur furthest south-west, and which we can with confidence claim as part of the same series as the Laxford granite intrusions, are seen in the following places: near the south side of Loch a' Mhuirt, a third of a mile from the foot, a third of a mile south, and two-thirds of a mile S.S.E., of the outlet of Gorm Loch, east of Scourie.

Other thin dykes, which may possibly belong to the same set of intrusions, but are now in a thoroughly granulitic condition, occur still further south-west in the following places: 70 yards off the north end of Loch an Laig Aird (one and a half miles north-east of Scourie, 200 yards west of Meall nam Breac, near the south side of Loch na Craobhe Moire (three miles E.S.E. of Scourie), and near the east end of Loch a' Bhaid Daraich. The dyke in the last locality can be traced in a northeast direction for half a mile.

## Pegmatites

Most of the coarse pegmatites are not foliated, which is perhaps due to their coarse grain, the plates of felspar and the quartz streaks being often several inches across. These veins are not all of the same age, for one is often cut by another, and the granite-gneisses which cut some pegmatites may in turn be cut by others. Some of the unfoliated pegmatites are cut by foliated granitic bands, and it is certain that the production of foliation had not ceased at the time these veins were produced. Pegmatites with graphic structure have been noticed in many places. Flakes of black biotite are tolerably abundant and sometimes large, as, for instance, in a graphic pegmatite two-thirds of a mile N.N.E. of the outlet of Loch an Leathaid Bhuain, where they are six or seven inches across. Grains and patches of some black iron ore, probably ilmenite, are common.

In the area west of the post-Cambrian thrusts pegmatites of the usual type, and several yards wide, cross, or occur within, foliated basic dykes, a quarter of a mile west of Loch na Seilge (west of Loch Stack Lodge) and a third of a mile west of Cnoc Bad na h'Achlaise.

Pegmatites are numerous in the N.E. belt of the district, where they are often several yards broad, and where, as already indicated, the granite-gneisses are most abundant. Many of them behave like sills for short distances, but their sides are rarely straight or sufficiently regular to be easily mapped. They decrease in number in a south-west direction, but even in the south-west belt broad examples occasionally occur. One conspicuous vein may be seen on the shore west of Scourie More, and east of Dubh Sgeirran, and another occurs near the road about 300 yards north-east of the Scourie Free Church.

Peculiar pegmatitic lumps, mostly varying in size from one to three inches across, and thin irregular streaks of similar material are often observable in, or at the sides of, bands of biotite-hornblende-rock. In the specimens of these pegmatites which have been examined the only felspar present is albite or an acid orthoclase. A thin pale-grey nearly horizontal pegmatite, only an inch thick, which displays an arrangement in layers parallel to the side and also a foliation crossing the margins, was noticed about 300 yards south of the west end of Loch Eileanach (two miles southwest of Loch Stack Lodge). Its outer layers are much finer in grain than those of the interior, and in both, the quartz streaks are arranged almost at right angles to the sides and parallel to the broad bands in the gneiss.

Among the Lewisian gneisses, reappearing above the Glencoul thrust plane, between Loch na Creige Duibhe and the Loch Beag of Glencoul, pegmatites occur in abundance, some of which cross foliated basic dykes.

About 140 yards W.N.W. of the top of Ben Stack, and nearly 200 yards from an outlier of Cambrian quartzite, the felspar in aegmatite has been partly converted into agalmatolite.

## Pre-Torridonian movements

The important lines of thrust and folding which took place before the deposition of the Torridonian strata, and by which such a profound modification of structure has been induced in the basic dykes and gneisses, are well developed in this area. In the tract which lies to the south of Scourie two main directions of these movements are observable, one trending about north-west and south-east and the other nearly east and west. The lines of disruption which run towards north-west, roughly parallel to the direction of the principal basic dykes, and often coincident with them for long distances, are perhaps the earlier of the two series. A marked example of them occurs in the large dyke between Scourie and Scourie More, which usually consists of a massive rock 50 yards in width. South of the Scourie road, however, it has been converted into a thin band of hornblende-schist, only a few yards wide, by a movement-line nearly parallel to the course of the dyke. Occasionally the north-westerly shear-lines are unconnected with dykes. The east and west lines of movement, however, are the most prominent. Most of them, as they approach the coast, incline more to the south of west, so that the direction becomes 20° or 30° south of west. An excellent instance may be traced inland for two miles from Duartbeg, about a mile south of Badcall Bay. The dykes on the north side of this thrust are apparently shifted at least a mile to the westward of their usual course. Other examples of displacement of the basic dykes occur in the area south of Loch na h-Airdh Sleibhe (one and three-quarter miles E.S.E. of Scourie), where the movement-lines run east and west, and are particularly numerous on the east side of Loch Bad nam Mult. They are not always straight nor of the same width; occasionally they branch and again unite, thus enclosing lenticular pieces of still granular gneiss. The large shear-zone north-east of Loch na Beiste Brice (three and a half miles S.S.E. of Scourie), which is about 130 yards in width and includes a band of limestone, splits up to the eastward into a great number of minor lines of movement, most of which die out or become unimportant, while its north and south margins continue as two great lines of disruption about 200 yards apart. The limestone just referred to is a lenticular mass tapering off both in an E.N.E. and W.S.W. direction, its length being about a quarter of a mile and its greatest breadth 25 yards.

Like all the adjacent sheared material, it is vertical. Two specimens of this rock have been examined microscopically. One ([S4646](#)) [NC 190 400] is a coarse-grained somewhat brownish aggregate of grains of ferriferous carbonate, together with some chlorite and a colourless mica. Another specimen ([S4894](#)) [NC 190 400] is a coarse-grained foliated rock largely composed of calcite, biotite, and hornblende, with epidote as an accessory.

Much vein-quartz has been developed in places along these movement-lines. A fine example of this is shown in (Plate 23), which represents a part of the shear zone near the north end of Loch na Coille, about three miles and a quarter south of Scourie. In some places the veins are themselves schistose parallel to their sides.

From the south slope of Ben Dreavie to near Ben Strome, a considerable tract, nearly two miles broad, is almost free from such thrusts. The two lines of disruption which bound it gradually approach each other westwards, until the breadth of less altered gneiss between them on the sea coast is only about a quarter of a mile. The thrusts seem not unfrequently to die out in an east or north-east direction: there are, for instance, many sheared bands on the coast at and near Creag a' Mhail, Scourie, which cannot be followed half a mile inland.

In most districts the thrusts and limbs of fold near them are nearly vertical. In the south part of the south-west belt they sometimes hade to north — a remarkable feature in view of the S.S.W. inclination of nearly all the axial planes of fold in the middle and north-east belts. About 300 yards south-east of Loch Dubh a' Chnoic Ghairbh (one and a quarter miles north-west of Kylesku), a thrust in some places dips north-west at 30° degrees, and in other places is nearly horizontal.

Along many thrusts, the dykes are broken into wedges, the sides of which represent crush-lines, so that the intrusive character of the rock is no longer apparent. In the thrust on the north side of Loch a' Ghille Ruaidh (one mile north of Kylesku), at least four dyke stripes may be seen near the north-east end of the loch. As the broken or ruptured rocks are often finely sheared, it is probable that the ruptures took place towards the close of the movements. In other cases the evidences of rupture are less pronounced, and the zones of alteration perhaps represent merely areas of sharp contortion. From the prevalence of foliation in the dykes in the middle belt, even where no ruptures have been detected, it

is inferred that foliation may often have been induced in dykes in consequence of folding. In the granulitic bands in the south-west belt the foliation in some of the dykes may also have been first set up during a period of folding.

It seems probable that in places where groups of close folds traverse vertical dykes which originally ran diagonally to the strike of the axes of plication, the course of each dyke has been bent, so as to make a less angle with these axes. If we take a sheet of paper and draw parallel black lines on it to represent dykes running in a north-west direction, and then fold the middle strip of the sheet into small folds with axes striking east and west, it will be seen, that, (1) the effect of the plication is to deflect the direction of the dykes and bring it nearer to east and west, (2) the changed paths of the dykes run in a westerly — not easterly — direction from their prolongations on the south side, (3) the dykes are diminished in breadth in the folded area in proportion to the closeness of the folds.

As a general rule the dykes are shifted westward on the north side of the thrusts, which is what might be expected, even if no actual rupture had occurred. A mile and a third E.S.E. of the top of Ben Auskaird, the gradual bending, thinning, and production of foliation in a broad dyke near a line of disruption can be clearly seen. About 20 to 30 yards on either side of the thrust, the dyke averages 50 yards in width, but in the deflected portions it is only three or four feet. Indeed, for a distance of 160 yards within the shear zone, no dyke-rock can be seen, but red crush-strings appear in the granulitic gneisses, striking parallel to the axes, of folding. Further west, three-quarters of a mile south of Ben Auskaird, the evidence for the gradual bending of this dyke on the north side of the disruption is less satisfactory, and the rupture there is probably greater.

It is important to note that in those cases where dykes have apparently been driven westward, on the north side of a thrust, the lines of stretching or elongation of minerals, both in the foliated dykes and granulitic gneisses, are generally diagonal, with their lower ends on the observer's right hand as he faces the north. On the other hand, in those rarer cases, where the dykes have been shifted eastward, the lines of stretching are generally diagonal, with their lower ends on the observer's left hand as he faces the north. These latter phenomena are seen in the most southerly of the thrusts which affect the broad dyke in Creag a' Mhail, north of Scourie Bay, about 160 yards east of the west point of the Creag, and more clearly close to, and about 350 yards north west of, the north-west end of Lochain Bealach an Eilein.

In some thrusts, the dykes show no lateral displacement but are cut into stripes separated by granulitic gneisses, and with their long axes parallel to the plane of disruption, an example of which is seen about 700 yards east of Cnoc na Glaise Moire (two miles E.N.E. of Scourie).

A further feature connected with the movements which have taken place along the lines of the dykes is well displayed by some examples in this district, where the gneisses next to the intrusive rock have been involved in the changes of dip and structure. Thus, in the case of the dyke which occurs at Creag a' Mhail, near Scourie, Mr Teall has noted that "the original character of the junction has been to a certain extent modified by subsequent movement more or less parallel with the margin of the dyke. This is indicated by the curving upward of the fella of the gneiss and by a change in structure from granitic to granulitic, as represented in (Plate 21). At the point where the photograph reproduced in this Plate was taken, a zone of disturbance crosses the dyke obliquely, and can be followed into the gneiss. Its course is indicated by quartz-veins, and the conversion of the massive rock of the dyke (which is here an epidiorite) into a hornblende-schist. The surrounding or 'country' rock is a biotite-gneiss".

As they approach the thrusts the less-altered gneisses may often be observed gradually to change their strike and dip, so as to become parallel, or almost parallel, to the strike of the contiguous granulitic bands, while, coincident with the alteration in strike, changes in lithological structure gradually appear. The gneiss is usually sharply folded along axial planes parallel to the strike of the granulitic bands. In this plicated zone the old broad bands in the gneiss are considerably thinned and modified in structure, but they can often be recognised, especially near the axes of fold, where there has been less drag than in the limbs.

Parallel to the axial planes of folia, or sometimes parallel to an adjacent line of rupture, a second foliation is set up which obscures the early bawling. But in places where there has been a distinct banding in the gneiss before the movements began, that banding is not wholly destroyed, except in the lines of rupture which occur within, or at the sides of, the folded areas.



In some places the modified old banding is parallel to the second foliation, and also to various lines of rupture, and, in such cases, it is uncertain whether some streaks represent lines of rupture or old bands with a greatly-modified structure. But it is rare to find exposures more than a few yards wide wherein the old banding cannot be recognised. The foliation in most parts of the granulitic gneisses represents an old banding which existed before these gneisses acquired their granulitic structure, just as the banding in schist of sedimentary origin represents an old banding (bedding). The old bands have, however, in both cases been intensely altered in physical arrangement and lithological structure.

The apparent amount of the displacement of dykes along the same line of disruption varies considerably, as shown in the case of the Ben Strome thrust. From half a mile E.N.E. of the top of Ben Strome, north of Loch Glendhu, a thin finely schistose dyke runs in an east or slightly north of east direction along the line of movement. Further west, the predominant materials in this thrust are flinty crush rocks, some of which seem to have been made out of the gneiss and others from the basic dykes. The apparent amount of displacement of this schistose dyke cannot there be less than a mile and a quarter. Again, a little N.N.E. of Loch Allt nan Ramh (one and three-quarter miles N.N.W. of Kylesku) the apparent displacement along the same thrust is not more than a third of a mile. Nearly three-quarters of a mile slightly west of north of the outlet of the same loch it is not appreciable, but by Loch Eucail it again becomes considerable.

Some of the phenomena seen along this Ben Strome thrust recall those observed in parts of Argyleshire, where groups of parallel basalt dykes approach older planes of disruption. The dykes follow these crush lines often for considerable distances with diminished thickness. They have also been affected by renewed movements along the same lines of weakness, but they have never been converted into schists or into flinty rocks like the pre-Torridonian dykes. The difficulty of explaining the variation in the displacement of dykes would be lessened, if we might suppose that a line of weakness already existed along the thrust, before the intrusion of the dykes, and that certain dykes followed this path for varying distances. The movements that followed might efface the evidence of such an early line of weakness. If such a disruption did exist, the interval between its formation and the intrusion of the dykes may have been considerable, and it is not necessary to suppose that at the time of the intrusion any movement was in progress along the line. In a few places the dykes have been folded after they were already in a foliated condition, an example of which occurs on the south-east side of Gorm Loch (three and a half miles east of Scourie).

In the north-east part of the middle belt, particularly near and in some broad yellow-weathering bands of crushed gneiss which run W.N.W. from Loch na Seilge to near Loch na Claise Fearna, the dykes are frequently crumpled, displaced, or represented by rows of lenticles. In some cases the constrictions between adjacent lenticles are probably due to thrust or crush-lines which have broken across an intrusion that was originally of regular dyke shape. In other cases the lenticles lie in lines parallel to the directions of the chief movements in the locality. A remarkable string of lenticles of this kind occurs two-thirds of a mile W.S.W. of Cnoc Bad na h-Achlaise and half a mile E.S.E. of the north-east end of Gorm Loch, the largest of which is about 100 yards long and 30 yards broad.

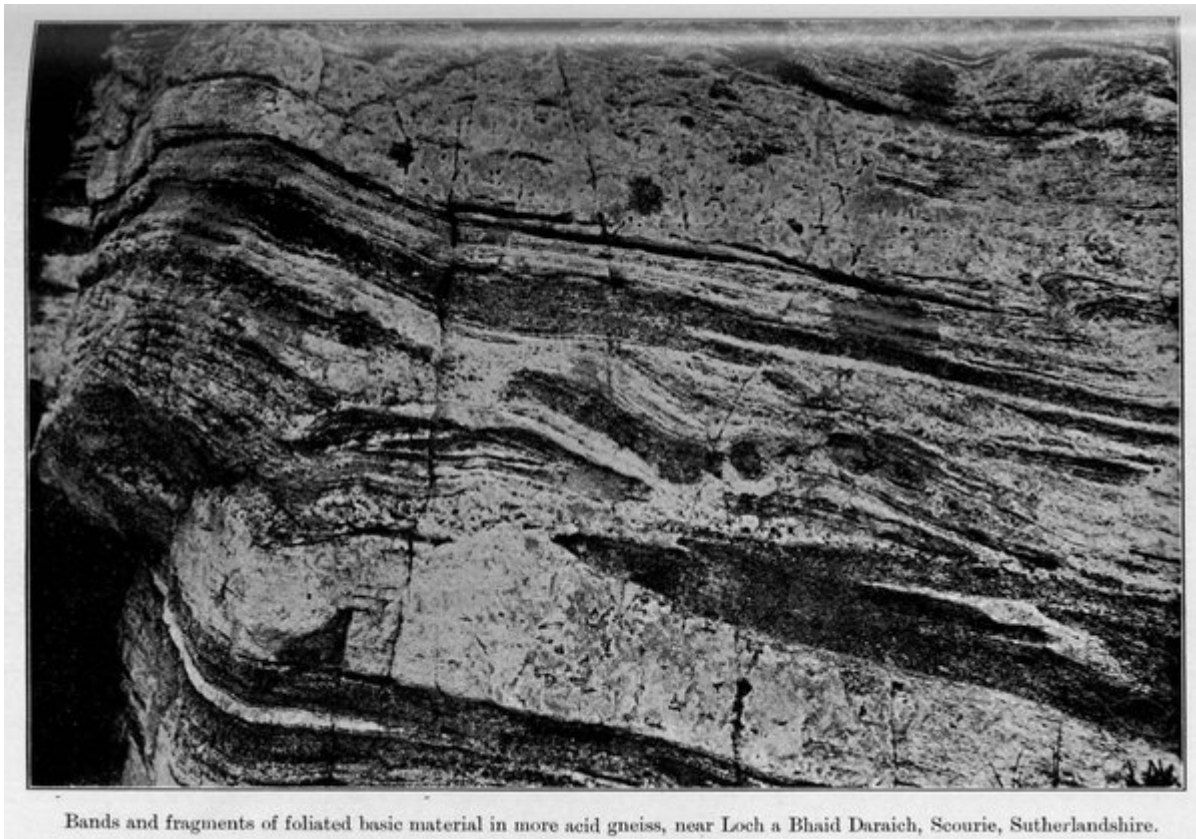
In many places, particularly in the middle belt, the foliation crosses the sides of dykes for great distances, and is parallel either to the early banding of the gneiss (in a modified form), or to a second foliation which crosses that banding in a direction parallel to the axial planes of fold. The later foliation in the gneiss corresponds to that in the dykes, and the schistosity common to both must have been produced at the same time. Where the foliation in the dyke agrees in direction with the early banding of the gneiss, then the latter is not in its original condition, but represents both the early banding and a second foliation which locally agrees in direction with the early banding, just as bedding and foliation often coincide in foliated sedimentary rocks.

The movements which were accompanied by the granulitisation of the gneiss and the foliation of the dykes were succeeded by others which mylonised the rocks, or which produced compact flinty material. The former condition chiefly presents itself in the granite-gneisses and pegmatites in the north-east belt, while the latter appears most commonly in the south-west district. A red granite-gneiss in the headland nearly a third of a mile northwest of Eilean Port a' Choit is mylonised in several bands, a few inches thick, nearly parallel to the old foliation planes. The matrix of the bands is extremely fine grained, but it encloses various small eyes of red felspar, and the movement planes display a faint sericitic lustre. Granite-gneiss bands in a partially mylonised condition occur also in the following places: three-quarters of a mile E.N.E. of Loch Stack Lodge, 300 yards south-east of Eilean Port a' Choit (at the head of Loch Laxford), a third of a mile and 350 yards S.S.W. of Badcall Quay, 300 yards and about 1000 yards slightly north of west of Laxford Bridge, and a

third of a mile S.S.W. of the foot of Allt an Rabhail, a tributary of the River Laxford. In the first three of these localities, pegmatites have also been partly mylonised and converted into fissile schists with parallel red and white streaks. In the last two localities this type of deformation occurs in dykes foliated parallel to the side, and as the mylonised bands are likewise parallel to the margins of these intrusions, it is evident that the dykes formed lines of weakness along which movements were repeated. Throughout the north-east belt the effects of such movements are more conspicuous in the granite-gneisses and pegmatites than in the gneisses of the early complex.

Along the Ben Strome line of disruption flinty crush rocks are especially abundant in the part between a third of a mile E.N.E. of the top of Ben Strome and Allt na h-Airbh, whilst further east the materials in the thrust are finely foliated or granulitic, but show less cataclastic structure. It is possible that the granulitic and flinty crush rocks were being formed simultaneously in different parts of the same line of movement, but it is also possible that, as in other localities, the rocks were first granulitised or finely foliated, and then subsequently crushed, and that this later deformation has in certain places destroyed the evidences of the earlier stages of alteration.

In the middle belt various bawls of yellow-weathering pyritous gneiss, often with small red garnets, are crossed by lines of fracture, most of which run nearly parallel with the strike of the early banding. These bands often give rise to little valleys or tracts which are smoother than the surrounding areas. One forms a flattish strip about half-way up the north-east side of Ben Stack, and can be followed from Airdachuilinn past Loch na Seilge and the head of Loch an t-Seana Phuill to the coast near Tarbat (one mile south-west of Loch Laxford), the width, between the two lochs mentioned, varying from 100 to 200 yards. In some of these gneisses considerable movement has taken place along some of the foliation planes. Between two parallel straight bands of gneiss a narrow stripe may occasionally be noted, in which the laminae are contorted along axial planes which strike at a considerable angle against the even gneiss on either side. An arrangement of this kind is well seen near the burn rather more than a third of a mile N.N.E. of the outlet of Gorm Loch, three and a half miles east of Scourie.



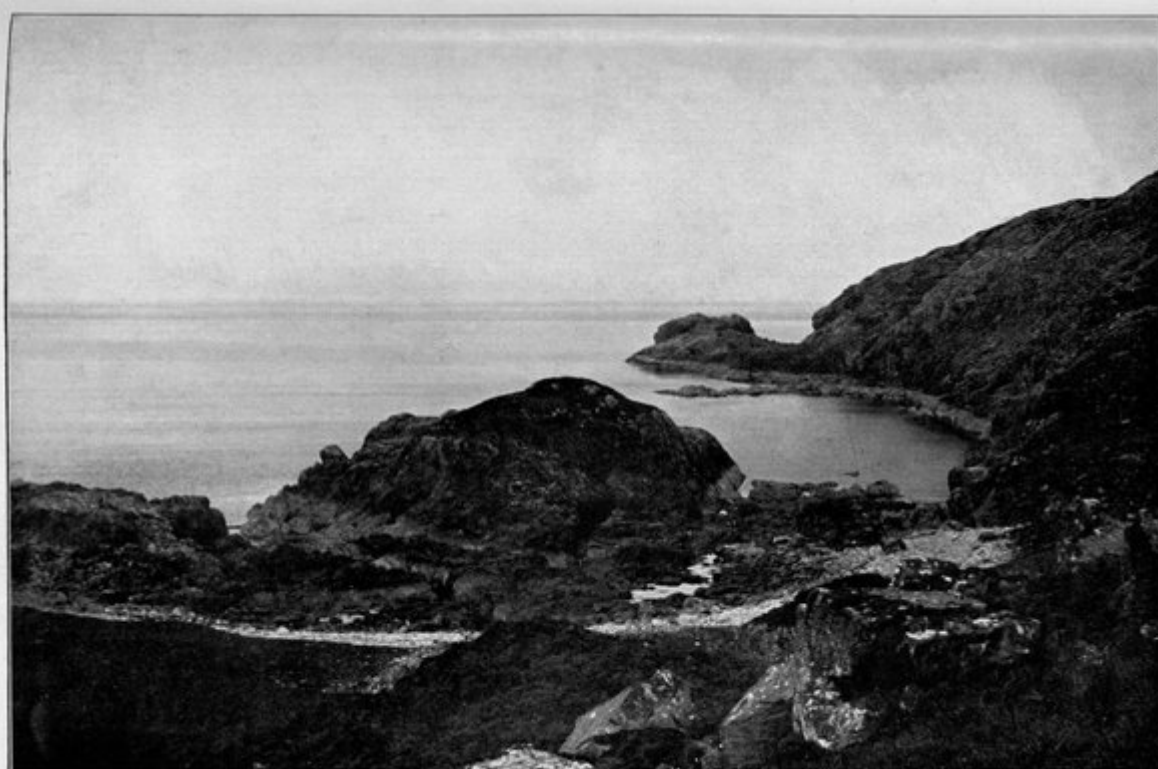
Bands and fragments of foliated basic material in more acid gneiss, near Loch a Bhaid Daraich, Scourie, Sutherlandshire.

*(Plate 14) Bands and fragments of foliated basic material in more acid gneiss, near Loch a' Bhaid Daraich, Scourie, Sutherlandshire.*



Junction of basic dyke with banded pyroxenic or hornblende Gneiss,  $\frac{1}{4}$ -mile south-west of Loch a Bhaid Daraich, Scourie, Sutherlandshire.

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



Dyke in Gneiss, Creag a' Mhail, Scourie. The notch in distant promontory, the small bay in middle distance, and notch in foreground are due to the dyke.

*(Plate 19) Dyke in gneiss, Creag a' Mhail, Scourie. The notch in distant promontory, the small bay in middle distance, and notch in foreground are due to the dyke. B8*



Granulitic Gneiss with quartz veins in secondary shear zone in Lewisian Gneiss. Duart Beg,  $1\frac{1}{4}$  miles south of Badcall Bay, near Scourie, Sutherlandshire.

*(Plate 23) Granulitic gneiss with quartz veins in secondary shear zone in Lewisian gneiss; Duart Beg,  $1\frac{1}{4}$  mile south of Badcall Bay, near Scourie, Sutherlandshire. B14*



Junction of Gneiss and dyke ; dyke on the right, Gneiss on the left. Secondary movement has taken place along the nearly vertical junction plane. Crag 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. Crag a' Mhail, north side of Scourie Bay, Sutherlandshire. B10*