

THE GEOLOGY OF THE FOYERS PLUTONIC COMPLEX AND THE
SURROUNDING COUNTRY

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MAPS

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One Inch to the Mile. The Foyers Plutonic Complex and
Surrounding Country

One Inch to the Mile. The Morvern-Strontian "Granite" Complex.

Six Inches to the Mile. The Gleann Liath Series

Horizontal Section across the Foyers Plutonic Complex.

The above maps and section are contained in the pocket at
the end of the thesis.

I. INTRODUCTION

A. PHYSICAL FEATURES

The district with which the present investigation is concerned lies in the county of Inverness along the south-east shore of Loch Ness. The area to be described extends from Loch Dun Seilcheig in the north-east to Beinn a' Bhacaidh in the south-west, and from Loch Ness-side south-eastward to Beinn Bhuraich.

From Loch Ness, the ground rises very steeply to an average height of 700 ft., forming a ridge of rocky crags along the side of the loch. Beyond Foyers, to the south-west, the ridge becomes higher and less regular in form; beyond Loch Knockie rising to 1812 ft in the rugged peak of Beinn a' Bhacaidh. To the south-east the ground slopes more gently to Strath Errick, a broad strath running parallel to and some two miles from Loch Ness. The middle of this hollow is occupied by Loch Mhor, the reservoir of the British Aluminium Company's factory at Foyers and formed by the union of two smaller lochs, Farraline and Garth. To the south-east again of Loch Mhor the ground rises to form smooth and generally grassy hills, with frequent exposures of bare rock on and near their summits. These hills reach a height of 2560 ft in Beinn Bhuraich, some three miles from Loch Mhor (Plate I)

The principal rivers which drain the district are the Farigaig and the Fechlin. The Farigaig rises in the high hills to the north of Beinn Bhuraich, one of its tributaries

coming from Loch Conagleann in the deep rocky gorge of Conagleann (Plate 4 A). The Farigaig first flows northward toward Loch Ruthven and Strath Nairn, then turns sharply to the south-west, about a quarter of a mile from Loch Ruthven, and flows into Loch Ness at Inverfarigaig.

The head-waters of the Fechlin lie to the south of the Strath Errick district, in the hills between Killin and Glen Markie (Laggan). The streams from these mountains unite to form the River Killin, which flows into Loch Killin, a small narrow loch, with a maximum depth of 67 ft. lying between high rocky crags. From Loch Killin, the outflowing river is known as the Fechlin. At Whitebridge it unites with the River Brein (Allt Breinag) which has its source in the mountainous district of Glen Doe Forest above Fort Augustus. The Fechlin flows into Loch Ness at Foyers. Like all the streams which fall into Loch Ness, the Fechlin has cut a deep rocky channel through the ridge bordering the loch, and in it occur the famous Falls of Foyers. The waters of the Fechlin are now, under the British Aluminium Company's hydro-electric scheme, augmented in dry weather by water from Loch Mhor, which is poured into the Fechlin from the reservoir along the River Gourag. Loch Mhor itself is fed by the Aberchalder Burn -- rising in the Beinn Bhuraich district, and by the River E, rising in the hills east of Killin. The E originally joined the Gourag directly, but has now been diverted into Loch Mhor (Loch Garth) at Garthbeg. The construction of the reservoir raised the level of Loch Garth some 20 ft., and the present Loch Mhor has a rise and fall of 22 ft. In dry weather, large areas of the floor of Loch Mhor are exposed; parts are flooded only in winter, and in summer carry

grass on which cattle are pastured. When the water in both the Fechlin and the Loch Mhor reservoir is at a low level, all the water in the Fechlin above the Falls is diverted into the intake of the hydro-electric works, reducing the waterfalls in the gorge below to a mere trickle. It is often stated that the Falls of Foyers have been "spoilt" by the hydro-electric works, but it seems that they were always reduced to a trickle in dry weather. Dr. Johnson wrote in his "Journey to the Western Islands of Scotland" (1775) :-

" Towards evening we crossed, by a bridge, the river which makes the celebrated fall of Fiers. The country at the bridge strikes the imagination with all the gloom and grandeur of Siberian solitude. The way makes a flexure, and the mountains, covered with trees, rise at once on the left hand and in the front. We desired our guides to shew us the fall, and dismounting, clambered over very rugged crags, till I began to wish that our curiosity might have been gratified with less trouble and danger. We came at ~~last~~ last to a place where we could overlook the river, and saw a channel torn, as it seems, through black piles of stone, by which the stream is obstructed and broken, till it comes to a very steep descent, of such dreadful depth, that we were naturally inclined to turn aside our eyes.

" But we visited the place at an unseasonable time, and found it divested of its dignity and terror. Nature never gives everything at once. A long continuance of dry weather, which made the rest of the way easy and delightful, deprived us of the pleasure expected from the Fall of Fiers. The river having now no water but what the springs supply, showed us only a swift current, clear and shallow, fretting over the asperities of the rocky bottom, and we were left to exercise our thoughts, by endeavouring to conceive the effects of a thousand streams poured over the mountains into one channel, struggling for expansion in a narrow passage, exasperated by rocks rising in their way, and at last discharging all their violence of waters by a sudden fall through a horrid chasm".

The sight of the Falls of Foyers when the Fechlin is in spate, after rain or snow, is indeed one of great magnificence. The peat-stained water heaves itself through the narrow gorge and over the two waterfalls, breaking into amber-coloured waves, the spray rising like mist to the pines on the crags upon either side of the gorge, three hundred feet above the stream.

Along the river valleys and in Strath Errick, there are a number of fields under arable cultivation; but for the most part, the district consists of moorland and hill grassland, interspersed with birch woods and the dense fir plantations belonging to the British Aluminium Company. Outcrops of rock are frequent over most of the moor and hill country, and in the stream courses.

The rough moorland and hill country support a number of sheep, both red and roe deer, and a few grouse, the number of the latter having much diminished within recent years. The numerous small lochs which occur scattered throughout the whole district frequently contain trout; salmon are unable to ascend the Fechlin because of the great height of the Falls (the lower fall is nearly 100 ft high).

Like most Highland districts, Strath Errick has suffered great depopulation, and ruined crofts and farms are frequent. Even in Knockie Forest, between the River Brein and Loch Ness, and now entirely given over to rough moorland and encroaching bracken, the home of the deer, the fox and wild cat, one may find some ruined buildings and short stretches of old tracks, pointing to a much greater use of the land in earlier times. Many of the primitive buildings were probably built of turves and branches so that no trace now remains of settlements which existed prior to the development of sheep farming in the Highlands.

The Foyers limestone was worked for local use both on the land and for building purposes, before the construction of the Caledonian canal and the consequent possibility of buying lime from the south.

Bog iron was worked in an ancient bloomery on the slopes of Carn Liath above the Allt an Rathain Ruaidh, near Aberchalder. Its site is marked by a few small piles of slag, near the line of an old drove road (now nearly obliterated) from Croachy to Killin.

The Foyers granite has been quarried at various times to provide stones for building and for road metal. There is a local tradition that the granite from the Garthbeg quarry was once exported from the district, being shipped from Inverfarigaig to Ireland, but I have been unable to verify this. The hard siliceous schists of Cnoc Carrach were quarried to provide the material for the reconstruction of the road from Whitebridge to Killin in 1944.

A glossary of the Gaelic place names referred to in the text is given at the end of the thesis.

B. SUMMARY OF GEOLOGY

The geological formations and rock groups of Strath Errick and Foyers are :-

- Pleistocene & Recent : Peat, freshwater alluvium.
Fluvio-glacial sand & gravel. Boulder clay
- Middle Old Red Sandstone : Conglomerate with thin sandstone bands.
Basal breccia.
- Foyers "Granite" : Plutonic complex of tonalite, granodiorite
and granite.
- Moine Schists : "Injection" gneisses
Semi-pelitic and siliceous schists.
- ? Lewisian : Gleann Liath series -- including the
Foyers limestone.

The oldest rocks of the district appear to belong to the Gleann Liath series; they outcrop in a narrow strip along Gleann Liath near Foyers and include the Foyers limestone. It is suggested that these rocks may be referable to the Lewisian.

The Foyers "Granite" is intruded into Moine schists (Central Highland granulites). The schists include both ordinary semi-pelitic and siliceous types, and permeation gneisses ("injection" gneisses). They have a regional north-easterly strike which round the plutonic complex, is modified to conform to the margins of the intrusion. In Strath Errick, their strike, therefore varies from north-westerly to north-easterly. The beds are highly folded and the dip is usually near the vertical. The period of regional "injection" and permeation is evidently earlier than the intrusion of the Foyers "granite", for the latter cuts across the permeation gneisses and contact-alters them. The earliest members of the Foyers plutonic complex appear to have belonged to the appinite suite. Xenoliths of appinite occur in the main complex, and several masses outcrop in Knockie Forest on the margin of the complex. The main Foyers complex is made up, however, of tonalite, granodiorite and granite. Its principal outcrop is in Strath Errick, covering about 25 square miles, and extending into the hills along the Aberchalder Burn and the River E. Some small satellites of the Foyers complex occur in Knockie Forest and bring the total area of the plutonic rocks up to about 27 square miles.

The schists and "granite" complex are cut by a few pegmatite and aplite veins and by dykes of felsite and lamprophyre.

The Middle Old Red Sandstone outcrops in a narrow strip bordering Loch Ness, finally dying out just to the south-west of Foyers. It rests unconformably upon the Gleann Liath series, the Moine schists and the Foyers "granite", and contains boulders derived from all these formations. The Foyers "granite" was therefore intruded later than the regional "injection" of the Moine schists, but was undergoing erosion in Middle Old Red Sandstone times. It may therefore be referred to the Caledonian intrusions of so-called "Newer Granites".

The Middle Old Red Sandstone is predominantly composed of conglomerates in the Foyers area. A few thin bands of red sandstone occur and there is a well developed basal breccia. The basal breccia is evidently a scree formation, and varies markedly with the underlying rock from which it was derived. The unconformity is magnificently exposed at Creag Dhearg and Crag nan Clag in the north-east of the district, where the breccias rest on the Moine schists; it is fairly well exposed at Dun Deardail near Inverfarigaig, where the Middle Old Red rests on the Foyers granodiorite, and again at Foyers limestone quarry, where it rests on the Gleann Liath series.

The whole of the Strath Errick district was heavily glaciated, the direction of ice movement being along the Great Glen in a north-easterly direction. Striated surfaces and roches moutonnées forms are of frequent occurrence. Much of the country is covered by boulder clay and by coarse fluvio-glacial gravels. At Whitebridge, on the side of Beinn Sgurrach, a fine series of terraces of coarse gravel occur (Plate V A 7). These terraces can be traced intermittently along the hillside to

Migovie and Aberchalder.

At some period during the melting of the ice, water appears to have spilled over the col between Beinn Sgurrach and Leachd nan Cisteachan. Upon the Strath Errick side of the ridge, the bed of a magnificent "fossil" waterfall can still be traced, the plunge pools of which are now filled in with peat. The water descended, in a series of three main falls from the top of the ridge, at about 1250-1300 ft, to 700 ft at Loch nan Losganan.

The pre-glacial course of the River Fechlin appears to have been along Gleann Liath (Plate III A) and into the Pass of Inverfarigaig (Plate XII A) to Loch Ness. The present gorge at Foyers is a post-glacial cut.

The principal fault affecting the rocks of this district is that of the Great Glen along Loch Ness. Along the loch-side the rocks are greatly crushed and altered, the Middle Old Red Sandstone conglomerates often being intensely compacted and hardened. A branch fault extends from Loch Ness near the mouth of the Allt an t-Sluichd (from Loch Kemp) along Gleann Liath. To this fault-line is due the deep, narrow and remarkably straight valley of Gleann Liath (Plates III A, XII B). Lines of crushing are, however, common throughout the whole district. In several localities, crush breccias have been formed, remarkably similar in appearance to the basal breccias of the Middle Old Red Sandstone.

C. RELATION OF GEOLOGY TO SCENERY

There is a close relationship between the scenery of Strath Errick and the underlying geology.



- A. Strath Errick from Cnoc Carrach. In the middle distance are Lochs Farraline and Garth (Loch Mhor) and the low-lying ground occupied by the Foyers "granite". The higher hills to the right are carved mainly in the Moine schists. In the distance are the hills of Middle Old Red Sandstone conglomerate, and the escarpment of the Middle Old Red on the schists at Crag nan Clag and Creag Dhearg. To the left, the Great Glen and Loch Ness.



- B. From Meall a' Bhuailt looking to Loch Garth and Carn Choire Riabhaich. The low-lying country is in the Foyers "granite", from which the schist ridge, ending in Carn Choire Riabhaich, rises steeply. The distant hill masses are on the north side of the Great Glen and include Mealfuarvonie.



- A. Typical Middle Old Red Sandstone topography. Tom Bailgeann(left) and Dunchia(right)from Carn an Dubh-ghlaic. The nearest loch is Ce-glais, beyond it is Dun Seilcheig. The escarpment of the Middle Old Red Sandstone on the Moine schists is to the extreme right.



- B. Typical schist country (Moine "injection" gneisses). From near Bochruben Farm(seen in foreground of A, above). Escarpment of Old Red Sandstone to left. Loch Ruthven, in the middle of the picture, is surrounded by rugged hills of gneiss.

The Middle Old Red Sandstone gives rise to rather bare and rounded, rocky hills, the rock faces being usually of a pink or reddish colour. They are frequently guttered by deep gullies cut by storms. The conglomerates tend to form sheer crag faces, of which the most impressive is perhaps Crag nan Glag (Plate X A) . The Moine schists, on the other hand, weather grey, and form hills of more ragged form. The "injection" gneiss, in particular, gives rise to grey craggy peaks, the bases of which are strewn with huge fallen blocks of gneiss (Plate IV A). The siliceous and semi-pelitic schists give rise to softer forms and more rounded hills; whilst in Knockie Forest, Beinn a Bhacaidh, carved in schistose grits, is rugged and rocky, with a jagged outline somewhat reminiscent of Ben Venue in the Trossachs (Dalradian schistose grits).

The Middle Old Red Sandstone in the Crag nan Glag district rests on the Moine schists, forming an escarpment, along the base of which the unconformity is well exposed. This escarpment is a prominent feature of the skyline from most parts of Strath Errick. The change in scenery at the escarpment, from the Middle Old Red Sandstone type to that of the Moine gneisses, is very marked (Plates II A & B, X B), and its character is reflected in the Gaelic names of the hills -- Tom, implying a smooth, rounded mountain in the Old Red Country, and Stac (meaning a precipice or a steep hill) and Craig for the hills about Loch Ruthven in the gneiss.

Whilst the Moine schists tend to form high ground, the Foyers "granite" forms the lower lying district of central Strath Errick. The line of contact between the intrusive

complex and the schists is often marked by a sudden change of level, the schist hills rising steeply ~~from~~ above the "granite" outcrop (Plate I B). The valleys of the Aberchalder Burn and the River E largely coincide with the two bays which extend back from the main outcrop into the hills, and there form two low lying districts separated by the higher schist ridge of Beim Mheadhoin and Carn Choire Riabhaich. Upon the Aberchalder side of this ridge, the line of contact between the grey schists and the white rocks of the "granitic/ complex can be seen at some distance, because of the contrast of the colours. (Plate I B)

The formation of the valley of Gleann Liath along a line of crushing and faulting has already been referred to (p 8). The course of the River E is partly along a line of crushing. The long straight course of Loch Ness and the Great Glen coincide with the trend of the Great Glen Fault. The sides of Loch Ness, both above and below water level, are steep or precipitous whilst the actual bottom of the loch is flat. It has, therefore, the characteristic form of a rock basin. It has a maximum depth of 754 ft, descending some 700 ft below sea level.

D. HISTORY OF PREVIOUS RESEARCH

Prior to the present investigation, very little geological research appears to have been done in the Foyers and Strath Errick district. Sheet 73 of the one-inch Ordnance maps (Old Edition) has not yet been surveyed by the Geological Survey. The presence of a complex of granitic rock near Foyers has been known for a considerable time, and its approximate shape is shown on the 10 miles: 1 inch geological map of Scotland (1910 edition)

published under the direction of Sir A. Geikie. The Middle Old Red Sandstone is shown as a strip extending along Loch Ness-side to a point opposite Invermoriston. These outlines are adopted on all subsequent small-scale geological maps of this part of Scotland, although in 1879 Mr. Wallace of Inverness had described the unconformity of the Middle Old Red Sandstone on the schists at Crag nan Clag and Creag Dhearg, and had pointed out that part of the old mapping was incorrect. He remapped the boundary of the Middle Old Red Sandstone as far as Bochruben, and the present research has confirmed his work, and made considerable alterations to the boundary of the Old Red further to the south-west. Mr. Wallace described the Dunchia conglomerates as well as the details of the Crag nan Clag unconformity (1879 p 204), and was the discoverer of the Fish bed at Lochan an Eoin Rudha. Mr. Wallace noted the sun-cracked sandstones which outcrop near Loch Ashie in the same district (1883 p ²⁷⁵ ~~337~~). In ~~the~~ ^a latter paper (1887 p 367), he described the terraces above Whitebridge on Beinn Sgurrach and mentions the fact that the gneiss of Loch Killin is interbedded with micaceous schists and "garnetiferous quartzites" (calc-silica bands in the Moine series).

Considerably earlier, A. Boué had visited the Falls of Foyers. He describes, in some detail, the outcrops of granite in the vicinity of the Upper Falls (1820 p 20) and also gives an account of the Middle Old Red Sandstone exposures along Loch Ness in the same district (1820 p 105).

Nicol (1844, p 194) mentions the presence of granite in Strath Errick and says that it is sometimes "sienitic"

and sometimes porphyritic. He also mentions the great hardness of the Old Red Sandstone conglomerate in the country between "Fyres" (this appears to be the old spelling of Foyers) and Inverness.

The presence of limestone in Gleann Liath is mentioned by Mr. Wallace (1887 p. 367) as well as the vein of graphic granite cutting it. Professor Heddle refers to this graphic granite (1901, Vol.II. p. 43) and says that the blue mineral Abriachanite occurs "disposed upon the letterings of quartz"). The limestone from the quarry at Foyers has been described in some detail in the Geological Survey's wartime series on Scottish limestones (T. Robertson & J. Knox, 1942 p.11). But prior to the present study, no attempt seems to have been made to study the series in which the limestone occurs, as a unit, or to attempt to correlate it with other Scottish rocks.

E. PRESENT INVESTIGATION

During the present investigation, the Strath Errick and Foyers district has been mapped on the six-inch scale. The boundary of the Middle Old Red Sandstone has been traced from Loch Dun Seilcheig to Carn Dearg near Foyers. The Foyers "granite" complex has been mapped, and the different members of the complex differentiated. Finally, the Moine schists into which the complex is intruded, and the series of metamorphic rocks in which the Foyers limestone occurs have been investigated. The mapping was carried out during the field seasons of 1944 and 1945. The following account must be regarded as that of a first "pioneer" survey, which may be modified by later, more detailed study.

II. THE GLEANN LIATH SERIES

(LEWISIAN ?)

A. DISTRIBUTION

The rocks which I have called the Gleann Liath Series outcrop in a narrow belt along the north-west side of Gleann Liath. The outcrop is bounded on the south-east side by the Gleann Liath fault, which extends along the marshy floor of the valley; and along the north-west side, at the top of the line of crags above the glen, the rocks are unconformably overlain by the Middle Old Red Sandstone. The outcrop is about two miles long, extending from immediately south-west of Creag an Fhithich, where its relationship to the Foyers granodiorite of the latter crag is nowhere exposed, to the Upper Falls of the Fechlin at the hamlet of Glenlia. The outcrop has a maximum breadth of a quarter of a mile.

The topography of the ridge separating Gleann Liath from Loch Ness is not well shown on the published maps. It consists of a double line of crags separated by a bog, which extends along the top of the ridge and is in part known as the Blar Nigheann a' Mhinisteir. The crags facing Loch Ness and the central bog, together with some of the crags overlooking Gleann Liath itself are in the Middle Old Red Sandstone; the outcrop of the Gleann Liath rocks is confined to the craggy slope above the glen, reaching the top of the crags only at Creag Nighean Iain Duinn at the south-west end of the outcrop.

The relationship of the Gleann Liath series to the neighbouring Moine schists is not known ; no contact is exposed, unless some of the very highly sheared granulites at the Upper Falls are a continuation of the outcrop of the Moine schists round Loch Bran. However, the fact that they are much veined with pegmatite, in marked distinction to the Loch Bran rocks, seems to indicate that they belong to the Gleann Liath rocks. The south-west termination of the outcrop is concealed under the alluvium of the Fechlin valley; it probably extends a short distance beyond the outcrop at the Upper Falls.

Access to the outcrops of the Gleann Liath series is difficult, except in the vicinity of the Foyers limestone quarry (disused) near Glenlia Farm. Most of the ground is covered by the dense fir plantations of the British Aluminium Company, which are nearly impenetrable. On the crags above, which were too steep to plant, there are birch woods and deep heather, the latter up to three feet high, for heather burning is rarely carried out on the ridge. The ridge is crossed only by one track, from Boleskine Farm over the Spital of Boleskine to Gleann Liath. A second track, shown on the six-inch map, from Foyers Hotel to the cross-roads in Gleann Liath can now only be traced by faint wheel ruts in the bog behind Creag Nighean Iain Duinn on the top of the ridge (Plates III A, XII B).

The outcrops of gneiss below the Upper Falls of the Fechlin can be reached by a certain amount of scrambling over rock when the water in the river is low. They are completely submerged when there is any volume of water in the Fechlin.

B. ROCK TYPES & STRUCTURE

The rock types of the Gleann Liath series can be divided into the following groups:-

- | | |
|-----------------------------|---|
| Rocks of sedimentary origin | a) The limestones |
| | b) The schists and gneiss |
| Injection rocks/Migmatites | c) The gneiss where injected or permeated by granitic or pegmatitic material. |
| Igneous rocks | d) The sheared hornblende-diorites of Creag Nighean Iain Duinn. |
| | e) The pegmatites and granite veins. |

The general trend of the strike of the limestones and gneisses is NE-SW, parallel to the direction of Gleann Liath itself, but there are many minor deviations. Near Creag an Fhithich the gneiss strikes nearly NW-SE, and this same strike is seen in the intensely sheared siliceous granulites above the Upper Fall of the Fechlin. At the plunge pool, below the Fall, the gneiss strikes NE-SW. The crushing of the rocks above the Fall is, however, so intense that the apparent direction of strike may be quite fallacious. The gneiss and limestone are highly folded. The gneiss usually dips to the SE at high angles, but at Glenlia the dip is to the North-west, so that it may be disposed as a complex anticline, the axis of which runs NE-SW. The limestone occurs in the core of this suspected anticline. In the Foyers quarry, it is overlain unconformably by the Middle Old Red Sandstone; whilst to the south-east, it passes underneath the gneiss at road level. The weathered surface of the limestone shows a complicated pattern of minor folds.

The Gleann Liath gneiss is a coarse muscovite-biotite-gneiss, usually greenish in hand specimen. It contains eyes, streaks and lenticles of white or pink pegmatitic material. It varies from a type rich in mica to a gneiss made up predominant of granitic material. In some exposures, pegmatite veins may be observed cutting the gneiss, small offshoots from the main vein penetrating along the foliation planes of the gneiss. The injectin material is sometimes pale pink in colour, sometimes white and rich in muscovite.

The outcrop of the gneiss extends along the whole length of the outcrop of the series. A very good exposure may be seen when the water is low, ^{immediately} downstream from the plunge pool of the Upper Fall of the Fechlin, where the rock surface is beautifully polished and smoothed by the water. The structure of the rock is also well seen on a glaciated surface on the roadside behind the Glenlia houses. This surface is crossed by a number of glacial striae ; the detailed structures are very well seen after rain. On another glaciated ridge in a plantation beyond the cross-roads in Glenlia, the gneiss appeared to contain some small hornblendic lenticles (Plate III B).

The limestone, which is a crystalline marble, outcrops in two localities : at the Foyers limestone quarry below Creag nam Broc, and to the south-east of Tomain Tarsuinn at the Spital of Boleskine, where it has also been quarried. The Boleskine outcrop as well as the quarry is much smaller than that at Foyers. Indeed, for many years, the existence of the outcrop seems to have been completely lost sight of; it was rediscovered during the present research.

PLATE III



A. Gleann Liath from Carn Dearg, looking north-east. Basal breccias of Middle Old Red Sandstone banked against Carn Dearg (left); outcrops of Foyers granodiorite (right). Centre — the long, straight valley of Gleann Liath. The (?) Lewisian inlier is to the left side of the valley, in middle distance. On the skyline are the hills of Dunchia and Tom Bailgeann (Middle Old Red).

B. Supposed Lewisian gneiss. Exposure below the plunge-pool of the Upper Fall of the Fechlin at Foyers.



The limestone is well exposed in the series of old quarries below Creag nam Broc. It is a pale bluish grey or greenish rock, passing into a pure white marble composed of moderately coarsely crystalline calcite, in the middle quarry. The bulk of the rock, however, is rich in thin bands of calc-silicate minerals. On weathered surfaces, these bands stand out in relief and show up the intricate minor folding of the limestone.

At the top of the quarries, the limestone passes up into flaky weathering impure layers rich in phlogopite. The basal breccia of the Middle Old Red Sandstone rests upon these impure calcareous bands. At the base of the quarries, on the level of the road from Gleann Liath cross-roads to the hamlet of Glenlia, the limestone passes down into ^{more} impure layers, rich in calc-silicate minerals. Below the level of the road, these layers appear to dip below the Gleann Liath gneiss, which is well exposed in this area. Laterally the limestone seems to die out fairly rapidly -- immediately south-west of the Foyers quarries, and just below the unconformable junction with the Middle Old Red, there is a small outcrop of a pale silver-grey tremolite-schist. Blades of green actinolitic tremolite up to a quarter of an inch in length are prominent in some of the impure layers near the road level.

The small outcrop of limestone in the Spital of Boleskine also appears to be lenticular in form. The Boleskine limestone is a white crystalline marble, criss-crossed by narrow crush-lines stained red with haematite. It is generally ^a pure, calcareous limestone, free from well-marked calc-silicate layers.

The Crags of Creag Nighean Iain Duinn, and

their prolongation as far as the Boleskine limestone quarry, consist of highly sheared igneous rock, most of which appears to be a hornblende-diorite . It is not foliated and does not share in the folding of the Gleann Liath gneiss and limestone. Its relation to the surrounding gneiss, and the mutual relationships of the various types in the mass are obscured by the intense crushing which the rocks have undergone. Most of the mass consists of a green crush-rock, showing beautiful mortar structure in thin section here and there occur lenticles of less crushed material in which the original structures can still be found.

The limestone, the gneiss and the rocks of Creag Nighean Iain Duinn are cut by veins of pegmatite, which average two or three feet across. The Foyers limestone quarry contains a number of pegmatite veins, ~~fn~~ of which the most prominent is one of pink graphic granite, about 2 ft wide, running vertically up the quarry face. It does not cut the overlying Old Red Sandstone. The pegmatite veins are sometimes ~~im~~ so crushed that all original structures are obliterated. It is noteworthy that the Gleann Liath inlier is the only part of the district under discussion in which pegmatite veins are at all prominent or abundant.

A specimen of a badly sheared lamprophyre dyke has been obtained from part of Creag Nighean Iain Duinn, it is apparently of a type similar to those found elsewhere in Strath Errick, and will therefore be included under the general description of the lamprophyre dykes of the whole area.

The whole of the Gleann Liath series is affected by severe crushing and brecciation, due to the effects

of the neighbouring Great Glen Fault and the Gleann Liath Fault, which forms the south-east boundary of the inlier. The rocks are traversed by innumerable lines of crush and microbreccia. The shearing is particularly marked in the dioritic rocks of Creag Nighean Iain Duinn, where the rocks have yielded by fracture and brecciation. Even the limestones, however, show some lines of microbreccia. Epidote has been developed on a large scale in the diorites and the limestones at the Foyers quarry, epidotisation being a characteristic feature of all the crush zones of Strath Errick and Foyers.

C. PETROGRAPHY OF THE GLEANN LIATH TYPES

i. Crystalline limestones and Calc-silicate rocks

The middle part of the Foyers limestone quarries contains a white marble. This is a coarsely crystalline rock, made up of interlocking plates of calcite. The bulk of the limestone in these quarries is, however, rich in calc-silicate minerals. It is normally greenish or bluish in hand specimen, rather hard and compact, with thin bands of calc-silicate minerals showing a darker green than the rest of the rock. In some of the very impure layers, tremolite occurs in groups of radiating needles up to $\frac{1}{4}$ " long.

In thin section, the typical limestone (311) is rich in calcite. The layers of calc-silicate minerals (Plate XIV A) consist of diopside, tremolite, phlogopite, zoisite and sphene, with subsidiary quartz, plagioclase, iron ore and apatite. The composition of these layers varies from band to band; in some diopside is

dominant, in others phlogopite or tremolite. The latter may be very abundant. It usually occurs in long bladed crystals, green in hand specimen, and in thin section, pale green and faintly pleochroic. Darker green pleochroic halos occur round tiny inclusions probably of zircon.

Diopside is also common. It sometimes occurs in large, irregular, poikiloblastic crystals, which are elongated parallel to the bedding of the limestone. It is also found in much smaller, compact grains, scattered through the rock or grouped in clusters, which may represent original nodules in the limestone prior to metamorphism. In some parts of the limestone, flakes of nearly colourless phlogopite occur. Some of the flakes have a bent appearance. Zoisite is common, in rather irregularly shaped crystals, which show characteristic deep blue polarisation colours. Sphene usually occurs in small, rounded grains, but occasionally forms larger individuals. Some subsidiary quartz and plagioclase is present, in small rounded grains, there is a little accessory black iron ore and a few fine needles of apatite.

Epidote is very abundant, sometimes forming distinct lenticles, or occurring along the thin lines of microbreccia which cross the limestone. Most of this epidote has probably been introduced at the time of the crushing of the Gleann Liath rocks.

The Boleskine limestone is a white crystalline marble, crossed by numerous haematite-stained lines of microbreccia usually a millimetre or so in breadth. The rock consists of a fairly coarse grained mosaic of calcite crystals. The sparse accessories are quartz, plagioclase, diopside, sphene, apatite and chloritised biotite.

ii. Schists and gneisses

The typical Gleann Liath gneiss (440c, 148a, 570) (Plates XIV B, III B) is a coarse grained muscovite-biotite-gneiss with eyes and lenticles of quartzo-feldspathic material. It is generally greenish in appearance because the biotite is usually partly chloritised; the very fresh rock from below the plunge pool at the Upper Fall of the Fechlin is more silvery in appearance. On the one hand, the type grades into a mica-schist with much reduced quartzo-feldspathic layers; on the other hand it may pass into a more siliceous phase with subordinate mica.

In thin section, the laminae of mica are seen to consist of biotite with subordinate muscovite in large plates lying parallel to the foliation. The biotite is frequently partly or wholly chloritised, but when fresh it is pleochroic from light to dark brown. Inclusions of zircon are surrounded by pleochroic halos. In the more altered flakes of biotite, webs of rutile needles are sometimes developed. A few small, colourless or pale pink garnets, prisms of colourless apatite and a little black iron ore are associated with the layers of mica.

The quartzo-feldspathic lenticles between the folia of mica are frequently rich in quartz. It always shows shadowy extinction, and contains many small globular inclusions (probably of liquid) and fine, curving hairs of rutile. The associated feldspars include both orthoclase and a sodic plagioclase; they are usually much sericitised and difficult to identify. The feldspar crystals are subhedral in form. Some of the larger plates of plagioclase contain small blebs of quartz.

In places the gneiss passes into more siliceous

schists, some variations of which resemble semi-pelitic types of Moine schist. Thus, the small exposures of rock on the village green at Glenlia consist of a light-coloured granulite. The bulk of this rock(308) is made up of quartz, oligoclase-andesine (An_{30}), orthoclase and microcline, with narrow layers of mica which, together with the elongation of the quartz grains, give schistosity to the rock. The quartz is crowded with lines of tiny inclusions (? liquid) which have a general tendency to run at right angles to the foliation of the rock. The quartz shows shadowy extinction; and some grains, under crossed Nicols, have a peculiar "watered" striping. The mica is green chloritised biotite with subordinate muscovite. Small zircons are enclosed in the biotite and are surrounded by pleochroic halos. The flakes of mica are frequently bent. There is a little, accessory colourless apatite.

The most siliceous phase is represented by the intensely hard and sheared granulite which outcrops at and immediately above the Upper Fall of the Fechlin. This rock is cut by sheared veins of pegmatite and pink granite. At the bridge, spanning the Fall, the rocks show slickensided surfaces, and are reduced to intensely rolled-out, green crush-rocks. Below the bridge and the Fall are outcrops of the typical gneiss, which appears to become more siliceous in character as one approaches the base of the waterfall. It seems likely that the rocks above and below the Fall both belong to the same series; the siliceous Moine schists round the neighbouring Loch Bran are not veined with pegmatite to any extent.

The schists above the Fall are grey or

slightly pink-tinted granulitic rocks, in which there appears to be a faint foliation marked by narrow laminae of mica. In thin section (307a) they consist of abundant quartz with subsidiary sodic plagioclase and orthoclase, and scattered flakes of biotite. The latter are altered to penninite and are all aligned in the same direction. The rock is much crushed, and is crossed by many lines of microbreccia. The twinning lamellae of the plagioclase are bent.

A very soft, green, garnetiferous mica-schist, which has only been found in loose blocks, but which almost certainly belongs to the Gleann Liath series, probably represents a more micaceous phase of the gneiss. Fragments of a similar rock have been observed in the basal breccias of the Middle Old Red Sandstone where they overlie the Gleann Liath rocks and are predominantly composed of fragments from that series.

About a third of the way along Gleann Liath from the Upper Falls, on the north-west side of the road, is a small and isolated opening for road metal. The rock exposed is a rather coarse, hornblende-bearing granulite, traversed by a small fault and crush line, and apparently intruded by a small mass of appinite: one of several small intrusions of appinitic affinity occurring along Gleann Liath, all of which with this exception, are exposed in the crags on the other (Loch Bran) side of the glen. It is doubtful whether or not the granulite should be grouped with the Gleann Liath rocks. It is a fairly coarse, light coloured rock with groups of hornblende and biotite crystals, and a faint suggestion of foliation. In section (95), it is seen to be composed of granulitic quartz, orthoclase, sodic oligoclase (An 15) hornblende and biotite with accessory sphene, apatite, magnetite and

epidote. Quartz is abundant and forms elongated granulitic patches, lying parallel to the foliation. It is crossed by many lines of small inclusions, running at right angles to the foliation. It shows shadowy extinction. The feldspars are subhedral or anhedral in form; the orthoclase is subsidiary to the plagioclase, but sometimes forms large plates which enclose blebs of quartz. Wart-like intergrowths of myrmekite are frequent along the margins of the orthoclase. Biotite and hornblende occur together in groups with which the small brown sphenes are associated. The biotite is sometimes chloritised, the fresh flakes being pleochroic from yellow to dark brown. The hornblende is generally in small compact individuals, usually rather poorly shaped. A few of the crystals are sieved with quartz. Faint halos are occasionally to be seen round small inclusions. The pleochroism is X = yellow with faint greenish tinge; Y = olive green; Z = bluish green. Colourless apatite in rather large prisms is a common accessory. The few scattered grains of epidote may have been formed later during the movements which took place in the district.

iii. Sheared plutonic rocks

It has already been mentioned that the dioritic rocks of Creag Nighean Iain Duinn are so sheared that it is very difficult to extract much information about them (pp. 17-18). The crags largely consist of green crush-rock, which shows beautiful mortar structure in thin section. It is often much epidotised. Eyes of less altered material occur in the crush; but they are never completely free from cataclastic effects.

The most basic type comes from a small outcrop

near the top of Creag Nighean Iain Duinn itself. It is a coarse-grained, dark green rock composed of abundant hornblende and plagioclase, with a small amount of interstitial quartz, chloritised biotite and accessory black ~~iron~~ iron-ore and apatite. The plates of anhedral plagioclase are filled with fine brown dust, through which a faint suggestion of fine lamellar twinning can still be made out. They have undergone some albitisation and are crossed by clear veins of albite. The hornblende is generally green and forms ragged plates, but some occurs in aggregates of small blades and is a more actinolitic variety. The rock is rich in large, clear crystals of apatite.

A coarse black and red hornblende-diorite occurs frequently in the less sheared patches on Creag Nighean. Nevertheless in thin section (387d) the rock is found to be much crushed. The feldspars, which appear to be largely sodic oligoclase (An_{10-20}) are bent and broken, and full of a brownish dust to which their red colour in hand specimen is due. There is a little perthitic orthoclase, and accompanying it a small development of myrmekite. Interstitial quartz grains have sutured edges and shadowy extinction. The dark minerals are green hornblende and chloritised biotite. The biotite is often bent or crumpled as a result of the later movements. There is accessory sphene, black iron-ore, brown orthite and apatite. Epidote has been developed in most of the specimens. Some of the Creag Nighean Iain Duinn rocks are rather finer-grained than the type described above, but are similar in their general characters. One slice contains a small, more hornblendeic enclave of finer grain. All the Creag Nighean diorites are characterised by relative richness in apatite. The apatite is

clear and colourless, and usually occurs as rather large, poorly shaped crystals. The crystals are sometimes observed to be broken across.

There are a few small intrusions of granitic material into the Gleann Liath series. These rocks are best exposed in the vicinity of Glenlia farm. One type is a much crushed, slightly foliated, pale pink, muscovite-biotite-granite. The rock is very quartzose and the micas are sparsely distributed.

Other types include a sheared biotite-granite, like that found on Carn Dearg, Foyers, and some small veins which resemble the granite of the Foyers mass. Correlation with other intrusions outside Gleann Liath is difficult because of the sheared condition of the rocks. The basal breccias and conglomerates of the Middle Old Red Sandstone near Glenlia contain many boulders of the pink biotite-granite (Plate II B). The detailed description of this type will be given later when the Carn Dearg mass is described (p. 103)

iv. Pegmatites and Aplites

Pegmatite veins, averaging two or three feet in breadth, are frequently found cutting the Gleann Liath rocks. They consist of quartz and feldspar with either biotite or muscovite. The crystals of mica are frequently quite large, the muscovite plates being sometimes more than an inch across.

The Foyers limestone is cut by a pink graphic granite, about 2 ft wide. The rock (311 e) consists of a coarse graphic intergrowth of quartz and feldspar -- the latter being itself a perthitic intergrowth of orthoclase and albite-oligoclase. The rock is found to be rather crushed in thin section, though the crushing is not so evident in hand specimen.

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The sheared pegmatites at the Upper Falls of Foyers have already been mentioned ; the shearing in their case has obliterated all or nearly all of their original structures.

There are also found a few veins of sheared aplite. A very badly sheared specimen, cutting the diorites on Creag Nighean Iain Duinn, consists of quartz, perthitic orthoclase and sodic plagioclase with a little chloritised biotite and accessory apatite and black iron-ore (603b). The rock is pink in hand specimen; in thin section, few of the original structures still remain.

D. THE STRATIGRAPHICAL POSITION OF THE GLEANN LIATH SERIES

The Gleann Liath series is of markedly different facies from that of the neighbouring Moine schists of Strath Errick¹. The problem thus arises -- whether these rocks are a part of the Moine series at all, or whether they should be referred to the Lewisian or the Dalradian. The discussion of the position of the Series will, however, be postponed until the Moine schists of Strath Errick have been described.

E. LIMESTONE-WORKING IN GLEANN LIATH

A short note on the working of limestone in Gleann Liath may not be out of place here.

Limestone has been quarried at both the known outcrops in Gleann Liath. The Foyers quarry is very much larger than the Boleskine one -- the latter had been forgotten locally and was rediscovered during the present research. I have found no references to it in any of the literature, though the presence of a quarry at Foyers is repeatedly mentioned. The Foyers quarry is

on the side of the road from Gleann Liath cross-roads to the hamlet of Glenlia, and is therefore very easily accessible; the tracks to the Boleskine quarry have completely disappeared. A possible hint as to the time at which the Boleskine quarry was used is given by the presence of neatly drilled holes for blasting out the rock.

There are ruins of lime kilns at both both quarries. The lime was not always burned at the quarry however, but was carted away to be burned where it was required. Ruins of lime kilns exist below Beinn Sgurrach near Whitebridge, on the moor between Loch Bran and Gorthleck, and also (doubtfully) in Knockie Forest. The fuel used was peat.

According to the New Statistical Account (Fraser 1845 Vol 14.p.54 the construction of the Caledonian Canal put an end to local lime-working. The account of the parishes of Boleskine and Abertarff speaks of the limestone as of good quality and regrets that it was no longer being utilised. It was, however, being worked when the Old Statistical Account was written (1798, Vol 20. p 28 The writer, who remains anonymous, says that there is an abundance of limestone but that it is not much used. He goes on to say that during the preceeding 5 or 6 years, Mr. James Fraser WS of Gortuleg bought some limestone from Mr. Fraser of Foyers (? from the Foyers quarry). Owing to the condition of the roads, the stone was transported on horse-back to the fields where it was required, being burned in kilns set up in the corners of the fields. The writer hoped that this good example would encourage other people to lime their ground, and put forward suggestions to raise money to mend the roads so that transportation would be easier.

The present resources of limestone in Gleann Liath do not appear to be very great. The Foyers quarry might be somewhat extended but the resources at Boleskiné appear to be very small.

III. THE MOINE SERIES

A. DISTRIBUTION, FACIES & STRUCTURE

The Moine Schists (Central Highland Granulites) form the country rock into which the Foyers Plutonic Complex is intruded. In this part of the Highlands, the schists are involved in an extensive permeation or "injection" complex, the limits of which extend southward beyond the boundaries of the district at present under discussion. The migmatitization of the schists is definitely earlier than the intrusion of the Foyers complex, for the latter both cuts and contact-alters the "injection" gneiss of Conagleann. Although the schists of the Strath Errick district are part of a large permeation complex, by no means all of the rocks have undergone migmatitization, and apparently "normal" Moine schist types bulk rather largely in the hills round the Foyers "Granite". The permeation process must therefore have been to some extent selective. During the present study, no attempt has been made to map the migmatites and "normal" schists separately; it is rather doubtful whether they could be

satisfactorily mapped separately. The chief localities at which the principal types occur will, however, be cited with the detailed description of each.

The "normal" Moine schist types of Strath Errick are predominantly siliceous and semi-pelitic varieties. With these siliceous rocks occur a few thin bands of hornblende-schist, while to the south of the complex at Loch Killin, calc-silicate granulites are abundant. In this district (Loch Killin) there is a large development of coarse pelitic schists. In the Glen Doe district, to the south-west, finer-grained mica-schists of a different facies from those of Killin are prominent; whilst the mountainous district of Beinn a' Bhacaidh is carved in schistose grits.

The migmatites include coarse muscovite-biotite-gneisses, principally developed in the Conagleann area, and to the north-east of it at Loch Ruthven and Brin, and highly siliceous augen schists, found in the country immediately south-west and south-east of the plutonic complex, as well as round Loch Bran, in a small outcrop which presumably forms part of the roof of the complex.

The Moine schists are highly folded isoclinally, often with vertical dips. In the Strath Errick district, the strike varies from north-westerly to north-easterly, and usually conforms to the margins of the Foyers "Granite". The strike is therefore predominantly north-westerly, becoming north-easterly or east-west in the Beinn Bhuraich and Black Falls (River E) country, where the trend of the margin of the complex is in these directions.

Beyond the influence of the Foyers intrusion, to the north-east, at Crag nan Clag and Creag Dhearg, the schists

strike north-east; again the prevalent dips are nearly vertical. On the Brin crag, the schists dip to the north-west at about 70° (Horne, 1915, p.25) At Loch Killin, the strike is ENE, the dip to the SSE at about 70°, on Glen Doe Hill and near Loch Tarff, the strike is again north-easterly. At Loch Tarff, the beds are vertical or highly inclined to the south-east.

B. OCCURRENCE & PETROGRAPHY OF PRINCIPAL TYPES

1. Normal Moine Schists

The Moine schists not affected by obvious permeation processes can be subdivided into the following types:-

- i. Quartzites
- ii. Siliceous granulites
- iii. Semi-pelitic schists
- iv. Pelitic schists
- v. Calc-silicate granulites
- vi. Hornblende-schists
- vii. Schistose grits.

i. Quartzites

In the Strath Errick district, a few bands of the Moine schists are sufficiently siliceous to be termed quartzites. Rocks of this type outcrop on Carn Gairbhthinn and in a large xenolithic mass of schist included in the granodiorite which is exposed in the course of the River Gourag. The quartzites are light-coloured, pale grey, white or pinkish weathering rocks. The texture is granulitic, and there is a faint banding indicated by thin dark layers of biotite.

The only sliced specimen of this type comes from the large xenolith exposed at the bridge over the Gourag. In

section (61), the rock is seen to consist of granulitic quartz with orthoclase and subordinate microcline; the small flakes of biotite, which occur sparsely scattered through the rock, are largely altered to green penninite.

ii. Siliceous granulites

Siliceous granulites containing a higher percentage of dark minerals and feldspar than the quartzite types, are rather common throughout the Strath Errick district. With a further increase in the content of dark minerals, they grade into the semi-pelitic types.

The typical siliceous granulites are light-coloured rocks, composed of granulitic quartz and feldspar and with narrow bands rich in biotite, the flakes of which lie parallel to the schistosity of the rock and impart a flaggy character to it when the mica-rich layers are narrowly and evenly spaced. Muscovite is subsidiary to biotite and only occasionally present in the Strath Errick schists.

The markedly flaggy type of granulite is well developed near Croftdhu; and at Crag nan Clag below the exposure of the unconformable junction of the Middle Old Red Sandstone on the Moine schists. In other cases, the fine bands of mica cross the beds in elongated sigmoid curves, which may represent original current bedding. It is very well seen, developed on a small scale, on Carn na Saobhaidhe, to the north-east of the Black Falls of the River E. The individual beds ~~of~~ with these "cross-bedded" mica-rich bands are mostly under a foot in thickness.

Not many of these siliceous rocks have been

sliced. A hard, fine-grained, grey rock (53) from Trinloist, where it forms part of the schist series round Loch Bran, is of this type but finer in grain than many examples of the group. Its outcrop is quite near the contact with the Foyers granodiorite. It is composed of granular quartz, orthoclase and oligoclase (both largely sericitised) and biotite, with a little accessory magnetite, colourless apatite and muscovite. The quartz shows strain shadows and encloses many tiny globular inclusions. The individual grains are flattened parallel to the foliation of the rock, which is also controlled by the alignment of the flakes of sparse biotite. The biotite is largely altered to chlorite; when fresh it is pleochroic from pale yellow to dark brown.

These siliceous granulites closely resemble the highly siliceous "augen" schists of the type developed round Loch Bran and elsewhere. These Loch Bran rocks will be described later in connection with the migmatites. They differ from the ordinary close-grained, siliceous schist in that large "eyes" of quartz and feldspar are developed. The development of these eyes appears to have taken place late in the history of the rock, for they enclose parts of the finer-grained matrix of the rock. It seems possible that none of the siliceous schists should really be separated from these Loch Bran rocks; there seems to be a complete gradation from granulites without augen into granulites with a larger or smaller development of them. Schists with and without augen occur closely interbedded with each other.

iii. Semi-pelitic schists

By an increase in the amount of dark minerals present, the siliceous granulites pass into semi-pelitic schists.

Schists of semi-pelitic type are probably the most common of those in Strath Errick , which are apparently unaffected by migmatitization.

There is much variation within the group. In some types, there is a marked banding of light and dark minerals, in others the distribution is more even and results in the "pepper and salt" type of Moine schist. A large increase in the amount of biotite produces dark, lustrous schists. The series therefore passes on the one hand into the flaggy siliceous granulites and on the other into fine-grained pelitic types. In the Foyers and Strath Errick district, the semi-pelitic rocks are normally not garnetiferous.

Of the darker, mica-rich types, a specimen from the shepherd's cottage below Beinn Sgurrach is typical (146). It is a dark, lustrous schist, very rich in small flakes of biotite, pleochroic from pale yellow to a deep foxy red, and which contains numerous inclusions of zircon, each surrounded by a pleochroic halo. The remainder of the rock consists of quartz and oligoclase-andesine with colourless apatite as a common accessory. The feldspar nearly always shows lamellar twinning and some examples exhibit incipient sericitisation.

A somewhat similar rock (427) from Carnoch Farm is not so rich in biotite. In it, narrow bands of quartz and feldspar alternate with slightly wavy layers of biotite. The rock outcrops near the edge of the Foyers tonalite and has suffered some contact alteration : eg. cordierite is associated with the biotite. The latter is a red, strongly pleochroic hornfels type, with well developed halos round small zircons. The bulk of the rock is made up of elongated granular individuals of quartz,

orthoclase and oligoclase (near An₂₀), with accessory colourless apatite and a few, tiny garnets, only visible microscopically.

A very typical, garnetiferous, semi-pelitic schist from Loch Killin (385) is a medium-grained, grey rock with finely alternating films of mica and quartz-feldspathic material. The individual bands have a tendency to be discontinuous when traced laterally. In thin section, the rock is found to consist of quartz, orthoclase and oligoclase (An ₂₀), with large plates of biotite and subsidiary muscovite and accessory garnet, black iron-ore, colourless apatite and pale-green epidote. The oligoclase sometimes encloses blebs of quartz. The biotite is a red hornfels variety, pleochroic from a very pale yellow to a deep foxy red. It encloses relatively large zircons, which are surrounded by strongly marked halos. The garnets are poikiloblastic, pale-pink in hand specimen and faintly pink in thin section. Their colour is almost identical with that of the garnets found in the associated calc-silicate granulites.

iv. Pelitic schists

Typical, coarse-grained, muscovite-biotite-schist types are not found in the immediate vicinity of the Foyers plutonic complex. Such rocks have, however, been observed at Loch Killin, to the south of the complex. In this latter district, they are found as coarse, muscovite-biotite-schists (386b) with small garnets. The biotite is a rather reddish variety; the garnets faintly pink in thin section. Again the rock contains colourless apatite as a common accessory. The layers of mica are sometimes separated by very thin bands of quartz-feldspathic material.

A mica-schist of very different facies occurs in the Glen Doe district. It has been observed in the cuttings on the Whitebridge-Fort Augustus road at the bridge over the river in Glen Doe, and between the bridge and Loch Tarff. These Glen Doe rocks are compact, silvery schists, with a soft, unctuous feel to the touch. They (521) consist of small flakes of muscovite and subordinate biotite, with numerous small garnets, a little quartz, and accessory pyrite, zircon, tourmaline and graphite. The biotite is frequently chloritised; when fresh it is pleochroic from pale yellow to a rich brown. Halos are developed round small zircons enclosed in the biotite. The garnets, mostly ~~from~~ about 2 mm. in diameter are abundant. They contain spirally arranged inclusions of graphite; in some cases they are partly or wholly altered to a green chlorite. In the latter case, the graphite inclusions with their characteristic arrangement still persist in the chlorite pseudomorph. On either side of the garnets a wedge of granular quartz is found, so forming a lenticle around which the micas sweep in smooth flowing curves. (Plate XV A). Graphite also occurs as disseminated specks through the rock. There is a very little tourmaline present, pleochroic from a deep olive-brown to almost colourless.

It will be seen from the above description that these Glen Doe rocks do not conform to the usual type of Moine pelitic schist, which is a coarsely crystalline muscovite-biotite-schist (Flett, 1923, p. 56). A small percentage of carbon is shown in an analysis of a Moine pelitic schist from Corriemulzie (Read, 1926 p. 135-137), but graphite is not mentioned in the description of the rock. It may be pointed out that "snowball" garnets of the type found at Glen Doe are not characteristic of the Moine type of crystallisation, and that the schist is generally more of Dalradian

v. Calc-silicate granulites

Garnetiferous zoisite-hornblende-granulites are very well represented among the boulders of the fluvio-glacial gravels through which the River Fechlin flows between Whitebridge and Dell. Such rocks have not been observed in the schists bordering the Foyers plutonic complex itself, but they are very well developed in the Loch Killin district. In the latter area they are associated with the pelitic and semi-pelitic schists already described (pp. 35)

The calc-silicate bands are often only a few inches thick and their maximum is only a foot or so. They are handsome rocks, white or pale grey in colour, with blades of dark-green hornblende lying parallel to the foliation of the interbedded schists, and numerous small pink garnets. They are very hard and compact rocks. There is some variation both in composition and in the coarseness of the texture from one band to another, and also within individual bands themselves. (Plate XIV C)

In thin section, a specimen of the finer-grained, slightly greyish, calc-silicate rock (386c A), is seen to consist of a granulitic mosaic of quartz and plagioclase, in which lie ragged ~~xynt~~ crystals of hornblende and poikiloblastic garnets; sphene, zoisite, apatite and zircon are accessory. Quartz is abundant; under crossed Nicols, it shows slight strain shadows. It is sometimes intergrown in vermicular fashion with the feldspar. The latter is clear and fresh, only rarely showing lamellar twinning, which sometimes appears as though it might be secondary, while in some cases, the actual lamellae are distorted. The ~~refractive~~ refractive index is well above that of quartz. The feldspar

is probably mostly labradorite (An_{60}). The hornblende occurs as rather ragged blades up to 6 mm long, with X = pale yellow-green, Y=olive-green and Z= pale blue-green. It shows pleochroic halos round small inclusions (? zircon). The garnets, with an average diameter of 1.5 mm, are pale pink in thin section, and sieved with both quartz and feldspar. Rather rarely, they enclose small blades of hornblende.

Small, granular, brown sphens are common in the rock; a little zoisite is present and there are a few stout, anhedral crystals of apatite.

The coarser-grained type of calc-silicate rock is represented by section 386c B. In hand specimen, this rock is a pure white granulite containing blades of hornblende and pink garnets, both of which are more widely spaced than in the first example. The garnets have an average diameter of 2-3 mm. In thin section, the general characters of the rock are very similar to the first example but zoisite is abundant and free calcite is present. The calcite occurs in granular form with the quartz and labradorite. The latter is less abundant than in the finer-grained type and does not occur in vermicular intergrowth with quartz. Calcite sometimes occurs enclosed in the poikiloblasts garnets. The zoisite occurs in large crystals, showing its characteristic deep blue polarisation tints. Round the margins of the crystals however, the polarisation colours are sometimes normal ~~xy~~ yellows like those of epidote. The hornblende crystals are paler in colour than in the previous type ; X = nearly colourless or very faint yellow-green, Y= very pale green and Z= pale blue-green. The cores of some of the hornblende crystals are sieved with quartz.

At Cnoc Carrach quarry, on the Whitebridge-Fort Augustus road, hornblende-bearing layers occur in a series of hard, compact, grey siliceous granulites. These rocks may have been hornfelsed to a certain extent by a neighbouring intrusion of granodiorite, satellitic to the Foyers complex. The hornblende-bearing layers are very thin, only one or two inches in thickness. In hand specimen (564b), they are pale coloured or white granulites in which lie small blades of green hornblende, conspicuously aligned parallel to the schistosity of the rocks. The hornblende shows the same pleochroism as that in the calc-silicate rocks of Loch Killin. The rock also carries small flakes of biotite, pleochroic from olive-brown to yellow. Colourless garnet (only visible microscopically) and brown orthite are also present. Titaniferous iron-ore, in irregular, elongated grains, sometimes edged with sphene, is rather abundant. This rock probably represents a slightly calcareous variety of the semi-pelitic facies.

Immediately to the south of Loch Tarff, garnetiferous granulites carrying free calcite have been observed. They are associated with the mica-schists of the Glen Doe and Loch Tarff district (p.36). These rocks are massive granulites, with a slight flaggy parting along lustrous mica-rich planes. The rocks weather white, though on fresh fractures they may be either whitish or brown. In thin section, the bulk of the rock is composed of granoblastic quartz with a slightly subsidiary amount of calcite also with a granulitic habit. The garnets are poikiloblastic, and faintly pink in thin section. The foliation of the rock is shown by the aligned plates of muscovite and biotite, the latter pleochroic from pale to dark brown. There is a little accessory magnetite and apatite.

vi. Hornblende-schists

Hornblende-schists occur throughout the Moine Series of the Strath Errick district. They are nowhere very abundant; the individual beds range in thickness from 2 to 8 or 10 feet. They are dark, heavy rocks, black with a greenish sheen. The individual crystals of hornblende are usually elongated with the foliation so that the rocks are rudely fissile. The hornblende-schists appear to be concordant with the schists associated with them.

A very basic variety from the north-east shore of Loch Kemp, near the margin of the Foyers complex, is a heavy black rock (464d) composed almost entirely of irregularly shaped, poikiloblastic crystals of green hornblende. The pleochroism of the hornblende is X = yellow, Y = yellowish-green and Z = blue-green. There is a little interstitial quartz and sericitised plagioclase, and a few flakes of chloritised biotite. The rock has accessory magnetite and apatite.

A hornblende-schist(522) from Tom Mor, Oldtown is rather similar but not so rich in hornblende. In this rock (Plate XV B) the poikiloblastic hornblende and a subsidiary amount of biotite, pleochroic from pale brown to a deep red brown, occur in thin and rather indefinite laminae separated by thin bands of granulitic quartz and labradorite(mostly sericitised). This particular rock outcrops near an offshoot of the Foyers tonalite and is itself cut by a thin vein of pegmatite. In thin section, a quartz vein, probably originating from the pegmatite has come in along the foliation of the schist.

Another section of a hornblende-schist (558) from Beinn Sgurrach, is characterised by the occurrence of

granules of pyrite and magnetite along particular layers. In all the hornblende-schists sliced, large colourless prisms of apatite are common as accessories.

All the specimens sectioned come from localities near the margin of the Foyers complex, and may therefore have suffered some effects of contact alteration.

A full discussion of the origin of the hornblende-schists in the Moine series in general and in Strath Errick in particular would be out of place here, nor has sufficiently detailed study been made of the Strath Errick types for such a purpose. Hornblende-schists in the Moine series may be of either igneous or sedimentary origin, but there appears to be ^{no} reliable criterion for discriminating between the two kinds. The hornblende-schists which always occur with the rare Moine limestones appear to be of sedimentary origin as also do the striped hornblende-schists of Durcha type described by Read (1926, p. 144-147). The hornblende-schists of supposed igneous origin are generally no more than a few feet thick and only rarely show transgressive relations to the surrounding rocks. (Read, 1926 p.141) In Strath Errick, no transgressive relations have been observed between the hornblende-schists and the surrounding rocks. Limestones are not associated with them. The rather poorly marked banding may be evidence of a sedimentary origin, it is only visible microscopically. In hand specimen the rocks appear uniformly dark.

vii. Schistose grits.

The mountain of Beinn a ' Bhacaidh, rising to the south-west of Loch nan Lann in Knockie Forest, is composed of green schistose grits. These grits, which vary somewhat in coarseness from

one band to another, are characterised by extreme richness in epidote. In hand specimen, the rocks are a silvery green with numerous small fragments of quartz and feldspar. In thin section (599) the grit is found to contain abundant epidote and numerous flakes of white mica, in which matrix lie the larger, rounded grains of quartz and feldspar. Rounded, but sometimes wedge-shaped sphenes, of a deep brown colour, are common. Magnetite occurs throughout the rock and there is a little apatite and chloritised biotite. The epidote occurs in small lozenge shaped crystals, pale green in thin section. Some of the crystals contain cores of brown orthite, which extinguish in a slightly different position from the rest of the epidote.

Green, schistose grits, similar to those of Beinn a' Bhacaidh have been found in the drift at Loch Garth, to the north-east. One specimen (470a) shows a marked layer of black iron-ore and sphene which may represent an original band of heavy residue minerals. In this rock some of the grit pebbles are composite, containing both quartz and feldspar. The quartz pebbles are made up of variously orientated grains, which show sutured margins and shadowy extinction.

The Beinn a ' Bhacaidh district lies beyond that covered by the main part of the present research, and the relationship of the grits to the Strath Errick types of Moine schist has not been observed.

2. Permeation Rocks (Migmatites) of the Moine Series

The rocks of the permeation ("injection") complex in Strath Errick can be divided into two main groups:- those in which the original schist was of a siliceous type, and those in which it was pelitic. Only the small part of the complex which surrounds the Foyers plutonic complex has been investigated during the present research, and the development of all the different types represented in the permeation complex as a whole cannot therefore be described here.

i. Migmatites derived from siliceous Moine schists

The first stage in the migmatitization of siliceous Moine granulites appears to be the coalescence of neighbouring quartz grains. A pink weathering, highly siliceous granulite from near the mouth of the Allt Leachd Gowrie (which flows from the bog near Easter Drummond to Loch Kemp) is of this type. The fresh surface of the rock is white, with small spots of pink feldspar and faint banding picked out by minute biotites (591b). In slice, the rock is a granulitic, interlocking mass of rounded individuals of quartz, orthoclase, microcline and a little oligoclase-andesine, with sparse flakes of chloritised biotite. The rock is very rich in quartz. The quartz shows strain shadows; and patches of coarser-grained quartz and feldspar are separated by finer-grained areas. It is probable that this finer-grained material represents the original grain size of the schist, prior to its further recrystallisation. But some of the effects may be due to the thermal effects of a neighbouring satellite of the Foyers plutonic complex.

This type of granulite does, however, seem to be a possible starting point in the development of augen schists like those found round Loch Bran and at Cnoc Carrach. Although the type (591b) is not largely developed in the Strath Errick district, the augen schists which may have formed from it, are abundant. The coalescence of contiguous quartz grains has been described by Read (1931 p. 112) in the early stages of the development of permeation rocks from siliceous granulites in the Loch Choire complex.

A light coloured, siliceous granulite (577) outcrops in the course of the River Brein near the waterfall at Whitebridge. It is coarser in grain than the ordinary Moine granulite, it shows however a slight banding due to the presence of narrow layers of biotite. In thin section, the texture is much coarser than that of the normal schist. The rock consists of abundant quartz, perthitic orthoclase, sodic plagioclase (much sericitised), biotite (most of which is chloritised), brown orthite and colourless apatite. The quartz grains show sutured edges and strain shadows. In contrast to the sericitised plagioclase the orthoclase is fresh and clear. Myrmekitic intergrowths of quartz and sodic plagioclase are associated with it. The chloritised biotite encloses a few zircons, surrounded by halos; sometimes it encloses the scarce orthite. The flakes of biotite are sometimes split by lenticles of epidote, which may also be found moulded onto the orthite crystals. The orthoclase and quartz tend to form larger individuals, slightly elongated parallel to the foliation, which are separated from one another by the finer-grained, sericitised plagioclase and chloritised biotite.

The predominant type of migmatite derived from

siliceous granulites in the Strath Errick district, however, appears to that of a type largely developed round Loch Bran, where they form part of the roof of the Foyers plutonic complex. Examples are also abundant in Strath Errick. They are well exposed at Torness bridge in the course of the Farigaig, on Carn na Glaice Moire above Migovie, near Carn na Saobhaidhe and at Cnoc Carrach and Loch Knockie.

Typically, the Loch Bran schists are highly siliceous, light grey or brown rocks, with augen of quartz and feldspar and with fairly well marked colour banding. The augen are white in colour and are usually elongated along the foliation directions of the schist. In a few cases however (for example, in the Carn na Saobhaidhe district), the lines of augen cross the banding of the schists. This would seem to indicate that they were being developed after the main dynamic stresses to which the schists have been subjected.

In thin section (404 a,b; 461)(Plate XIV D), the bulk of the schist is seen to be made up of small rounded or slightly flattened granules of quartz and feldspar. The latter includes both orthoclase and oligoclase, both of which may be largely sericitised. The schists tend to be rather fine-grained with occasional coarser bands. The banding is picked out by tiny flakes of biotite. When fresh, the biotite is pleochroic from pale yellow to dark brown, but it is often altered to green chloritë. A little muscovite is also usually present. Black iron-ore, sphene and epidote are distributed in streaks suggestive of original heavy mineral layers.

The augen consist of quartz, orthoclase and

less abundant microcline and oligoclase-andesine. The quartz tends to be lenticular in form, it is usually crowded with minute granular inclusions and shows shadowy extinction. The outlines of the feldspars are usually irregular or embayed against the surrounding finer-grained matrix, in which they appear, in some cases, to be developing ground. In other instances, blebs of quartz are fairly common in the big feldspars. Wart-like growths of myrmekite, consisting of a vermicular intergrowth of quartz and sodic plagioclase, occur along the margins of the orthoclase crystals into which they project.

From these facts, it seems that the augen have grown by replacement in the schist and at least in those cases where they cross the foliation, at a date subsequent to the main movements affecting the Moine series.

Augen schists, formed from siliceous and semi-pelitic Moine schists have been described from the Loch Choire complex (Read, 1931 pp. 116-118). These Loch Choire rocks resemble those of Loch Bran in a general way, though they appear to be somewhat coarser in texture. At Loch Choire, the augen may coalesce to form continuous layers, but coalescence has not been observed in the Loch Bran series. On Carn Suidhe Ghoiril, on the ridge between the Black Falls of the River E and the Loch Killin valley, a rather different development of the augen schist is found. In this type (453), there is a great increase in the number of augen, but without coalescence of individual augen with one another.

The Carn Suidhe Ghoiril type is associated with siliceous granulites with and without augen, which form the predominant type of schist of that district. In hand specimen

the rock is light brown or grey, highly siliceous and without marked schistosity. It is crowded with large, subhedral white feldspar crystals, averaging 4mm in length. There is sometimes a faint tendency for the crystals to be aligned parallel to the slight foliation; the finer-grained matrix usually curves round them.

In thin section, the fine-grained matrix is found to consist of granular quartz, orthoclase and sericitised plagioclase, with a little biotite, muscovite, iron-ore, apatite, sphene and epidote. Quartz is very abundant. It sometimes occurs in rather larger lenticles, and is usually crowded with minute inclusions arranged in lines, running at right angles to the foliation. The quartz does not show very marked strain shadows. With it, occurs fairly fresh subhedral orthoclase and patches of highly sericitised plagioclase. Biotite, of reddish brown colour when fresh, is mostly altered to penninite. It occurs in small flakes lying parallel to the foliation, and encloses small zircons each surrounded by a halo. The muscovite occurs in large plates, which often enclose the other components of the matrix. The black iron-ore is segregated along lines suggestive of original heavy mineral layers. The big crystals are all orthoclase. Some of them are elongated at right angles to the foliation. They often enclose parts of the granulitic matrix and sometimes blades of muscovite. One large crystal is seen, in thin section, to be traversed completely by a string of quartz granules. The margins of the large orthoclases are embayed against the surrounding finer-grained matrix.

In this rock from Carn Suidhe Ghoiril, the

evidence again seems to point to the development of the big feldspar at a period subsequent to the main dynamic metamorphism of the Moine schists, since some of the crystals are elongated at right angles to the main foliation of the schist. The plates of muscovite would also appear to be of late growth, since they enclose parts of the granulitic matrix, but they may have formed before the large orthoclases, since muscovite has been found enclosed in one of these crystals.

It may be pointed out that on Carn na Saobhaidhe, which hill is some three-quarters of a mile to the ENE of Carn Suidhe Ghoiril, the lines of augen in the siliceous schists have been noted lying athwart the main trend of the foliation (p.45). This observation and the elongation of some of the orthoclases in the Carn Suidhe Ghoiril rock at right angles to the foliation, confirm the inference that all these rocks with feldspar augen belong to one group, which underwent migmatitization at some period after the main folding of the Moine schists. During this process, potash must have been introduced in the formation of the augen of orthoclase. The permeation evidently took place prior to the intrusion of the Foyers plutonic complex, for ^{as} pointed out later (p. 75), the Foyers granodiorite contains numerous xenoliths of the Loch Bran type of schist as seen in its outcrops both between Loch Bran and Druim Teampuill and to the south-east of Carn Dearg, Foyers.

ii. Migmatites derived from semi-pelitic and pelitic Moine schists

Banded rocks which, structurally, can properly be described as injection gneisses are developed in the Strath Errick district. Unlike the first group of migmatites already described, they contain a considerable amount of mica and are free from augen of feldspar and quartz.

One type (5) from Torr Shelly quarry, is a coarse-grained, rather evenly banded rock, with alternating stripes of white quartzo-feldspathic material and narrow laminae of biotite with subsidiary muscovite. The light coloured bands are composed of quartz, orthoclase and subsidiary oligoclase. Blebs of quartz are sometimes enclosed in the orthoclase and plagioclase crystals. Wart-like growths of myrmekite are locally developed at the margins of the orthoclase. The quartz and feldspar associated with the mica-rich layers occur in smaller individuals than those in the broader, quartzo-feldspathic bands. The biotite is in large plates, pleochroic from a pale yellow-brown to a deep foxy red. Enclosed in it are numerous zircons, surrounded by rather strongly marked pleochroic halos. Zircons also occur scattered through the rest of the rock. There is a little accessory magnetite, sillimanite and colourless apatite.

The most typical injection-gneiss of the Strath Errick district, however, is that developed at Conagleann. The same type of gneiss occurs also round Loch Ruthven and Loch a' Chlachain and at the Brin Rock (Horne, 1914 p. 38, 1915 pp. 25, 33)

The Conagleann injection gneiss (Plates II B, IV A & B, XVII D) is typically developed in Conagleann on the crags of Creag a' Chliabhain and Conagleann and in the deep, ravine-

PLATE IV

A. Loch Conagleann and Creag Conagleann from the Dunmaglass end of the loch. The crags are of "injection" gneiss cut by sheets of Foyers tonalite, granodiorite and granite.



B. The Conagleann injection gneiss. Summit of Creag a'Chliabhain to the south-west of Creag Conagleann.



A. Beinn Sgurrach from Whitebridge Hotel. A glacially moulded hill cut in Moine schists, rising from a series of terraces of coarse, fluvio-glacial gravels.



B. Part of Knockie Forest. Looking from Tom a'Chliabhain to Lochan a'Chinn Mhonaich and Loch Ness.

like gully of An Fhail which flanks Beinn Dubhcharaidh. It is an extremely handsome rock: a coarse muscovite-biotite-gneiss, in which wavy, black, mica-rich layers alternate with broader, white quartzofeldspathic ones. The structure is typically gneissic. Small pink garnets are usually present.

The Conagleann gneiss gives rise to very characteristic crags and steep rocky peaks, below which lie jumbled masses of huge fallen blocks of gneiss. In Strath Errick, the Conagleann crags are some 400 ft in height; in Strath Nairn, the gneiss forms the steep crag of Brin and the rocky hills (Cas Garbh) between Brin and Loch Dun Seilcheig.

In thin section (410 c, 529), the gneiss is found to consist of layers very rich in quartz, with orthoclase and sodic oligoclase, of anhedral form, alternating with mica-rich layers composed of biotite and subordinate muscovite. The biotite has a strong pleochroism from straw-yellow to a deep foxy red. It encloses zircon around which well developed pleochroic halos occur. Zircon also occurs disseminated through the whole rock. The quartz forms large granulitic patches, often crowded with minute, rounded inclusions. Colourless apatite in stout prisms is a rather abundant accessory.

At the Cas Garbh, the gneiss contains prominent basic lenticles, carrying a higher percentage of biotite and also a considerable amount of green hornblende. These lenticles contain numerous, large, pink garnets, ranging up to an inch in diameter. The outlines of the garnets are irregular and in thin section, they are found to be sieved with the quartz of the matrix of the rock. The garnets also sometimes enclose sphene. The plagioclase of the basic lenticles appears to be mainly basic

andesine. It occurs in rather large plates and encloses blebs of quartz. The hornblende forms ragged crystals, which may enclose sphene. Colourless apatite is accessory.

On the Brin Rock, the gneiss is very well exposed. The most pelitic type is a coarse muscovite-biotite-gneiss with lenticles of quartzo-feldspathic material, but this passes into a less micaceous and more regularly banded rock. In this latter type (595b) there is a very regular banding of mica layers with pink or white, granulitic quartzo-feldspathic ones. Muscovite and biotite occur in about equal amount but the muscovite is in slightly larger plates than the biotites. ~~and~~ The flakes of mica may be sometimes slightly bent. The biotite is strongly pleochroic from straw-yellow to a deep foxy red and contains zircons with well marked halos. The quartzo-feldspathic material is generally coarse-grained, though a few of the lenticles associated with the mica layers are of finer texture. Quartz is abundant; the associated feldspars are oligoclase and subsidiary orthoclase. There is accessory colourless apatite in irregularly shaped grains, and a few tiny, colourless garnets.



IV. THE STRATIGRAPHICAL POSITION OF THE GLEANN LIATH SERIES

The problem of the correlation of the Gleann Liath series can now be discussed. It will be seen from the account of this series and the neighbouring Moine schists that the Gleann Liath rocks are of a markedly different facies from the schists developed in the rest of Strath Errick. The Gleann Liath rocks are separated from the augen schists round Loch Bran by the Gleann Liath fault; the contrast between the rock types upon one side of the glen compared with those on the other is extremely marked. The whole facies of the Moine series in Strath Errick is siliceous or semi-pelitic, while the Conagleann "injection" gneiss is also very different from the Gleann Liath gneiss. Further no limestones are known to be associated with the gneiss at Conagleann, nor have they been found in association with the muscovite-biotite-schists and calc-silicate granulites of Loch Killin.

Should the Gleann Liath rocks then be grouped with the Moine series at all, or should they be correlated with the Dalradian or the Lewisian?

The paucity of limestones in the Moine series is one of its distinguishing features (Flett, 1923, p. 56). Limestones have, indeed, been reported from a few localities; among them Shinness in Sutherland and Rebeg near Beaully to the north of the Great Glen; and Kyllachy in the Findhorn valley to the south of the Great Glen. A noteworthy feature of the few limestones in the Moine series is their invariable association with hornblende-schist, much of which is probably of sedimentary derivation.

The outcrop of limestone at Kyllachy (Horne, 1911 p. 26, Flett 1915 p. 53)

in the upper part of the Findhorn valley (Strath Dearn) is the nearest exposure of undoubted Moine limestone to the Foyers limestone on the south side of the Great Glen. The limestone is exposed in an old quarry, now nearly grassed over, above the wood surrounding Kyllachy House. The limestone forms a sharp anticlinal fold, trending NE-SW. It ranges from white, coarsely crystalline types, which can be crumbled between the fingers, to rather harder, but still very coarse varieties. The limestone is always white and pure, small pale green diopside crystals and scales of graphite are sometimes sparsely scattered through it. It never shows the minor folding and puckering which is characteristic of the Gleann Liath limestones. Associated with the limestone is a hard, compact, pale green calc-silicate hornfels. A similar limestone and associated calc-silicate hornfels is ~~x~~seen in a few small quarries on the other side of the ridge abote Kyllachy House, $\frac{1}{4}$ mile W.S.W. from the summit of Carn na Seanalaich, and reached by an old track from the ruins of Ardachy. The calc-silicate rock is rich in diopside and also contains scapolite. It may have been affected by contact metamorphism due to the Findhorn granite. Associated with the limestone in the small quarries under Carn na Seanalaich, is a narrow band of hornblende schist.

At ~~neither~~ of these quarries in the Findhorn valley are the associated schists exposed. The hills are covered by peat and heather and there are few rock outcrops in the immediate vicinity. From these few, it would appear that the associated rocks are of normal Moine types -- pelitic and semi-pelitic schists.

North of the Great Glen, at Shinness, in Sutherland (Read, 1926 pp. 126-7. 138-41), the limestone, some

of which is very coarse-grained, is associated with hornblende-schists, some of which are garnetiferous, and with siliceous and semi-pelitic schists.

The group of quarries in limestone of the Moine series at Rebeg, South Clunes and Blairnachenachie (Horne, 1914 p. 37-38, 101) in the **Beauly** area, have long been disused. Rebeg quarry furnishes the most valuable information, for from it, a cutting was made through the schists associated with the limestone. Rebeg quarry, however, is now almost grassed over and the details of the sections described in the Geological Survey memoir are no longer exposed. The rock cutting, which was probably made as a means of exit from the quarry, still provides a good section of the associated schists.

The **Rebeg** limestone itself is a white crystalline limestone with sparse accessory mica (nearly colourless), feldspar, iron oxides and scales of graphite. It is associated with hornblende-biotite-schists and flaggy mica-schists. In the cutting these are succeeded by flaggy granulites of Moine type. Some of the mica-schists and hornblende-schists contain lenticles of pegmatite. Neither the limestone nor the associated schists bears any resemblance to the Gleann Liath series.

It appears, therefore, that the Gleann Liath series cannot be correlated lithologically with the limestone-bearing facies of the Moine series. The limestone and the associated schists of Gleann Liath differ widely from the Moine limestone series. No hornblende-schist of the type commonly associated with Moine limestones is found in Gleann Liath; Moine limestones, on the other hand, do not appear to be associated with limestones of Gleann Liath type.

Is the Gleann Liath series then to be grouped with the Dalradian? Dalradian rocks have not been recorded, so far, in this part of the country, though it must be remembered that it has not yet been surveyed in detail. The silky garnetiferous mica-schists with graphite of Glen Doe (p. 36) might conceivably belong to the Dalradian series. They bear some resemblance to Dalradian mica-schists in the southern part of the Highlands, but they show no affinities with the Gleann Liath gneiss nor is limestone known to occur with them. Moreover the Foyers limestone itself bears no resemblance to the Dalradian limestones further south, such as those of Loch Tay and Blair Atholl.

A third possibility is that the Gleann Liath series represents a small inlier of Lewisian age. It must be admitted, at once, that no Lewisian rocks have hitherto been recorded south of the Great Glen Fault. The nearest inlier of Lewisian type, north of the Great Glen, occurs in Glen Urquhart, to the immediate north of Foyers and upon the other side of the fault. (Cunningham Craig, 1914, p.20-23, 101). The inlier of Glen Urquhart provides excellent material for comparison with the Foyers rocks, since it includes a good development of limestone associated with gneisses of sedimentary derivation. It may be noted, in passing, that the Glen Urquhart series closely resembles the rocks of the very much larger Lewisian inlier at Glenelg.

The Urquhart inlier consists of a series of paragneisses and limestone, which are arranged anticlinally, the axes of folding trending north-west. Into them is intruded a mass of serpentine of uncertain age. The following order of succession

has been made out -- the limestone occupies the core the anticline:-

- 3. Feldspathic banded gneisses with basic patches and lenticles
- 2. Rusty micaceous gneiss with kyanite.
- 1. Limestone

The Glen Urquhart limestone is a white marble containing bands very rich in calc-silicates. The pure white marble cannot be distinguished in hand specimen from the pure white variety of the Foyers limestone. The quarries of Glen Urquhart have long been famous for their development of calc-silicate minerals. Some parts are very rich in large green tremolite crystals. Wollastonite, phlogopite and diopside are also prominent. Apart from wollastonite, this assemblage of calc-silicate minerals can be exactly paralleled at Foyers. At the latter locality, of course, the whole development is on a smaller scale; there is less limestone actually present, the exposures are smaller and fewer, the calc-silicate layers are less conspicuous and the very large crystals of tremolite are unrepresented. Furthermore, the rocks at Foyers have been subjected to considerable crushing. Spinel and forsterite, characteristic of the Glenelg limestone, have not so far been recorded either from Glen Urquhart or from Gleann Liath.

The Glen Urquhart limestone is cut by veins of coarse pegmatite, another parallel with the Foyers rocks.

The rusty-weathering, micaceous gneisses which succeed the limestone of Glen Urquhart, are rich in blades of blue kyanite. No kyanite has been observed in Gleann Liath. In other respects however, the gneisses of the Glen Urquhart inlier are very similar to those developed in Gleann Liath. Along the margin of the Urquhart inlier, the gneisses are folded-in with Moine gneisses of similar type, except that they do not contain

basic lenticles as do the Lewisian gneisses. The absence of these basic lenticles was used as a criterion to map the boundary of the inlier.

No detailed correlation of the Glen Urquhart Lewisian inlier with the Gleann Liath series is here either intended or implied. The fact that the general facies of the limestone and gneisses of Glen Urquhart (disregarding the more peculiar and particular attributes of the Glen Urquhart rocks, such as the kyanite and the coarsest calc-silicate bands) do bear a strong resemblance to the Gleann Liath limestone and gneiss, is however, felt to be of considerable significance. In fact, the Gleann Liath rocks seem to resemble the rocks of the Lewisian inliers north of the Great Glen more closely than those of any other group. In the absence of any evidence of their relations to the surrounding Moine schists, or of evidence of the occurrence of Lewisian inliers south of the Great Glen, it is not possible to be certain about their position. All that can be said with certainty is that the series bears a close general resemblance to the Lewisian of Glen Urquhart. The correlation of the Gleann Liath series with undoubted Lewisian can never be definite; but the present facts strongly suggest that in ^uGleann Liath there exists a small inlier of that series.

V. THE FOYERS PLUTONIC COMPLEX

A. FIELD DESCRIPTION

i. Distribution

The Foyers plutonic complex consists of a large granitic intrusion in Strath Errick together with a series of satellite intrusions in Knockie Forest between Whitebridge and Loch nan Lann. The complex in Strath Errick covers about 25 sq. miles. It has a maximum length of 7 miles, from Loch Kemp in the south-west to the neighbourhood of Loch a'Bhodaich in the north-east; and a maximum breadth of $5\frac{3}{4}$ miles from Lochan Torr an Tuill at Creag an Fhithich to the hollow between Meall a'Bhuailt and Beinn Bhuraich. The satellite intrusions in Knockie Forest probably cover another 2 sq. miles, they tend to be rather irregular in form, but appear to have a general elongation in a north-westerly to northerly direction. But the district of Knockie Forest has not been studied in great detail during the present research.

The main complex is bounded to the north-west by the Gleann Liath fault, except at Creag an Fhithich and Dun Deardai where granodiorite is brought up on the Loch Ness side of the fault line; and at Carn Dearg, Foyers, where there is a small outcrop of intensely sheared pink granite on the top of the carn. From its north-easterly termination, the boundary of the complex runs in a south-east direction from Tom Mor and Loch a'Bhodaich to

Meall Donn, and to the north-east of Meall a'Bhuailt. Between Errogie and Oldtown, the junction line is marked by a fairly sharp change of level in the ground, the schists rising steeply from the boggy moorland of Aulnagoire in the plutonic complex. Beyond Errogie, the contact line is at first concealed but is again exposed on Meall Donn and in Conagleann. South-east of Carn Liathdoire, the contact is again concealed under the drift and peat. The boundary of the complex runs along the hollow between Meall a'Bhuailt and Beinn Bhuraich, and the actual contact is again exposed on the north-eastern flanks of Beinn Mheadhoin and Carn Choire Riabhaich. These hills form a ridge of schists, much veined with tonalite and granodiorite, which separates the larger more northerly bay formed by the outcrop of the plutonic complex from the smaller and more southerly one. The latter extends back from Garthbeg into the hills along the course of the River E, to a point just short of the Black Falls. From this district, the junction, which is largely concealed, extends north-west along the northern flank of Carn Gairbhthinn to Compass and then a more westerly direction to Loch Kemp. (Plate I, A, B)

ii. Rock-types and Internal Structures

The principal rock-types found in the plutonic complex may be divided into the following groups:-

1. Appinites
2. Tonalites
3. Granodiorites
4. Biotite-granite

Rocks of appinitic type appear to have been the earliest members of the complex. Xenolithic masses of appinitic type have been observed in the granodiorite of the main complex

both at Lochan Torr and Tuill and between Garthbeg and Corriegarth. There are a few small intrusive masses of hornblende-diorite, probably to be grouped with these rocks, cutting the Loch Bran augen schists in Gleann Liath. The principal outcrop of the appinite series is, however, in Knockie Forest. There, they are cut by and are therefore earlier than both the Cnoc Carrach type of granodiorite and the granodiorite-porphyry.

In Knockie Forest, the largest mass of appinitic rocks is that to the south of Loch na Sgorthaich, and it extends across Loch Knockie to the moss south of Drummond Plantation. It also extends into Drummond Plantation, but for what distance is not certainly known, for most of the exposures die out at this point. Around Loch Knockie, the appinites are veined by the Cnoc Carrach granodiorite and the mapping shown is generalised to include xenoliths separated by small veins of granodiorite in the outcrop shown as appinite.

A smaller mass of coarse appinite occurs in contact with granodiorite-porphyry near Creag a'Ghiubhais (north of Lochan a'Choin Uire), and appinitic rocks also outcrop in a crag running from this locality toward the Allt an t-Sluichd (from Loch Kemp to Loch Ness). On Carn Dearg, Foyers, there is a small mass of hornblende-diorite, weathering dark green with white feldspathic lumps, which should probably be grouped with the appinite series.

Typically, in Knockie Forest, these appinites are coarse-grained rocks, often of striking field appearance with their large green hornblende crystals set in a white-weathering background. Finer-grained types are also prevalent.

The contacts of some of the appinite xenoliths in the Cnoc Carrach granodiorite, are marked, in some cases, by a selvage of large hornblende crystals.

The tonalite is a coarse-grained, grey hornblende-biotite-quartz-diorite. Its relationship to the appinites is not exposed, though a block of appinite in the moss near Ballindalloch is very probably derived from a xenolithic inclusion in the tonalite. The tonalite outcrops round the margins of the main intrusion in Strath Errick, though the ring is not quite complete. The largest continuous outcrop of tonalite is in the north-eastern part of the complex in the Errogie district. The tonalite contains many basic dioritic inclusions (Plate VI A), finer in grain than the surrounding tonalite and rich in biotite and hornblende. Both tonalite and inclusions are often very rich in sphene. The basic inclusions occur both as large masses and as small lens-shaped enclaves derived from the bigger inclusions.

The granodiorite, a hornblende-biotite-variety, is rather similar in appearance to the tonalite, from which it differs in containing large pink phenocrysts of perthitic orthoclase. These phenocrysts usually have a maximum length of half-an-inch, and are sometimes very abundant. However, they are often more sparsely distributed corresponding to the fact that the granodiorite petrographically grades into the tonalite. The presence or absence of the pink orthoclase phenocrysts has been adopted as a field criterion to distinguish between tonalite and granodiorite. Like the tonalite, the granodiorite is usually rich in small brown sphenes. It contains a smaller number of lens-shaped basic enclaves. Both tonalite and granodiorite contain numerous xenoliths of schist.

The granodiorite outcrops within the tonalite of the ~~margin~~ margin of the complex, or, as in the Errogie district, in smaller outcrops cutting the tonalite. The contact between tonalite and granodiorite is not sharply marked, and in some cases there appears to be a transition between the two -- the granodiorite becoming progressively poorer in orthoclase and eventually passing over into the tonalitic type. In these cases, the drawing of a boundary line between the two types becomes a matter of approximation. In some cases, however, the change from one type to another takes place sharply. Near Lochaan Ordain, the granodiorite veins the tonalite and is therefore of later emplacement.

In both the tonalite and the granodiorite the component minerals show a marked parallelism. This lineation is well seen on weathered surfaces of the granodiorite where it is picked out by the alignment of the orthoclase phenocrysts. Compass bearings of this foliation have been taken and the results plotted on the ~~tracing~~^{INSET} accompanying the map. The alignment nearly everywhere coincides with the strike of the surrounding schists and with the strike of the schist inclusions. Further mention will be made of this point, later, in connection with the schist inclusion.

The tonalite is not represented in the intrusions of Knockie Forest, except by a few tonalitic veins of various sizes on Tom Rathail, Torr Paiteag and round Loch Kemp. These veins are fine-grained, biotite-tonalites from which hornblende is normally absent.

Granodioritic rocks are well represented in the satellite intrusions of Knockie Forest. Along the margin of the Foyers complex at Loch Kemp, the granodiorite, which is

typically developed on Torr Clunie, sometimes appears to pass into a finer-grained type of granodiorite with numerous small pink orthoclases in place of the large orthoclase phenocrysts of the typical Foyers rock. This finer-grained rock is a biotite-granodiorite and unlike the typical Foyers granodiorite it is often free from hornblende. It outcrops on the edge of the main complex between Loch Kemp and Loch Clunie, and again above Loch Ness in part of the ridge between Carn Dearg and the Allt an t-Sluichd (Loch Kemp--Loch Ness). It also forms a complex with siliceous schists in the Meall nan Aidhean-Loch na Sgorthaich district. This complex ranges from siliceous schists with numerous sheets and veins of granodiorite, through granodiorite with numerous schist xenoliths to granodiorite without schist xenoliths. The latter occurs in the central part of the outcrop and forms a ridge of high ground running from the top of Meall nan Aidhean past Lochan nan Nighean toward Loch Knockie. The amount of schist present seems to increase toward Loch Ness as one goes down Meall nan Aidhean, and also toward Loch na Sgorthaich. The granodiorite usually intrudes the schists along their foliation planes, but locally cuts across them.

The biotite-granodiorite of this type, also outcrops in an irregular strip from Tom a'Chliabhain to Lochan a'Choin Uire. It is intrusive into the siliceous granulites bordering Loch Kemp and forming Meall na Targaid, in the same fashion as at Meall nan Aidhean.

The close-planted Whitebridge plantation has now been felled, and above the thick carpet of pine needles and broken branches, a few outcrops of rock appear, bleached white by

the acid soil of the pines. The Torr an t-Sagairt end of the plantation (the north end) appears to be mainly composed of this same type of biotite-granite with siliceous schist masses, but part of the complex in this area is more tonalitic. On Tom Rathail, tonalite is seen to be intrusive into semi-pelitic schists.

At Cnoc Carrach, there occur sheets of a coarse-grained granodiorite, distinguished from the typical Foyers rock by the much larger size of the orthoclase phenocrysts, by the presence of large phenocrysts of white plagioclase in addition to the orthoclase, and by its more quartzose character. The Cnoc Carrach type of granodiorite is also seen in knolls on the low ground between Drummond Plantation and the Knockie Lodge road, where it is intrusive into appinite; and on the high ground above Knockie Lodge and the north bank of the Allt Luaidhe (Loch nan Lann to Loch Ness). The development of the large phenocrysts is rather patchy and the rock sometimes seems to shade off into the biotite-granodiorite.

A fine-grained granodiorite, previously referred to ^{as} the granodiorite-porphry, with rather large phenocrysts of pink orthoclase and fairly abundant quartz occurs as dyke-like masses in the schists along the north-east shore of Loch Kemp. The full extent of the intrusions there are concealed under the water. They are also found on the crags between the head of the Allt an t-Sluichd and Creag a'Ghuibhais and in the course of the River Brein above the Killin road bridge. Knockie Forest is the only part of Strath Errick, where this type has been observed in situ; erratic blocks have been found at Corriegarth and Creag an Fhithich (Pass of Iwerfarigaig).

The final major rock-type to be intruded in the Foyers complex was biotite-granite. This rock is finer in grain than either tonalite or granodiorite. It is a pink, highly quartzose non-porphyrific rock with sparse biotite and sometimes a little accessory hornblende. In the field, it frequently shows a very marked flaggy jointing, but is free from foliation or the alignment of its components. It cuts sharply across both granodiorite and tonalite.

The principal outcrop of the biotite-granite is to the south of Migovie, extending across Carn Liath almost to Meall a'Bhuailt, and northward to Conagleann. The rock is well exposed both in Conagleann and in the course of the Aberchalder Burn at the Chalder Falls. Much of the outcrop is, however, concealed under peat and glacial deposits. Near Migovie and on the shore of Loch Garth at Wester Aberchalder, the biotite-granite is seen to occur as numerous narrow and closely spaced dyke-like intrusions. Since much of the outcrop is concealed, it has been mapped as a continuous stretch of biotite-granite; in actual fact, over a considerable part of the mass it may be a complex of dykes and highly inclined sheets of granite cutting tonalite and granodiorite. Whenever seen, the junctions between the two earlier members and the granite are vertical or highly inclined. Between Meall a'Bhuailt and Carn Liath, there appears to be a rather intricate pattern of granite cutting granodiorite, but the exposures are few and it is difficult to do more than generalise about the form of the outcrop.

It will be seen from the map that the granite is assymmetrically placed in the more northern "bay" of the Foyers

complex. Below Carn Choire Riabhaich, it is in contact with the schists, elsewhere it cuts either tonalite or granodiorite.

There are a few other intrusions of granitic rock in Strath Errick. There is a small intrusion of the biotite-granite, much involved in a line of severe crushing, at Trinloist between Lochs Ruairidh and nan Deala. At Garthbeg, on the slopes of Creag Bheag, there is a small intrusive mass, elongated in a N-S direction, consisting of a variety of biotite-granite which differs from the main type in being slightly finer in grain and having less biotite and no hornblende. This intrusion cuts not only the schists of Creag Bheag (really a crag of Carn na Glaise Moire) but also the granodiorite of Garthbeg. The granite has been quarried at this locality in two small quarries --- known as the Garthbeg quarries, and it is this rock that is locally stated to have been shipped to Ireland (p. 5). The Garthbeg granite is one of the road-stones tested by Igvegrove and Page (Attrition Tests of British Road-stones, 1929, pp 22-25; 70-71)

A very much coarser, quartzose biotite-granite occurs in a small outcrop near the line of the Gleann Liath fault in the Cos an t-Sionnaich in the Pass of Inverfarigaig, and again below the Fall of the Farigaig along the same crush-line. At the latter locality, it is abundant in the basal breccias of the overlying Middle Old Red Sandstone.

Two ~~oather~~ granitic types must be mentioned. In the course of the Rivers Fechlin and Brein at Whitebridge, there are outcrops of a pink, biotite-granite, with a marked flaggy jointing, intrusive into the siliceous schists. It differs from the biotite-granite of the Aberchalder district in having a higher content of biotite and a faint foliation. Its extent is not known

since the only exposures are in the rocky channels of the two rivers at Whitebridge. On the top of Carn Dearg, near Foyers, there also occurs a pink granitic rock, finer in grain than the Whitebridge type, but so intensely sheared that correlations with other areas are difficult. It has been very badly sheared and brecciated and emerges from the mantling Middle Old Red Sandstone breccias only along the top of Carn Dearg. Toward Knockie Forest, it is seen in contact with the siliceous Moine schists.

All the granitic rocks of the Strath Errick district appear to be almost free from xenolithic inclusions.

The intrusive history of the Foyers complex can now be summarised. The earliest known phase was the emplacement of the basic rocks of the appinite suite, now preserved only in Knockie Forest and as a small number of xenoliths in the main Strath Errick complex. In the main complex, the tonalite is the earliest member preserved, with the exception of the xenoliths and it forms a series of peripheral outcrops with the principal exposures at the north-eastern end. The emplacement of the tonalite was followed by that of the granodiorite. At probably more or less the same time, the various slightly different granodioritic rocks of Knockie Forest seem to have intruded into the schists. Finally, a highly siliceous, biotite-granite came into place, largely as an intricate complex of dykes and highly inclined sheets within the tonalite and granodiorite.

Pegmatite veins cutting the Foyers plutonic complex and the surrounding schists are rare. Where they are found, they are developed on a very small scale. Aplitic veins and dykes are also rather scarce; but dyke-like intrusions of

alsbachite type are rather common cutting both the biotite-granite and the schists, particularly in the Conagleann district. Lamprophyre dykes are found cutting both the complex and surrounding schists, but are neither very large, nor very abundant. The Moine schists in the Loch Ruthven district are cut by numerous felsite dykes. A sill, about 20 ft. thick, of deeply weathered quartz-porphry cuts the Moine schists to the south-east of Leiterchullin on Loch Dun Seilcheig.

iii. Relation of the Complex to the Surrounding Schists

At only one place, the north-west side of Conagleann, is the contact between the plutonic complex and the surrounding schists exposed in a high crag face. Here the position is complicated by numerous highly inclined sheets of tonalite and granodiorite cutting the schists immediately along the margin of the main mass. In Conagleann, on the face of the crag, the contact is between tonalite and highly siliceous schists. The typical Conagleann "injection" gneiss succeeds these schists slightly further to the north-east, but on the top of Creag a'Chliabhain is seen in contact with the tonalite. The siliceous schists dip to the south-west at 80° , and into the tonalite, the margin of the latter conforming to the inward-dipping planes of the schists. The tonalite appears to be somewhat crushed, however, along the contact line. In other exposures of the contact of the complex with the schists, the tonalite or granodiorite may be locally transgressive to the foliation of the schists; but in general the strike-lines of the schists curve round to conform with the margin of the complex and with the lineation of the tonalite and granodiorite.

Conagleann is the only place where the contact is seen in vertical section, but since the boundary of the complex remains unaffected by changes in the levels of the topography, it appears that the contact between the plutonic complex and the schists must be vertical or highly inclined. In Knockie Forest, however, the intrusions seem to be more in the form of sheets, intruded along the foliation planes of the schists.

The actual contact between individual members of the plutonic complex and the surrounding schists is always very sharp. The plutonic rocks remain coarse right up to the junction. The schists are cut by veins of tonalite and granodiorite. These are numerous on Tom Mor, Oldtown, and at Croftdhu, and ~~so~~ again on Creag Conagleann and Beinn Dubhcharaidh, where their presence complicates the mapping of the main boundary of the complex. On Beinn Dubhcharaidh there are also dykes and sheets of the biotite-granite in the schists. Traced along Beinn Dubhcharaidh from the summit cairn, toward Carn Crom-gleann, the veins of granite and granodiorite die out until tonalite alone remains. The tonalite veins are there usually intruded parallel to the foliation of the schists. The tonalitic veining corresponds to the tonalitic margin of the complex in this district, the veining by all three types of Beinn Dubhcharaidh with the presence of all three in the margin of the complex there.

On the ridge of schist separating the two "bays" of the outcrop, a ~~similar~~ similar change in the veining of the schists takes place sympathetically with a change in the rock forming the ~~inner~~ outer margin of the complex. On Beinn Mheadhoin and Carn Choire Riabhaich the veining is predominantly

tonalitic, though a little granodiorite is also present. The margin of the complex on either side of the ridge is also tonalitic here. At the Choire Riabhaich, between Carn Choire Riabhaich and Carn na Glaice Moire, there is a fairly well marked change from predominant tonalite to predominant granodiorite in the veins. It will be seen from the map, that the granodiorite outcrops along the margin of the complex on the flanks of Carn na Glaice Moire. Veins of granodiorite are very abundant at the north-west end of the schist-ridge on the slopes of Carn na Glaice Moire above Loch Garth. This change in the rock veining the schists concurrently with the change in the rock forming the periphery of the complex seems to imply that the tonalite and granodiorite now exposed on either side of the schist ridge are continuous in depth beneath it. Further, the schists of the ridge outcrop on the higher slopes, the granodiorite and tonalite below them, as if the schists formed part of the original roof. The intrusion, in this part of the complex, may, therefore, be U-shaped in form. If, as seems almost certain, the Carn Choire-Riabhaich-Beinn Mheadhoin schists form part of the roof, the plutonic rocks must have risen to higher ~~level~~ levels, for some structural reason, upon either side of it.

The schists of Carn na Glaice Moire above Loch Garth include rocks of the Loch Bran augen schist type. They are separated from the outcrop at Loch Bran by a stretch of about a mile of granodiorite, possibly less, since the ground is poorly exposed. It seems likely that the outcrop of siliceous schists round Loch Bran is also a part of the roof. The Loch Bran outcrop is mostly at a height of 600-700 ft. above sea-level; the lowest

outcrop of schist on the Carn Choire Riabhaich ridge is at about 650 ft. The Loch Bran schists, especially round the edge of the outcrop, where they are in contact with the granodiorite, are veined by the latter. It seems highly probable that the Loch Bran mass represents a detached part of a once continuous band of rather siliceous schists, which extended at least from the fault line in Gleann Liath to Beinn Mheadhoin. On this hypothesis, at an earlier stage in the denudation of the Foyers complex, there may have existed two outcrops of granitic rock in Strath Errick separated by a ridge of schists.

The diversion of the regional strike of the Moine schists to conform to the margin of the Foyers complex has, on the south-west margin, at Carn Bhreabaig and Carn Gairbhthinn been accompanied by the formation of "breccias" of fragments of schist, in a matrix of white, granulitic aplitic material. (Plate VII) Elsewhere in this locality the schists are very heavily veined and dissected by a variety of tonalite having a finer-grain than the normal Foyers type.

The best exposures of the "schist-breccia" are on the top and north-eastern flanks of Carn Gairbhthinn; similar breccias have been developed on a smaller scale on Carn Choire Riabhaich. This complex, as typically developed on Carn Gairbhthinn near the hollow between the two principal peaks of the hill, consists of fragments of siliceous, semi-pelitic and less common hornblendic rocks, usually from six inches to a foot in length, and enclosed in a granulitic matrix of white aplitic type. The schist fragments are broken across their foliation, but they do not appear to have been moved far relative to one another, for particular bands in the schist can be traced as a line of

PLATE VI



A. Basic xenoliths in tonalite. Shore of Loch Farraline at Erroglie.



B. Basic xenoliths in porphyritic granodiorite. South shore of Loch Sunart, Strontian, in cutting of new road.



A. Schist breccia on the margin of the Foyers tonalite. Summit, Carn Gairbhthinn.



B. Basic xenoliths in tonalite. Block at Torr Shelly quarry.

detached fragments. The edges of the fragments tend to be subangular or rounded off. In some cases, there is very little "matrix", and the exposure consists almost entirely of broken schist fragments closely packed together.

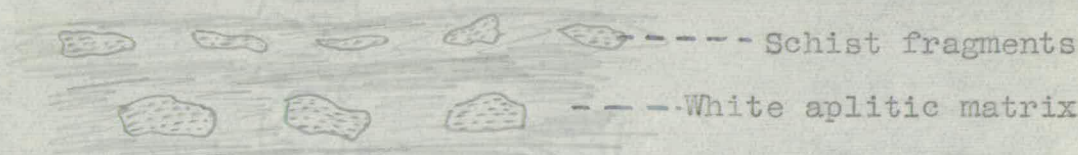


Diagram of schist breccia on Carn Gairbhthinn (cf. Plate VII A)

The formation of breccias in the schists surrounding granitic intrusions has been described from Strontian-- where it is connected with a regional deflection of strike around the complex (Kennedy & MacGregor, 1932, p. 115); and at Beinn a' Chaoinich on the margin of the Glenelg-Ratagain granitic complex (Clough, 1910 p. 86).

On Carn Bhreabaig between Garthmore and Loch nan Losganan, there is an intricate complex of schist invaded by veins and sheets of a fine-grained variety of the tonalite, rich in sphene, and with a well marked alignment of its components. The schists are chiefly siliceous, sometimes quartzitic, types with some semi-pelitic and hornblendic bands. There is a small intrusive mass of pink granite exposed on the top of the hill itself. The schist masses have been swung round from a north-east strike at Loch nan Losganan to a north-west strike on the top of Carn Bhreabaig and its flanks above Garthmore. This latter strike is parallel to the margin of the Foyers complex at Garthmore. Evidently, this sudden diversion of strike was accompanied by

fragmentation of the schist masses into larger or smaller units and the intrusion of tonalitic magma between and into the fragments. The veining is so extensive in this locality that mapping the margin of the Foyers complex becomes a matter of discriminating between tonalite with schist xenoliths, and schists dissected by tonalitic veins.

The complex of schist and tonalitic veins passes into unveined, normal schists on the foothills of Beinn Sgurrach and Leachd nan Cisteachan.

There is no mappable aureole of contact-metamorphism round the Foyers plutonic complex. For long distances no contact effects can be detected ^{even} ~~even~~ within an inch or two of the contact, and the distribution of contact-effects tends to be sporadic. The quartzitic types sometimes show a slight glazing, which appears to be due to the coalescence of contiguous quartz grains. In the permeation ("injection") gneiss in contact with the tonalite in Conagleann, blades of sillimanite, 2-3 mm long, and also a little cordierite and andalusite are developed. Cordierite is found in the semi-pelitic Moine schists at Croftdhu, and these may have been slightly enriched in biotite. Black, mica-rich hornfelses with andalusite crystals averaging $\frac{1}{4}$ " in length occur interbedded with siliceous types near Loch Bran and near the Lochan a'Chinn Mhonaich in Knockie Forest (Plate V B). These andalusite-schists occur as bands about 8" thick.

The semi-pelitic schists on the margin of the complex at Loch Kemp contain sillimanite (visible as shining tufts of crystals in hand specimen) and andalusite. They also tend to have a typical equigranular hornfels texture.

Contact metamorphism is most marked in xenoliths of schist enclosed in the granodiorite and tonalite, and will be described in the next section on the xenoliths.

The degree of contact-metamorphism developed around the Newer Granites of Scotland seems to be variable. Around some of the intrusions, there is marked contact-alteration. In the Ross of Mull, for example (Bosworth, 1910 p.376) the schists near the contact are sillimanite-andalusite-cordierite-hornfelses (and incidentally hornfelsed schists of almost identical type have been found as xenoliths enclosed by the Foyers tonalite). But at Strontian (Kennedy & MacGregor, 1932, p.115), no contact-metamorphism has been recorded from the Moine schists surrounding the "granite" complex. In the Findhorn complex, not very far distant from Strath Errick, sillimanite is developed in the pelitic Moine schists, but the more siliceous types do not seem to have been appreciably affected (Flett, 1925 p.53-55). It is improbable that the siliceous types of Moine schist would show marked contact effects as they ~~are~~ were already in a highly crystalline condition. In Strath Errick, only in the more pelitic bands are new minerals developed. It is interesting to note that the "injection" gneiss of Conagleann has suffered contact-alteration, evidently after it became a gneiss. At Strontian, however, neither the siliceous nor the pelitic schists have been found to show any traces of thermal alteration.

iv. Inclusions in the Foyers Plutonic Complex

The biotite-granite, principally developed in the Aberchalder district, appears to be almost completely free from inclusions. The tonalite and the granodiorite, however, contain numerous inclusions. These inclusions may be divided into three main groups:-

1. Larger or smaller masses of Moine schists, largely unaltered, or, in the case of the more pelitic types, converted to hornfelses.
2. A series of basic dioritic inclusions, typically developed in the Loch an Ordain and Errogie district, as inclusions in the tonalite; smaller lens-shaped enclaves of this type are fairly common in the granodiorite.
3. Xenoliths referable to the appinite series. These are rare; and will not be further described under this sub-heading, the details of the known outcrops are given on p 59.

1. Xenoliths of Moine schist

Xenoliths of Moine schist are common both in the tonalite and the granodiorite. Siliceous types, representing the commonest type of country rock, are probably the most abundant, but there is also a fair proportion of pelitic schist xenoliths showing contact metamorphism of varying degrees of intensity. Many of the xenolithic fragments are quite small, under a foot in length, but there are many large rafts, 12 feet or more in length. In the country between Loch Ness and Creag Mhor, the schist xenoliths are much larger, and form long, narrow and very persistent strips with an arcuate form. A similar long, narrow strip of schist is enclosed in the tonalite below Meall Donn near Ballindalloch. In a majority of the xenoliths, the strike of the schist of the xenolith is approximately parallel to the lineation of the surrounding granodiorite or tonalite, and also to that of the schists at the neighbouring margin of the plutonic complex.

In the country between the Fechlin near Dell and Loch Scristan and the crags above Loch Ness, the schist inclusions form **arcuate** strips, which curve round from the crags of Creag Mhor, facing Dell, to those above Loch Kemp and Loch Scristan. The strips are long, but vary in thickness. They range from 10 feet up to much broader bands such as those which make up the greater part of the crag face above the new reservoir behind Dell Farm (ref. map of these xenoliths , p. 76 a, overleaf). On Creag Mhor, several such narrow bands of schist occur one above the other, separated by layers of granodiorite. They are predominantly siliceous granulites, with a rather glazed appearance; on Creag Mhor there is also subsidiary mica-schist in which some cordierite has been developed. Further over toward Loch Ness, above the new reservoir, there is a bigger development of pelitic types, comprising black, biotite-rich hornfelses with abundant cordierite, sillimanite and andalusite (Plate XVII C). In some cases, the sillimanite occurs as ~~crystals~~ groups of shining crystals, up to 1/2" long, but more often it is not visible macroscopically. Between the hills to the north-east of Loch Kemp and Loch Scristan, the schist inclusions are found as several long narrow strips, composed partly of siliceous granulites and partly of mica-rich hornfelses. The granulites dip into the granodiorite to the north-east at 45° (Plates VIII A, IX B). There is also a mass of epidiorite veined with white aplite in this series of inclusions.

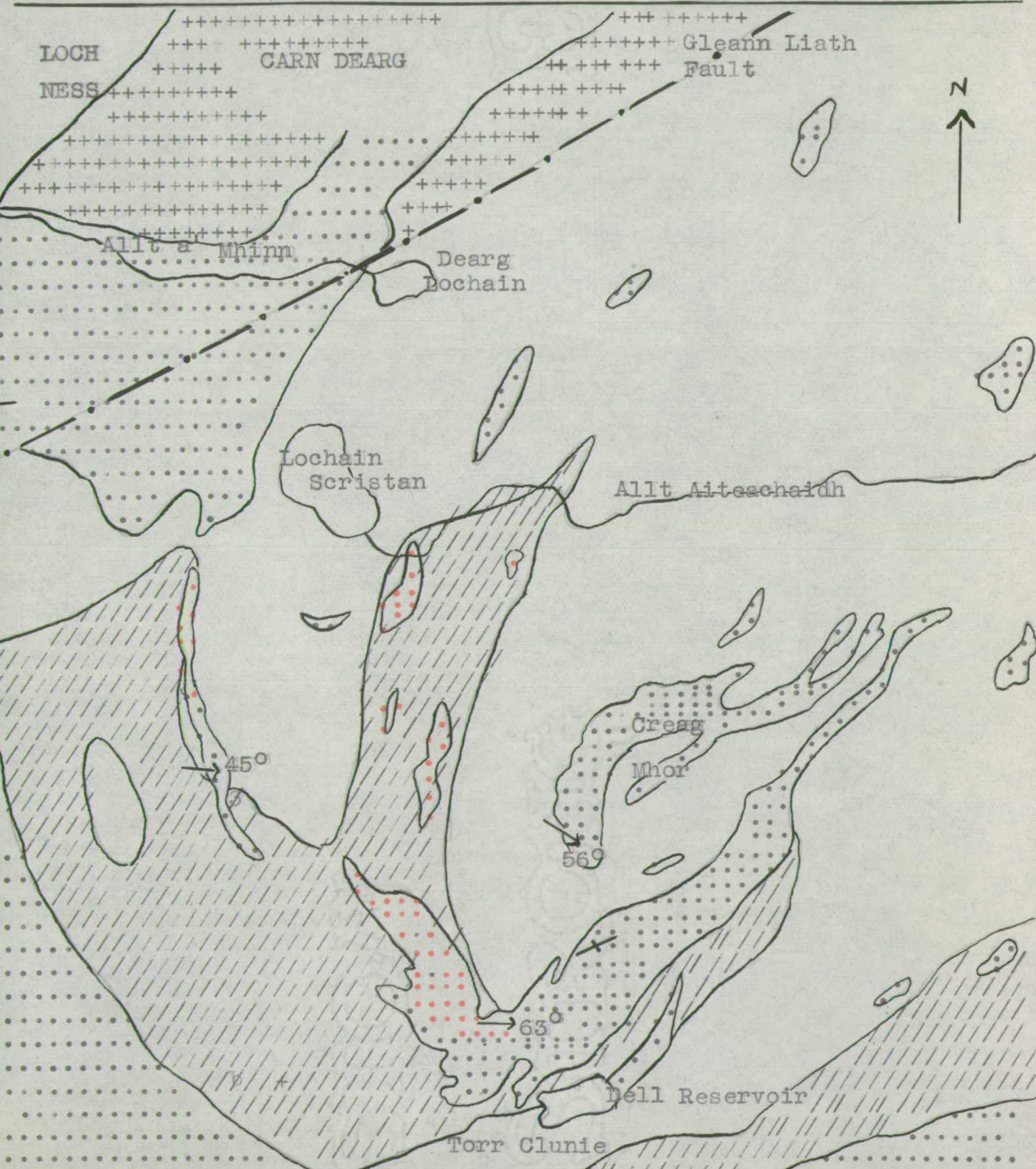
It will be seen from the plan (overleaf) that the pelitic inclusions are usually in the tonalite, the siliceous ones in the granodiorite. In some occurrences, eg. on Creag Mhor, a few inches of tonalite occurs along the margin of the siliceous

DISTRIBUTION & FORM OF SCHIST XENOLITHS

IN THE FOYERS PLUTONIC COMPLEX IN THE DISTRICT DELL--CREAG MHOR--LOCH NESS

Middle Old	++
Red Sandstone	++
Granodiorite	
Tonalite	//
Pelitic schists	••
Siliceous	••

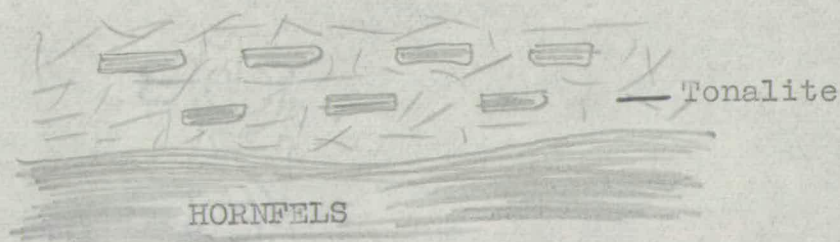
Scale: 6" : 1 mile



inclusions. The junction between the tonalite and the schist is quite sharp, a little way from the margin the rock develops the typical pink orthoclase phenocrysts of the granodiorite. In some other cases, tonalite is found veining schist-xenoliths enclosed in granodiorite. These last occurrences suggest that both the schist and the veining tonalite are xenolithic in the granodiorite.

The black, mica-rich hornfelses occurring as xenoliths in the tonalite are sometimes, like the epidiorite mentioned above (p.76) extensively veined with white aplite, and there is sometimes a narrow margin of aplitic material(about an inch wide) between xenolith and enclosing tonalite. These xenoliths are also cut by quartz veins, which range up to a foot in width. The contrast between the black hornfels and the white vein-material is often very striking in the field. The hornfels with the large sillimanite needles (p. 76) forms the margin of one of these xenolithic strips close to its contact with the tonalite and with a quartz veinlet.

Contacts between tonalite or granodiorite and the schist inclusions in this part of the district are always very sharp, although in some cases, fragments of hornfels are obviously frayed off into the surrounding tonalite.



Hornfels-tonalite contact. Moss, south of Loch Schistan

The long arcuate strips of schist sometimes give rise to little undercut crags. This can be seen to the south of Loch Scristan above Loch Ness, and at the base of Creag Mhor. The pelitic hornfelses weather more rapidly than the enclosing tonalite; the siliceous granulites, however, weather more slowly and do not give rise to caves along the base of hillocks and crags.

On the slopes of Meall Donn above Ballindalloch there is another long, strip-like inclusion of schist in the tonalite-- in this case of semi-pelitic Moine schists. But the vast majority, except in the Cregg Mhor-Scristan district, of xenoliths are smaller in size, ranging up to some 12-15 feet in length. The long arcuate xenoliths may be compared with a similar long strip of siliceous granulites in the Morvern-Strontian "Granite" (Kennedy & MacGregor, 1932, p 113). This strip, which is 20 yards in width, has been traced for a distance of two miles, throughout its length it maintains a parallelism with the tonalite-schist contact-surface at the complex margin, both in strike ^{and} in dip. Kennedy and MacGregor suggest that the strip represents a thin sheet of country rock stoped off along an arcuate fracture surface. It may be that a similar explanation could be applied to the strips at Foyers; on the other hand they may be symptomatic of a sheet-like habit of country-rock invasion.

The smaller xenoliths are predominantly siliceous granulites or semi-pelitic schists (Plate VIII B) Again the contacts with the enclosing tonalite or granodiorite are very sharp. Where the dips and strikes are not too distorted for measurement, the strike of the xenoliths is usually parallel to

to that of the schists at the neighbouring contact. The foliation of the enclosing tonalite or granodiorite also conforms to the strike of the xenolith. Narrow veins from the granodiorite, in Garthbeg Bay, can be seen penetrating xenoliths of semi-pelitic Moine schist (Plate VIII B) along the foliation planes. Thus large xenoliths are eventually split into narrow dyke or sheet-like forms. It is much less usual for the veining to cut across the schistosity.

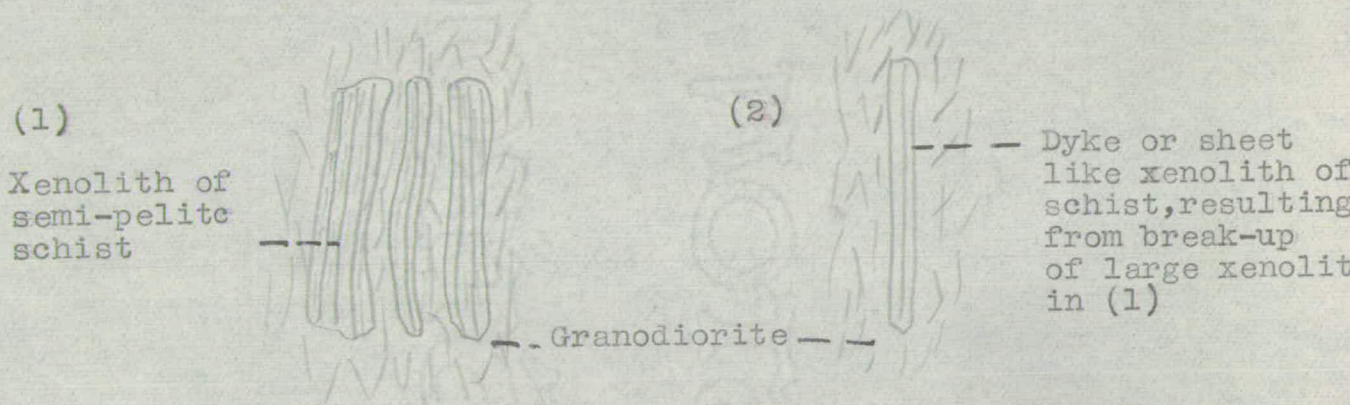


Diagram to show formation of dyke-like xenoliths

In Garthbeg Bay, a rather fine-grained green hornblende-schist (perhaps derived from a fine-grained member of the appinite suite) occurs as a long, narrow xenolith (about 6 inches wide) in the granodiorite. Its form exactly suggests a later intrusion, but it appears to be earlier than the granodiorite since it is contact-altered by the latter. Hornblende-schist of similar type forms ^a broader, dyke-like mass in the granodiorite on the shore of Loch Garth, a little further to the north-east from Garthbeg. A lenticular inclusion of the same rock is also found in a dyke of aplo-granite in Garthbeg Bay.

Xenoliths of dyke-like form have recently been discussed by Millar (1945 pp. 175-190) and the difficulties of distinguishing them from later intrusions, especially when all

PLATE VIII



A. Long lenticular strip of siliceous Moine schist in granodiorite, between Loch Kemp and Loch Scristan. The schist dips into the granodiorite at 45°



B. Xenolith of semi-pelitic Moine schist in granodiorite, Garthbeg Bay, Loch Garth. Veins of granodiorite are seen penetrating the xenolith along the planes of schistosity.

PLATE IX



- A. Long, lenticular xenolith of hornblende-schist in granodiorite Garthbeg Bay. This xenolith has a sheet-like form. Below it, is a tiny vein of aplite.



- B. The continuation of the cliff shown in Plate XIII A, toward Loch Scristan. A long lenticular strip of contact-altered mica-schist (black) is enclosed in tonalite (white).

the rocks have been subjected to later foliation. In Strath Errick the forms of the inclusions are dyke- or sheet- like, but they can always be distinguished from later intrusions. The narrow, thin strips of Moine schist are obviously xenolithic; the hornblende-schist inclusions might be mistaken in the field for later intrusions; but when sectioned, they show contact-alteration and are found to contain plagioclase porphyroblasts resembling the plagioclase in the surrounding granodiorite.



Diagram to show occurrence of hornblende-schist xenolith in granodiorite. Garthbeg Bay (to annotate Plate IX A)

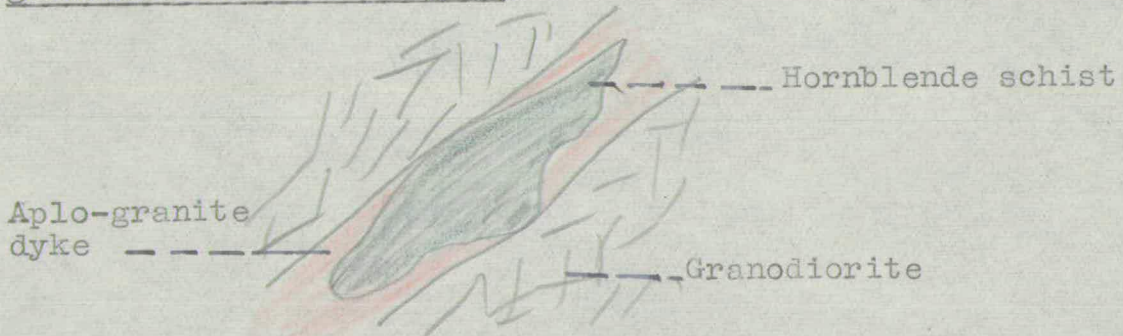


Diagram of hornblende-schist enclosed in aplo-granite dyke Garthbeg Bay

Small xenoliths of the surrounding schists occur in the veins of granodiorite and tonalite cutting the Moine series. The xenoliths usually lie with their long axes parallel to the sides of the vein, but sometimes they have been swung round to lie across the vein. One or two small, light coloured, greenish xenoliths from the granodiorite veins on Carn na Glaice Moire, and from the tonalite on Carn Gairbhthinn are hornfelsed calc-silicate

granulites, but they are very rare. The majority of the xenoliths in the veins are siliceous or semi-pelitic fragments of the schists cut by the veins themselves. No calc-silicate hornfelses have been found as xenoliths in the main Foyers complex.

2. Basic dioritic inclusions

Lens-shaped inclusions of dark, basic material occur throughout the granodiorite and the tonalite. The long axes of these inclusions lie parallel to the lineation of the enclosing rock. In certain districts -- Aultnagoire Moss and in the neighbourhood of Errogie and Loch an Ordain, the basic material is more abundant than the enclosing tonalite in which it occurs in large masses. Tonalitic veins penetrate these larger units along their foliation and isolate smaller lens-shaped enclaves. The foliation of the basic inclusions is fairly well marked, and the foliation of the tonalite is not only parallel to it, but is also more marked where the tonalite is in contact with the basic rocks. The foliation is also parallel to the strike of the neighbouring semi-pelitic Moine schists.

The basic inclusions are well seen on the shores of Loch Farraline in the Errogie district (Plate VI A) and near Loch an Ordain. The inclusions are of dioritic composition, rich in biotite and hornblende and with abundant accessory, brown sphene. They vary somewhat in type from one xenolithic mass to another. At Loch an Ordain, they can be seen grading into the typical tonalite through a stage of finer-grained tonalite. In some of the exposures, ghost-like outlines of small inclusions can be seen in the tonalite. In

general, however, the margins of the xenoliths are sharply marked off against the tonalite, which may remain coarse right up to the junction. Plagioclase porphyroblasts, of similar type to the plagioclase found in the tonalite, are frequently developed in the xenoliths (Plate VI A).

The basic material is most abundant near the contact with the semi-pelitic schists below Croftdhu, the proportion of tonalite increasing with distance from the contact. But there seems to be no marked difference in type between the basic material near the contact and that found further from it. Throughout its outcrop in the north-eastern end of the Foyers complex, the tonalite tends to be crowded with larger or smaller inclusions of these dioritic types; it is difficult to find any extensive stretch of typical tonalite free from them.

The basic inclusions vary from fairly coarse-grained types with lustrous plates of biotite and long prisms of hornblende, to finer-grained and more granulitic types. The latter can be well studied in Torr Shelly Quarry, where they occur in a highly inclined sheet of tonalitic rock, intruded parallel to the nearly vertical, north-south striking schists of the hillside. The tonalite of the quarry is not quite identical with the type rock of the main complex, but is very similar. The ~~intra~~ intrusion is full of basic inclusions (Plate VII B), which are orientated with their foliation parallel to the sides of the nearly vertical sheet and the enclosing "injection" schists. In the same quarry, there are a few xenoliths of pelitic schist, apparently enriched in biotite. They sometimes have selvages of large biotite crystals along their margins. It does not seem possible, however, to trace an unbroken series from schist inclusions into basic enclaves

v. Later crushing and shearing

The development of the Great Glen Fault, along the line of Loch Ness has resulted in considerable crushing and shattering of the Foyers "granite" and associated rocks. This crushing is not confined to the line of Loch Ness itself, but extends some distance southward from the loch. Parallel crush lines occur along the side of the loch; the chief of these may be traced from the mouth of the Allt an t-Sluichd (Loch Kemp to Loch Ness) along the south-east side of Carn Dearg and along Gleann Liath. The movements have evidently been spread over a long period of time; some are earlier, some later than the Middle Old Red Sandstone. The crush and fault line of Gleann Liath seems to be earlier than the Middle Old Red Sandstone, for at Ballagan, where it meets the margin of the Old Red, the shattering stops and has not been traced further into the breccias and conglomerates.

Various crush-lines, some parallel to and some at right angles to the line of the Great Glen are common throughout the district. One such can be traced along the course of the River E; another along Loch Garth and yet another from Loch Kemp to Dell and Druim Teampuill. From Dell along Druim Teampuill, the crush-line is marked by a line of wells. A crush-line running just north of Loch nan Lann and along the base of the crags behind Knockie Lodge, is also marked by several springs.

The movements, which are mainly prior to the time of the Middle Old Red Sandstone, are represented by thin lines of brown microbreccia, an extensive introduction of epidote and a general reddening and shattering of the rocks involved, the

rocks finally being rolled out to a fine crush. For the most part these effects are not seen in the Middle Old Red Sandstone, although one or two lines of microbreccia have been observed traversing it in the Carn Dearg, Foyers, district; so that, for the most part this series of crush effects would seem to be earlier than the Middle Old Red Sandstone.

Movements affecting all the rocks including the Middle Old Red Sandstone involve mechanical shattering on a large scale. This fragmentation is usually accompanied by the extensive introduction of haematite. To the latter is due the prominent red colour of the rock cuttings along the road in the Middle Old Red Sandstone on both sides of Loch Ness in the Foyers district. The new road on the north side of the loch is fringed with red, broken rock, as yet uncovered by vegetation.

It is very noticeable that where the granodiorite is involved in crush-lines, as it is on the flanks of Carn Dearg (Foyers) and below the Falls of the Farigaig, it changes in colour from grey to red. The first stage in this process is the deepening in colour of the orthoclase phenocrysts, until they become brick red. When crushing has taken place only along a particular band on a cliff face, the effect may simulate the appearance of an intrusive dyke with red feldspars.

The next stage, well seen on the conical hill between Carn Dearg and Carn na Daila-riach, is the reddening of the whole rock. Usually epidote is introduced at the same time. The epidote occurs both in veins and as disseminations through the rock. The individual crystals, which are bright green, may be quite large. Striking colour effects are sometimes produced

by the rich red of the feldspars, the black of the hornblende and biotite and the bright green of the epidote. At Dearg Lochain at the foot of Carn Dearg (Dearg is the Gaelic name for red), these crushed rocks weather to a pale rose colour.

In thin section, the effects on the granodiorite are seen to be even more marked. The red colour of the feldspars seems to be due to incipient decomposition -- the crystals are crowded with brown dust and tiny flakes of sericite. Individual crystals are broken across, the twinning lamellae of the plagioclases are bent and secondary twinning is also developed. The larger crystals of ~~re~~ orthoclase show strain shadows as also does the quartz, which is usually ground down to small fragments. Biotite is bent, and altered to green chlorite and epidote. Hornblende, sphene and apatite seem to be least affected by the crushing. In the field, the identity of the crush-rock can often be recognized more readily on weathered surfaces than fresh fractures. On Carn Dearg, the granodiorite is reduced to a greenish crush-rock, with scattered residual red feldspars. The more intensely crushed part, which may be greenish or brown, is a rolled-out micro-breccia. Epidote occurs both along the lines of micro-breccia and in groups of pale yellow crystals scattered through the rest of the rock.

At Knockie boathouse, on the shore of Loch Ness, the Cnoc Carrach granodiorite is involved in extensive shearing. It becomes a red rock, with darker red phenocrysts and develops a marked flaggy jointing. In thin section, the rock is found to be so intensely crushed and rolled out that the normal structures have been obliterated.

The rocks in Whitebridge plantation are

frequently badly crushed and epidotised. The dyke of granodiorite-porphry, which cuts the pink granite in the course of the River Brein just above the bridge carrying the road to Killin, is involved in these movements. It is altered from a grey rock with feldspar pink phenocrysts to a red, cataclastic rock with brick-red feldspars and streaks of epidote. In section, it is found to be intensely crushed; broken crystal remnants lying in a matrix of micro-breccia.

Thin, persistent, brown or reddish lines of micro-breccia, either with or without a narrow fringe of reddened rock are of frequent occurrence in the plutonic complex in Strath Errick. A number may be observed together on one rock surface, either in parallel or intersecting one another. They are normally only about 0.5 cm in breadth, but may persist right across large exposures. Two such lines, traced across an outcrop of granodiorite on Carn Liath, were at least 700 cm in length -- passing under the heather at both ends of the outcrop.

The lines of micro-breccia are usually straight or slightly curved. Being more resistant to weathering than the uncrushed rock in which they occur, they stand up as tiny ridges on the rock surface. Epidote may or may not occur along these lines of microbreccia; sometimes it is found in separate veins, which have been observed to cut the brown lines of micro-breccia, in such cases the latter must be the earlier. Epidote is not developed in the uncrushed rocks, but is confined to the bands of crushing and movement.

In a few cases, including the shore at Errogie, the blue abriachanite (crocidolite) described by Heddle (1880,

-87-

p. 111) from the northern side of the Great Glen, has been observed along crush-lines.

Along some the bigger crush-zones, the amount of micro-breccia increases until a crush-breccia is formed, consisting of angular fragments of granitic rock in a brown matrix of finely comminuted material. A small outcrop of the Aberchalder granite is thus affected at Trinloist; as also are the granodiorites of Creag an Fhithich and Dun Garbh. The resultant rock is almost identical in appearance with the basal breccia of the Middle Old Red Sandstone and may occur within a few feet of the latter.

Obviously the coarse mechanical shattering and the production of the micro-breccia are of different ages. The production of thin lines of micro-breccia, the introduction of epidote and the reddening of the granodiorite seem to be pre-Middle Old Red Sandstone. The shearing and fine brecciation are perhaps due to prolonged but slow shearing stresses; the coarser fragmentation to more sudden shocks.

B. PETROGRAPHY OF THE FOYERS PLUTONIC COMPLEX

i. Introductory

It will have been seen from the previous description of the field occurrence of the Foyers plutonic complex that there are three principal rock types -- tonalite, granodiorite and granite. There is also a much smaller development of earlier appinitic rock. In the following account of the petrography of the Foyers complex, the appinites will be described first and then the tonalite, granodiorite and granite. The description of each principal type will be followed by those of the various modifications of it, such as those found in Knockie Forest. Finally, the latter intrusive phases, aplites and lamprophyres, will be described.

ii. The Appinites

In Knockie Forest coarse-grained appinitic rocks are developed between the head of the Allt an t-Sluichd and Creag a' Ghiubhais, and immediately to the south of Loch na Sgorthaich. These appinites are all of dioritic composition, they differ from normal diorites in containing a high percentage of hornblende. They are handsome rocks, white or grey in fresh fracture, with large dark-green hornblende crystals (580, 541) Epidote is conspicuous as isolated crystals of a bright green colour and as a coating along joint-planes.

In thin section, the specimen from Loch na Sgorthaich consists of plates of oligoclase-andesine, subsidiary

orthoclase, large and abundant hornblende crystals, interstitial quartz and accessory sphene, iron ore and apatite. The plagioclase is largely altered to sericite and calcite. The green hornblende occurs in large, often rather irregularly shaped plates and forms nearly half of the rock. The cores of these crystals are sometimes brown, but they extinguish in the same position as the rest of the crystal. The apatite crystals are clear and colourless, and are usually large and abundant.

The specimen from near Loch Kemp (541) is very similar but richer in orthoclase and quartz than no. 580. It ~~is~~ also contains a little microcline. The quartz shows strain shadows and is crowded with small granular inclusions. The feldspars are largely sericitised. The large green ~~green~~ hornblendes are often irregular in shape and poikiloblastic. They enclose little sphenes and a few flakes of chloritised biotite.

The finer-grained type (582) as developed near Loch Knockie is also dioritic, and very rich in hornblende. Some of these hornblende crystals have brown cores like those in the adjacent, coarser-grained variety. A little chloritised biotite is associated with them. Apatite is again prominent as an accessory, and is found as colourless needles. The feldspars are sericitised. A still finer-grained type, from the edge of Drummond Plantation, where it is in contact with the Cnoc Carrach granodiorite, shows green hornblende with lighter-coloured cores, which are relics of original pyroxene.

Epidote and sometimes calcite, have been introduced into all these rocks as described in the previous section.

There are a few, small intrusive masses of hornblende-rich diorite in Gleann Liath, cutting the Loch Bran augen schists. These rocks are dark-coloured, medium-grained diorites, rich in hornblende and with subsidiary biotite. The Feldspar is predominantly calcic oligoclase (An_{25}), but there is subsidiary orthoclase, which may be perthitic (475b). The plagioclase is largely sericitised. The hornblende occurs in large, ragged, poikilitic crystals and is usually associated with subsidiary chloritised biotite. There is accessory sphene, colourless apatite, black iron-ore and in some specimens, a little quartz. Calcite and epidote have been introduced rather extensively probably during later crushing (see previous section on crush-effects).

iii. The Tonalites

The typical tonalite of the complex is a coarse-grained, grey, hornblende-biotite-quartz diorite. Sphene is an abundant accessory and is usually visible in hand specimen. The rock generally has a more or less marked alignment of its components, particularly noticeable on large exposures. Owing to the presence of numerous inclusions of basic dioritic material (p. 81) and of various types intermediate between tonalite and inclusions, the bulk of the tonalite outcrop tends to be somewhat variable in character. An analysis of a typical specimen of the normal rock is given on p. 91 (overleaf).

In thin section (Plate XV C) the tonalite consists of quartz, orthoclase, oligoclase-andesine(An_{30}) biotite and subsidiary hornblende, with accessory sphene, apatite and iron ore. (193, 195)

Analysis A

Percentage	Molecular Proportions	Norm	von Wolff values
SiO ₂	54.95	9149	Q 0.42
Al ₂ O ₃	20.57	2018	Or 16.25
Fe ₂ O ₃	1.87	117	Ab 40.95
FeO	4.68	652	An 21.42
MgO	2.68	665	Cor 1.78
CaO	4.82	860	Hyp 12.43
Na ₂ O	4.84	781	Mag 2.71
K ₂ O	2.75	292	Il 2.06
H ₂ O+	0.72		Ap 0.93
H ₂ O-	0.13		Water 0.85
CO ₂	none		
TiO ₂	1.09	136	<u>99.80</u>
P ₂ O ₅	0.43	30	
MnO	0.26	37	
	<u>99.79</u>		

Tonalite. Foyers Plutonic Complex. Old quarries in field immediately south of Wester Aberchalder Lodge. sp. 193
Analyst. W.H.Herdsman

Mode.

Quartz	13
Orthoclase	10.5
Plagioclase	50.
Biotite	12.5
Hornblende	11.
Accessory sphene, magnetite, apatite	3.
	<u>100.0</u>

Plagioclase is the predominant feldspar, orthoclase being quite subsidiary. The plagioclase occurs in large, mutually interfering plates. Most of it is near oligoclase-andesine (An_{30}) but some of the larger crystals are zoned. The cores in these bigger crystals range from sodic labradorite (An_{55}) to calcic andesine (An_{45}).

Myrmekitic intergrowths of sodic plagioclase and quartz are common. They usually have a wart-like form and are found along the margins of the orthoclase into which they project. Quartz is not very abundant and occurs ~~initially~~ interstitially. Biotite is the principal ferro-magnesian mineral. It occurs in large plates, strongly pleochroic from pale yellow to dark brown. Green hornblende is subsidiary. It frequently shows twinning. Its pleochroism is X = yellowish green, Y = green and Z = green with a bluish tinge. Small crystals of both biotite and hornblende are enclosed in the feldspar. Sphene is an abundant ~~is~~ accessory. It forms large, lozenge-shaped crystals (up to 2mm in length). The other accessories are colourless apatite and black iron-ore.

Specimen no. 253 of the British road-stones tested by Lovegrove and Waller Page from a quarry in the Pass of Inverfarigaig somewhere near Tom an t-Sionnaich is probably a tonalite from the plutonic complex. The exact location of the quarry is not available; no quarry at present is being worked in that particular part. The results of the test are given on p. 98.

The finer-grained variety of the tonalite (287) which is found veining the schists in the Carn Gairbhthinn area, is very similar to the above type, but richer in hornblende.

The accessory sphene of the tonalites is usually conspicuous in hand specimen, but the amount present varies somewhat from place to place.

In the Knockie Forest-Loch Kemp district, veins of tonalitic composition are common in the schists near Torr Paiteag and on the north side of Loch Kemp as well as at the head of the Allt an t-Sluichd and on Tom Rathail. In appearance, these rocks are grey and often rather granulitic and much finer in grain than the Foyers type tonalite. Sphene is only sparsely present; both it and hornblende may be altogether absent.

A specimen from Tom Rathail (345) in Whitebridge plantation is a biotite-tonalite. The plagioclase is predominantly oligoclase, but the crystals are usually zoned. The cores in these latter crystals are calcic oligoclase (An₂₅) are surrounded by oligoclase-andesine(An₃₀) and a rim of calcic oligoclase. The subsidiary orthoclase sometimes encloses small plagioclases and biotites. Wart-like growths of myrmekite occur along its margins. Quartz is fairly abundant and shows strain shadows. The biotite is pleochroic from pale straw yellow to deep brown. Accessory apatite is abundant in this type, occurring both in large prisms and in small needles, some of the former being coloured blue by numerous rod-like inclusions. There is also a little tourmaline present, pleochroic from pale yellow to nearly black.

A narrow vein of biotite-tonalite(589) in the schists between Torr Paiteag and Loch Kemp carries microcline as well as orthoclase. The biotite is of a redder brown than that of no.345 on Tom Rathail. Hornblende is absent.

iv. The Granodiorites

The typical granodiorite of the Foyers complex is a coarse-grained, grey, hornblende-biotite-granodiorite, with prominent phenocrysts of pink perthitic orthoclase. These phenocrysts average about $\frac{1}{2}$ " in length. They usually have a rude alignment parallel to the lineation of the rock. Sphene is an abundant accessory, prominent in hand specimen. An analysis of a typical specimen of granodiorite, from the old road-metal quarries in the Dell Marsh is given on p. 95 (overleaf). The results of a Lovegrove attrition test on rock from the same quarry is given on p. 98, no. 252.

In thin section (45) the granodiorite consists of quartz, oligoclase, orthoclase, hornblende and biotite with accessory sphene, apatite and black ore (Plate XVD). Plagioclase is in excess of orthoclase, most of it is oligoclase, but some of the larger crystals are zoned from more basic cores (sodic andesine An_{35}). The orthoclase is perthitic and often encloses blebs of quartz and small plagioclase crystals. Wart-like myrmekitic intergrowths of sodic plagioclase and quartz are frequent along its margins. Quartz, which occurs interstitially, contains trains of tiny, rounded inclusions and commonly shows strain shadows. The biotite and hornblende are of the same types as those found in the tonalite. Corresponding to the smaller percentage of alumina relative to lime, hornblende is more abundant than in the tonalite. The hornblende usually shows twinning; the cores of the larger crystals are sometimes sieved with quartz. Some of the colourless apatite is enclosed in biotite, which also contains inclusions of zircon surrounded by

Analysis B

Percentage	Molecular Proportions	Norm	von Wolff values
SiO ₂	60.77	10118	Q 11.60
Al ₂ O ₃	16.44	1613	Or 20.03
Fe ₂ O ₃	1.77	111	Ab 31.56
FeO	3.92	546	An 18.09
MgO	2.71	672	Diop 2.07
CaO	4.44	792	Hyp 10.43
Na ₂ O	3.73	602	Mag 2.57
K ₂ O	3.39	360	Il 1.80
H ₂ O+	1.53		Ap 0.55
H ₂ O-	0.05		Water 1.58
CO ₂	none		
TiO ₂	0.95	119	100.28
P ₂ O ₅	0.25	18	
MnO	0.26	37	
	<u>100.21</u>		

Tonalitic granodiorite. Foyers plutonic complex. Dell Marsh quarries, 1/2 mile SW of Upper Falls of Foyers. sp. 45
Analyst W.H. Hendsman

Mode

Quartz	20
Orthoclase	39.5
Plagioclase	21.
Biotite	8.
Hornblende	6.5

Accessory sphene, magnetite, apatite & epidote not estimated.

poorly developed pleochroic halos. In some localities, the granodiorite becomes impoverished in orthoclase and passes into tonalite. In other outcrops, the orthoclase phenocrysts become more abundant and slightly larger than in the typical rock. Various granodioritic rocks, more or less related to the Foyers type rock, are found in Knockie Forest. They may be divided into three main types : the Cnoc Carrach granodiorite ; the Meall nan Aidhean granodiorite; and the granodiorite-porphiry.

a) The Cnoc Carrach granodiorite

The highly porphyritic grey granodiorite developed at Cnoc Carrach and above the north bank of the Allt Luaidhe (Loch nan Lann to Loch Ness) is a very handsome rock. It is coarsely crystalline and contains large and prominent phenocrysts of pink orthoclase and rather less abundant phenocrysts of white plagioclase. The usual length of these phenocrysts ranges from one to two inches, whereas in the Foyers type granodiorite, the largest rarely exceed $\frac{1}{2}$ " in length. Locally these very large phenocrysts are not developed and the Cnoc Carrach rock then becomes almost identical with the normal granodiorite. Orthoclase and oligoclase also occur as a second generation of smaller crystals together with a little microcline. The orthoclase is perthitic. The oligoclase is strongly zoned from more basic cores. The bigger feldspars have inclusions of blebs of quartz, biotite flakes and hornblende. Myrmekite is often developed between orthoclase and plagioclase. Quartz, which is rather more abundant than in the Foyers type rock, shows strain shadows, and the edges of adjacent grains often have irregular sutured margins.

The dark minerals are brown biotite and green hornblende. There is accessory sphene, colourless apatite in stout prisms and black iron-ore.

b) The Meall nan Aidhean granodiorite

The biotite-granodiorite developed on Meall nan Aidhean, Tom a'Chliabhain and the neighbouring hills (sections 587 533, 544 b, 592, 490) is a much finer-grained rock than the Cnoc Carrach type. It often shows a rather marked alignment of its biotite flakes. It normally shows numerous small pink orthoclases and is rather quartzose. Sphene is not prominent in hand specimen, though tiny crystals are often visible with careful inspection. Oligoclase is predominant over perthitic orthoclase and microcline. In some specimens, the plagioclase is strongly zoned, eg. from calcic oligoclase (An_{28}) in the core, through zones of oligoclase-andesine (An_{30}) and calcic-oligoclase (An_{25}) to oligoclase (An_{20}) which forms the rim. The core is commonly more sodic than the immediately succeeding zone. Myrmekite is developed as wart-like growths in the orthoclase where it is in contact with plagioclase. Quartz occurs interstitially and shows strain shadows. It is crowded with tiny inclusions -- perhaps of liquid. The margins of the individual quartz grains are often sutured. Biotite, pleochroic from yellow to brown, and subsidiary green hornblende, are the common dark minerals; but in some localities, hornblende is lacking and the rock then contains a small proportion of yellow orthite (slices 490 Tom Rathail; 592 Allt Leachd Gowrie) There is accessory sphene, apatite, black iron-ore and zircon. Epidote sometimes occurs in the vicinity of crush-lines, along which the rock sometimes develops a flaggy jointing.

From "Attrition Tests of British Road-stones" : Mem. Geol. Survey 192

Tests by E.J. Lovegrove (pp 22-25)

Ref. No.	H or M broken	Chips		Dust % of loss		Specific Gravity	
		%detached from parent stones		average			
		dry test	wet test	dry test	wet test		
252	H	1.51	.0	13.04	18.70	15.87	2.69
253	H	.0	4.39	9.81	14.65	12.23	2.66
255	H	2.39	.54	8.79	10.40	9.59	2.60

Tests by Logan Waller Page (pp 70-71)

Ref. No.	Water absorbed per cubic foot	Hardness	Toughness	Cementing Value
252	0.23	18.8	10	20
253	0.52	18.8	7	6
255	0.17	18.3	10	13

-
- 252. Biotite-hornblende-granite. Glenlia(West)quarry. 1/2 mile SE of Falls quarry.
 - 253. Biotite-granite. Glenlia(East)quarry, on SE side of Loch Ness, 10 miles from the north-east end of the loch.
 - 255. Pink aplite or binary granite. Garthbeg quarry. 3 miles SE of Falls of Foyers

(The first series of figures are the results obtained from attrition tests with a Lovegrove attrition testing machine. The second series, by Mr. Page, measure hardness (amount of rock lost after grinding a 1" diameter core of rock against a sand-fed disc for 1000 revs:) toughness (breakage under impact) and cementing value. For hardness, below 14 is soft, 14-17 medium and above 17 hard; for toughness, below 13 low, 13-19 medium and above 19 high; and for cementing value (no. of blows required to break a briquette of the ground rock) below 10 low, 10-25 fair, 26-75 good, 76-100 very good and above 100 excellent. H (hand) or M (machine) broken in the quarry).

Near Loch na Sgorthaich, the igneous rock cutting the siliceous schists is quartz-diorite(585b). It occurs on the margin of the main mass of Meall nan Aidhean granodiorite in the complex of schist with igneous veining.

c) The granodiorite-porphry

The granodiorite-porphry developed near Loch Kemp is a much finer-grained rock than the two previous types. It is a grey, rather granulitic-looking rock, containing large phenocrysts of pink orthoclase. It is more quartzose than the normal granodiorite

(540) In thin section, the groundmass of the rock is seen to be made up of a rather xenomorphic-granular aggregate of orthoclase, with subsidiary microcline, oligoclase-andesine, quartz, small flakes of biotite and hornblende. Myrmekite is developed between orthoclase and plagioclase. The latter sometimes shows zoning from more basic cores. The quartz is crowded with small inclusions(? fluid) and shows strain shadows. The biotite is pleochroic from straw yellow to dark brown. Inclusions of zircon have not been observed in it. The green hornblende often shows twinning. Sphene, colourless apatite and black iron-ore are accessory.

The large phenocrysts consist of perthitic orthoclase. They enclose rounded blebs of quartz, crystals of plagioclase, apatite, sphene, ~~microcline~~ biotite and hornblende. Their margins tend to be embayed against the surrounding finer-grained components.

This rock bears a general likeness to the granodiorite-porphry described from the Strontian Complex(Kennedy & MacGregor, 1932, p 111) The Foyers rock however is finer in grain and is developed on a very much smaller scale than that of the Strontian examples.

v. The Granites

The biotite-granite of the Aberchalder district is of finer grain than the typical granodiorite and tonalite. It is a highly quartzose, pink rock with very sparsely distributed flakes of biotite. It is not porphyritic and shows no directional alignment of its components. It varies somewhat in texture from place to place, but not sufficiently to justify subdivision.

An analysis of the rock is given on p. 101 (overleaf).

In thin section (526) the rock is seen to consist of quartz, perthitic orthoclase, microcline-microperthite and sodic-oligoclase (An₁₅) with very subsidiary biotite and accessory hornblende, sphene, apatite and black iron-ore. (Plate XVI A). Quartz is very abundant. It occurs in large irregularly shaped areas, showing shadowy extinction. Tiny, rounded inclusions occur in trails following two directions mutually at right angles. Plagioclase is subsidiary to orthoclase and microcline. The feldspar crystals are usually subhedral or anhedral. The larger feldspars enclose blebs of quartz and smaller feldspar crystals, Myrmekitic intergrowths are abundantly developed. Biotite is very sparsely distributed. It forms small flakes, pleochroic from pale to dark brown with inclusions of zircon surrounded by halos, or of apatite crystals. Rare green hornblende in ragged shreds is seen in some of the sections. Sphene is not abundant and is visible only in thin section. It is sometimes found surrounding the sparse grains of black iron-ore.

The rock of the small intrusion near Garthbeg is very like the type granite from Aberchalder. It (63) differs in being almost free from dark minerals. Biotite is very sparsely

scattered through the rock but hornblende and sphene are absent. There is a little accessory magnetite. For Levegrove tests on this rock see p.98, no. 255.

It has already been mentioned that there are one or two small exposures of a much coarser, red granite along the line of the Gleann Liath fault between the Fall of the Farigaig and the pass of Inverfarigaig (p. 66). This type is a coarse, red granite, very rich in quartz. It is coarser than the Aberchalden granite described above, and the feldspars are more nearly euhedral. It appears (275) originally to have been composed of abundant quartz perthitic orthoclase and microcline, oligoclase, sparse biotite and accessory magnetite. The specimens from the Gleann Liath line of crush are very badly sheared and much of the rock is ground down to a micro-breccia. The feldspars are crowded with specks of brown dust, to which much of the red colour of the rock may be ascribed. The biotite has been completely altered and is now represented only by magnetite dust, which still preserves the bent outlines of the original mica.

The granites which are exposed in the courses of the Rivers Fechlin and Brein (Allt Breinag) at Whitebridge are light coloured, fine-grained, non-porphyrific biotite-granites with a marked flaggy jointing (11.140,131) They often have a faint lineation due to the parallelism of the biotite. They consist of perthitic orthoclase with subsidiary microcline, oligoclase, quartz and biotite and accessory apatite, sphene and black iron-ore. Myrmekite often occurs in the orthoclase and between it and plagioclase. The latter is not zoned. It is frequently cloudy with brown dust and sometimes the twinning lamellae are bent. Both these latter

effects reflect the presence of neighbouring crush-lines. The quartz grains have sutured margins and mostly show strain shadows. The brown biotite has commonly been altered to green chlorite. Sphene is not very common. Epidote has sometimes been introduced near crush-lines; in the field it is frequently seen as a coating along joint planes.

The small granitic intrusion on Carn Bhreabaig is of the same type as that found in the neighbouring exposures in the Fechlin at Whitebridge.

The scattered exposures of the badly sheared pink granite (448c) on the top of Carn Dearg near Foyers consist of rock that is rather finer grained than that of the Whitebridge exposures, though it is a similar type. It is too badly sheared to permit of detailed study. The quartz occurs in lenticular streaks, rudely aligned. Numerous lines of minute inclusions cross the quartz at right angles to this crude foliation. Strain shadows are very marked. The twinning lamellae of the plagioclases are bent and they are usually much decomposed. The biotite is chloritised.

vi. Later Intrusive phases

a) Pegmatites

Pegmatite veins are rare in the Foyers and Strath Errick district, with the exception of those, probably much older, cutting the Gleann Liath series. A few small pegmatitic veins, mostly under a foot in thickness, cut the Foyers plutonic complex in Strath Errick. Graphic intergrowths of Quartz and feldspar are commonly present. The pegmatite veins

have been observed to cut aplites, and are therefore probably mostly later than the aplite intrusions.

b) Aplite & Alsbachite

Small intrusions of aplitic type are fairly common cutting the Foyers complex. Some are coarse enough to be termed aplogranites. There are two chief types : those rich in orthoclase and pink in colour, and white varieties with oligoclase in excess of orthoclase. The oligoclase-rich aplites are found principally cutting the schists outside the complex and also cutting xenoliths in the plutonic complex. Quartz is abundant in these rocks, with it occurs subsidiary orthoclase, oligoclase, biotite and sometimes muscovite. The texture is typically saccharoidal.

The pink, orthoclase-rich aplites are more frequently found cutting the plutonic complex itself.

The most commonly developed rock of this group is, however, porphyritic and sometimes garnetiferous, and should be called alsbachite. Rocks of this type are abundant as dykes cutting the biotite-granite in the Aberchalders district and also cutting the schists on the north-east margin of the complex as well as on Beinn Sgurrach. In the latter locality there are garnetiferous varieties.

These alsbachites are rocks of medium to fine grain with a typical saccharoidal texture. They are pink in hand specimen with phenocrysts of biotite and feldspar, the latter sometimes with a faint bluish colour. In thin section, these rocks consist of a granulitic aggregate of quartz and orthoclase with a little sodic plagioclase, in which lie phenocrysts of plagioclase, orthoclase, microcline and biotite. There is accessory

zircon, apatite, black ore and sometimes sphene, in the Beinn Sgurrach rocks also ragged garnet, colourless in thin section(21) In some of the quartz-grains of the fine-grained matrix, there are peculiar tubular intergrowths with the feldspar. The phenocrysts of plagioclase appear to be a calcic oligoclase, the cores of which are sometimes more basic. The orthoclase is perthitic. Both may show tubular intergrowths with quartz, or enclose larger and more irregularly shaped quartz inclusions. Both orthoclase and plagioclase phenocrysts may occur separately or grouped together. The biotite is mostly fresh, pleochroic from pale yellow to dark brown and encloses a few small zircons. Apatite, often blue in colour, is found both as inclusions in the biotite and dispersed through the rock. In one specimen, found cutting the biotite-granite in Conagleann, the apatite prisms enclosed in the biotite are strongly pleochroic from a dull brownish-purple to a clear deep blue. This colour is restricted to a wide central zone of inclusions which appear to consist of short rods, irregularly arranged transverse to the elongation of the prism.

In the coarser-grained alsbachite types (523), the phenocrysts increase in proportion at the expense of the intervening finer-grained matrix, which itself becomes coarser in texture.

c) Graphic granite and felsite

Cutting the Moine schists below Crag nan Clag a small intrusion of a graphic granite occurs. It (367a) is a medium-grained pink rock, composed of quartz, perthitic orthoclase, microcline-micropertthite, subsidiary albite-oligoclase and a few flakes of biotite with a little accessory iron ore. It is chiefly notable for a very beautiful intergrowth of quartz and alkali-

feldspar. In some cases the intergrowth forms a fringe round small sericitised plagioclase crystals.

Dykes of felsite are the most prominent minor intrusions in the country to the north-east of the Foyers plutonic complex. They have not been studied in any detail during the present research, but appear to be very numerous. Felsite boulders are very abundant in the Middle Old Red conglomerates overlying the schists in this district.

The Brin rock felsite, described by Horne(1915 p.45) is typical of the series. On the grey crags and scree derived from the gneisses of the Brin crag, the pink talus of felsite debris is a very marked feature, especially when the rocks are wet after rain and the colours brighter. Dykes of felsite occur below the unconformity of the Middle Old Red Sandstone on the Moine schists at Crag nan Clag and at Creag Dhearg(Loch a'Choire). These felsites (595c, 367b) are fine-grained, pink rocks with a few scattered phenocrysts of biotite, feldspar and quartz. In thin section, the rocks show beautiful micrographic intergrowths of quartz and orthoclase. The phenocrysts are quartz, perthitic orthoclase, oligoclase and biotite. There is a little accessory iron-ore and a little muscovite -- the latter is probably secondary. The felsite from Crag nan Clag (367b) also contains a few ragged garnets, colourless in thin section.

The sill of quartz-porphry below Creag Dubh, south of Leiterchullin on Loch Dun Seilcheig is very deeply weathered. A thin section has not been made of this rock.

Felsites have been found cutting the biotite-granite in the course of the Aberchalder burn, but the majority of the dykes seem to be found outside the plutonic complex margin.

It may be noted here, that, to the north-east of the Foyers plutonic complex in the Dunmaglass district, a few granitic veins have been observed cutting the schists. Some of these rocks have a marked foliation and it is possible that some of them may belong to the so-called "Older Granite" suite and be connected with the regional injection complex. It is thought that mention should be made of their existence although during the present research, neither these rocks nor the Dunmaglass hills in which they occur were studied to any extent.

d) Microdiorites

One or two small, dyke-like intrusions of microdiorite have been observed cutting the schists and the complex near the new reservoir loch behind Dell Farm and on Carn Bhreabaig.

The rock from the reservoir(498) is a light-grey compact rock with phenocrysts of plagioclase, hornblende and biotite. The Carn Bhreabaig rock (182) is rather darker in colour. The groundmass of this rock is predominantly made up of laths of oligoclase, while that of the reservoir rock contains much micropegmatite. There is accessory sphene, black iron-ore, apatite and epidote in both rocks.

The large phenocrysts of plagioclase may enclose quartz and smaller plagioclase crystals. The rock from the reservoir(498) shows very beautifully, oscillatory zoning of its plagioclase phenocrysts. A typical crystal showed the

- following zones:-
- | | | |
|---------|------------------|---------------------|
| 1. Core | An ₆₅ | Calcic labradorite |
| 2. | An ₃₀ | Oligoclase-andesine |
| 3. | An ₄₅ | Calcic andesine |
| 4. | An ₄₀ | Andesine |
| 5. | An ₄₅ | Calcic-andesine |
| 6. | An ₃₅ | Sodic andesine |
| 7. Rim | An ₁₅ | Sodic oligoclase |

e) Lamprophyres

There are a few dykes in the Strath Errick district belong to the lamprophyre suite. They are found cutting both the plutonic complex and the schists. They are never very thick, usually only a few feet. Those in which it was possible to determine the direction have a general NNE to NE trend. Both kersantite and spessartite are represented. A typical kersantite(554) from Carn Gairbhthinn carries fairly numerous phenocrysts of diopside. In the spessartite series, the laths of plagioclase in the ground-mass are nearly always zoned. In a specimen from Crag nan Clag, cutting Moine schists (578), three zones could be detected : a core of calcic andesine(An_{45}) surrounded by oligoclase-andesine (An_{30}) with an outer rim of calcic-oligoclase (An_{25}). In some specimens (358f) a little purplish augite is present as well as green hornblende. In most of the spessartites, biotite and hornblende are the mafic minerals, the hornblende occurring both as fairly stout prisms and as acicular needles. These latter crystals together with flakes of biotite are sometimes associated together and have apparently replaced pyroxene -- the characteristic outline of which they still preserve.

C. THE SCHISTS AT THE MARGIN OF THE PLUTONIC COMPLEX

i. Petrography of the Contact-altered Moine schists

It has already been pointed out that there is no well-marked aureole of contact-metamorphosed schist around the Foyers plutonic complex. The more pelitic facies of the schists does, however, show the effects of contact-alteration and these will be described in detail.

The semi-pelitic Moine schists near the margin of the plutonic complex in the Carnoch district show a small development of cordierite (427) now altered to pinitite and associated with the biotite. The latter has a red "hornfels" type of pleochroism.

More conspicuous effects were observed in a semi-pelitic granulite(567) on the margin of the tonalite on the north-east side of Loch Kemp. Here shining tufts of sillimanite are visible in hand specimen. In thin section, the rock is found to consist of quartz, feldspar, cordierite, biotite, muscovite, sillimanite, andalusite and iron ore. Quartz, feldspar and cordierite occur as rounded individuals, whilst the biotite still preserves the original schistose alignment of its flakes. The cordierite sometimes shows sector twinning, but no yellow halos round inclusions have been observed. There is some myrmekitic intergrowth of quartz and feldspar. The biotite is strongly pleochroic from pale brown to foxy red, and there are marked pleochroic halos round enclosed zircons. Sillimanite occurs as isolated blades, small tufts and clusters, and as lenticular felted masses associated with the biotite folia. Andalusite is

less abundant than the sillimanite; it occurs both as isolated crystals and in the felts of sillimanite crystals. Black iron-ore, in finely disseminated grains, is abundant. It is sometimes concentrated in lenticular streaks, and is sometimes found enclosed in the biotite. The felts of sillimanite and much of the black ore seem to have been formed at the expense of the biotite, and the few flakes of muscovite are perhaps also formed as a result of contact alteration.

A case of slight hornfelsing and slight enrichment in biotite was observed along the margin of one of the veins of biotite-tonalite near Loch Kemp (589: ref. p. 93). The schist cut by the vein is a semi-pelitic Moine, the more pelitic bands of which show small-scale puckering. Along the contact with the tonalitic vein, the schist loses its obvious foliation (which the vein cuts at right angles) and becomes more compact. It develops a hornfels type of texture and is also somewhat enriched in biotite along the marginal zone. In the tonalite vein, the accessory apatite crystals near the margin of the vein are blue in colour, further from it, they are colourless.

The Conagleann injection gneiss, in Conagleann, shows the effects of contact-metamorphism where it is in contact with the Foyers tonalite (410, 529) (Plate XVII D). Sillimanite is sometimes visible in hand specimen. It occurs both as tufts of fine needles and ~~xxx~~ as longer, larger blades. Andalusite, colourless in thin section, is also found. Cordierite is associated with the biotite laminae. Most of the cordierite is altered to yellow pinite or to "shimmer aggregates"; but original yellow halos round inclusions are still preserved.

Green mica-schists above the boathouse at Knockie carry andalusite and graphite. Their outcrop is close to that of the Cnoc Carrach type of granodiorite (p. 96). The andalusite is entirely altered to greenish sericite, in which the graphite, included in the original andalusite, still forms a cross. The andalusite may be derived from part of the muscovite. The schist is garnetiferous, the garnets being sometimes partly chloritised. Biotite, pleochroic from pale to dark brown, is subordinate to muscovite. There are a few lenticular streaks of quartz. This schist may ~~be~~ belong to the Glen Doe series of mica-schists (p. 36).

Graphite inclusions in
altered andalusite



Andalusite-schists have been found as thin partings in siliceous granulites at Lochan a'Chinn Mhonnaich(534) and near Loch Bran(563) (see also p. 73). At these places, it is not possible to trace the particular layers back to unaffected types; they probably represent partings of ~~origin~~ ordinary pelitic schist in a siliceous series of granulites. The only effect due to contact-metamorphism on the surrounding siliceous schists seems to be a slight glazing.

The andalusite schist from Lochan a'Chinn Mhonnaich is a black mica-schist with prominent andalusite crystals. These average $\frac{1}{4}$ " in length, the largest being about $\frac{1}{2}$ " long. They stand out in relief on the weathered surfaces. The rock consists of abundant biotite, subsidiary muscovite,

quartz, cordierite and andalusite, with accessory tourmaline, graphite and black iron-ore. Cordierite and quartz occur as a mosaic of rounded grains; the biotite mostly retains its alignment parallel to the general foliation of the schists. The latter is pleochroic from pale yellow brown to a dark foxy red. The andalusite forms large, well shaped crystals, pleochroic from colourless to rose pink. Sillimanite is found in numerous tufts of small needles. Specks of black iron-ore and almost certainly graphite (the rock as a whole has a slightly graphitic feel) occur abundantly disseminated through the rock. There is a little accessory tourmaline, pleochroic from very pale to deep yellow. In the specimen from Loch Bran(563) the cordierite has been altered to micaceous pseudomorphs, in which the yellow halos round inclusions are still present. In this rock, sillimanite appears to be partly formed at the expense of biotite.

ii. Petrographic note on the schist "breccia" of Carn Gairbhthinn

The collection of thin sections of rocks from the Strath Errick district includes one(553b) showing the contact between a fragment of semi-pelitic schist and the surrounding "matrix" of white aplitic rock belonging to the schist "breccia" developed on Carn Gairbhthinn (p. 71 : Plate VII A).

The semi-pelitic schist consists of a fairly coarse mosaic of granular quartz, orthoclase and oligoclase, in which lie aligned plates of biotite, with subsidiary muscovite, and accessory apatite and zircon. The schist is rich in quartz; the feldspars are fresh and unaltered. The biotite is strongly pleochroic from pale yellow to dark foxy red. Inclusions of zircon in it are rather numerous, and each is surrounded by a dark halo.

Apatite is also enclosed in the biotite, sometimes it is also surrounded by pleochroic halos.

The contact of the semi-pelitic schist is not sharply defined against the "matrix" but fragments of it are obviously frayed off into it. The "matrix" consists of granulitic quartz, orthoclase, oligoclase and biotite with subsidiary muscovite and accessory apatite. In texture, it differs from the schist fragment in that the feldspars are larger and more nearly euhedral. Myrmekite is developed in some cases along the margin between orthoclase and plagioclase. Muscovite occurs in large plates which grow round and enclose parts of the granulitic quartz and feldspar. In one case, muscovite threads through a large orthoclase. This same orthoclase crystal also encloses chloritised biotite flakes, quartz and apatite. The biotite, when fresh, has the same red "hornfels" type of pleochroism as that in the schist, but most of it is altered to green chlorite with webs of sagenite. Apatite is more abundant than in the schist fragment.

In the same neighbourhood, rocks very similar to those forming the "matrix" of the schist "breccia" occur as veins cutting the unbrecciated schists. In thin section (286) one such vein was found to carry a little orthite. The broader intrusive masses in this complex on Carn Gairbhthinn are fine-grained tonalites, which grade into the type rock on the margin of the plutonic mass. Some of them (553a) are more quartzose than the typical Foyers tonalite. They consist of quartz, oligoclase-andesine, orthoclase, biotite, hornblende and accessory sphene, apatite, zircon and black iron-ore. The biotite is not a red "hornfels" type, but is pleochroic from pale yellow to deep olive

brown as in the type tonalite. The green hornblende is also of the same variety as that in the type rock. The orthoclase is frequently margined by myrmekite. Large orthoclase crystals enclose blebs of quartz and small crystals of plagioclase. The tonalitic rocks cutting the schists in the Carn Gairbhthinn and Carn Bhreabaig district are rather markedly rich in sphene.

D. PETROGRAPHY OF THE INCLUSIONS IN THE FOYERS PLUTONIC COMPLEX

The petrography of the xenoliths in the Foyers plutonic complex will be described under the following three main headings:-

- i. Contact-altered schists
- ii. Appinite inclusions
- iii. Basic dioritic inclusions

i. Contact-altered schists

Many of the xenoliths of Moine schist enclosed in the Foyers plutonic complex show very little contact alteration. This is particularly true of the siliceous and semi-pelitic xenoliths; the pelitic types on the other hand, are usually more or less reconstructed.

a) Siliceous granulites

Some of the siliceous granulites enclosed in the Foyers plutonic complex have a glazed appearance. A thin section of a siliceous granulite from one of the strips of schist enclosed in the granodiorite on Creag Mhor (185) shows that this glazing is due to the coalescence of contiguous quartz grains.

In general, the siliceous granulite xenoliths show little change apart from this glazing, and a general hardening. The biotite is sometimes partly altered to chlorite. There is usually a little muscovite associated with it, which sometimes forms plates enclosing quartz and feldspar. It seems likely that some of ~~this~~ this sparse muscovite has been developed during contact-alteration.

b) Pelitic schists

Like the siliceous granulites, the semi-pelitic schist xenoliths show very little alteration due to contact metamorphism (Plate VIII B).

The more pelitic xenoliths, however, are usually in the condition of hornfelses, and in them, new minerals, such as sillimanite, andalusite and cordierite are developed. The best examples of these hornfelsed schists come from the long lenticular strips enclosed in the tonalite between Creag Mhor and Loch Ness (Plate IX B). Typically, these xenolithic strips are black, lustrous hornfelses rich in biotite. In thin section, they are found to have a typical hornfels texture in which the constituent minerals show no common orientation. Quartz and cordierite form an equigranular mosaic in which lie numerous flakes of biotite and a little subsidiary muscovite. The rock is heavily charged with small specks of black iron-ore. The biotite is strongly pleochroic from yellow to a deep brown with a red tinge. It encloses zircons, which are surrounded by strongly marked pleochroic halos. There is a little accessory apatite.

Above the new Bell reservoir, on the margin of one of the xenolithic strips in the tonalite, this type of

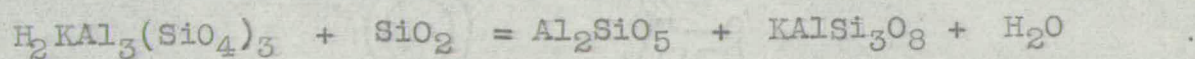
hornfels passes into an andalusite-sillimanite-cordierite-hornfels. In the latter rock (500)(Plate XVII C)sillimanite needles reach a length of $\frac{3}{4}$ " and are prominent on the weathered surfaces. The hornfels is a heavy black rock composed of granoblastic cordierite abundant biotite with a decussate habit, muscovite, sillimanite, andalusite, spinel and iron ore. The cordierite is very fresh and shows both sector and lamellar twinning, though it is free from halos. The biotite is a strongly pleochroic variety, with a "hornfels" red colour. There is a little subsidiary muscovite. Sillimanite occurs both in groups of large needles and as tufts of smaller ones. The andalusite which occurs as large crystals, devoid of inclusions, shows no pleochroism in thin section. The whole rock is heavily charged with specks of black iron-ore and also contains a few grains of pale green spinel.

It has been found that this andalusite-sillimanite-cordierite-hornfels closely resembles the hornfels developed on the margin of the Ross of Mull granite (Bosworth 1910 p.376; Bailey & Thomas, 1925 p.49-55). In the aureole of the Ross of Mull granite, the development of such hornfelses can be traced from unaltered Moine pelitic schists. A complete series of this type is not available in the Strath Errick district, but it is ~~possible~~ probable that the sillimanite-andalusite-cordierite-hornfels was formed from pelitic Moine schist by a similar series of mineralogical changes. It may therefore be useful to summarise the stages described from the Ross of Mull aureole.

At the Ross of Mull, the regionally metamorphosed pelitic Moine schist is a muscovite-biotite-siliceous schist with garnet. Kyanite, andalusite, sillimanite and cordierite are absent.

Rocks of this type could be matched with some of the more pelitic types from Killin. About two-thirds of a mile from the Ross of Mull contact, slight mineralogical changes become apparent. The crystallisation becomes more irregular, the garnets appear to be undergoing a destructional change and cordierite appears in the biotite-rich clots. At a third of a mile from the granite, cordierite is much more prevalent, garnets are less frequent, sillimanite occurs rather sparingly in siliceous areas, often in association with muscovite, and andalusite also appears. Closer still to the contact with the granite, the superposed contact alteration becomes even more marked with the production of hornfelses very similar to those described from Strath Errick.

At the Ross of Mull, it is supposed that muscovite plays an important part in the mineralogical changes and gives rise, by reaction with silica, to sillimanite or andalusite and orthoclase:-



It is pointed out that where the schists were quartz-feldspar-biotite-granulites with only subsidiary garnet and muscovite, they underwent little change in the aureole. This also appears to have been the case in Strath Errick. It is further suggested that in the Ross of Mull aureole the garnets gave rise to cordierite, since it is observed that garnet decreases as cordierite increases. It must be noted, however, that at the actual contact of the Moine schists with the Ross of Mull granite, both garnet and muscovite reappear in the hornfelses.

It should be mentioned that in the Foyers case, as in Mull, the andalusite persists right up to the contact with the plutonic

rock. The Strath Errick hornfels is very rich in biotite, and it seems probable that the xenoliths and the mica-rich andalusite-schists of Loch Bran and Lochan a'Chinn Mhonnaich may have been enriched in biotite (p.111).

c.) Calc-silicate granulites

One or two examples of hornfelsed calc-silicate granulites have been found as xenoliths in the Foyers complex. There are a few small xenoliths of this type, usually under a foot in length, in the granodiorite veining the schists on Carn Bheag (Garthbeg), and also on the margin of the tonalite on Carn Gairbhthinn in the schist "breccia".

In hand specimen the rocks are hard, compact hornfelses, green, or white with green streaks and patches. In thin section, they are found to consist of granulitic quartz and calcic oligoclase (An_{25-30}), hornblende and diopside with accessory sphene, apatite, biotite, garnet, zoisite, pyrite and epidote. Much of the plagioclase is sericitised. The hornblende is in small crystals, which are elongated parallel to the foliation; the pleochroism is X = yellow ; Y = greenish-yellow and Z $\frac{1}{2}$ dark blue-green. The diopside is found in large poikiloblastic crystals, with a faint blue-green colour. In some specimens, there is a little subsidiary zoisite, and irregular poikiloblastic garnets. In thin section, the garnets have the faint pink colour seen in the usual Moine calc-silicate variety. Sphene is often abundant, in irregular grains of a fairly deep brown colour.

d) Epidiorites

A lenticular xenolith of epidiorite much veined with white aplite occurs in the tonalite between Loch Scristan and Creag Mhor (Plate XVIII). Both veins and epidiorite ~~with~~ appear to be xenolithic.

The epidiorite(479) consists of green hornblende with subsidiary (largely sericitised) feldspar, quartz, iron-ore and colourless apatite. The rock shows a faint foliation. The hornblende occurs both in compact individuals and in rather larger poikilitic blades. The feldspar is probably mostly near andesine. The granules of iron-ore tend to occur along particular layers, suggestive of original heavy mineral banding. As the aplite vein is approached, the hornblende is pseudomorphed by biotite, which is pleochroic from pale brown to dark reddish brown. Like the replaced hornblende the biotite is found both as compact and as poikiloblastic crystals. The change from hornblende to biotite takes place from $\frac{1}{4}$ - $\frac{1}{2}$ " from the contact with the aplite vein and is quite sharp. There is also an increase in the amount of apatite present (Plate XVIII B). Along the margin of the vein, hornblende is entirely absent (Plate XVIII C). The actual contact is not very regular and frayed-off streaks of the biotitised epidiorite occur in the vein.

The aplite itself is composed of quartz, andesine and subsidiary orthoclase, with a few flakes of biotite and accessory apatite. It differs from other aplitic veins in Strath Errick in the presence of andesine (p.104) (Plate XVIII D). It is obvious that the reaction along the margin of the epidiorite must have involved introduction of alumina and potash, together with P_2O_5

to provide for the slight increase in the amount of apatite. The formation of biotite in place of hornblende would result in the liberation of lime. This lime has not been traced with certainty, unless the presence of andesine instead of oligoclase in the aplite is due to it.

ii. Appinites

Xenoliths of coarse-grained appinites are rare in the main Foyers complex in Strath Errick. One such xenolith of this type occurs in the granodiorite at Lochan Torr an Tuill at the back of Creag an Fhithich. It is a fairly large xenolith of dark coloured, coarse-grained appinite (549) which has a granitic texture and is rich in hornblende and plates of bronzy biotite. It is composed of orthoclase, oligoclase, quartz, abundant biotite and hornblende, and accessory sphene, apatite and iron-ore. Secondary epidote and ~~calcite~~ calcite are also present. Orthoclase is fresh, and in ~~xxxxxxx~~ less amount than the highly sericitised plagioclase. There is a very little interstitial quartz. The biotite occurs as large plates, still showing pleochroism from light to dark brown, but showing various stages of alteration. Magnetite dust is deposited along cleavage planes and may eventually replace the whole crystal. Alteration to chlorite is very rare. Green hornblende, often ^{showing} twinning, is abundant, and sometimes poikilitic. The pleochroism is X = pale green, Y $\frac{1}{2}$ pale olive-green and Z = blue-green. Sphene is an abundant accessory, often in lozenge shaped crystals. Colourless apatite is also rather common.

An appinite xenolith from the granodiorite between Garthbeg and Corriegarth is similar except that its biotite appears black in hand specimen and its content of quartz is

slightly greater (525). In thin section, much of the biotite is found to have been altered to green chlorite ; when fresh it is pleochroic from straw yellow to dark, slightly reddish brown.

The fine-grained hornblende-schists which occur in the form of dyke-like and sill-like xenoliths in the granodiorite in the Loch Garth district (p.79, Plate IX A) are probably derived from fine-grained members of the appinite suite. They are compact, green rocks in which the parallelism of green actinolitic hornblende crystals gives rise to a slight foliation (361d,199a,446a). In thin section, these rocks are found to consist of altered feldspar, hornblende and subsidiary biotite with accessory sphene. The feldspar has a granoblastic habit though in the four foot wide dyke-like inclusion in the granodiorite between Migovie and Garthbeg, the crystals tend to be more nearly euhedral. It is much altered and difficult to identify, but appears to be a sodic plagioclase. The green actinolitic hornblende occurs both in needle-like crystals disseminated through the rock and associated with the biotite. Most of the biotite is altered to penninite; it and the hornblende are found in shapes suggestive of original pyroxene. The accessory sphene is found in small, granulitic crystals. These rocks seem to have suffered some contact alteration further evidence that they are earlier than the enclosing granodiorite is provided by the presence of one or two large crystals of oligoclase similar to those found in the granodiorite as already noted on p.79.

iii. Basic dioritic inclusions

The presence and mode of occurrence of numerous basic enclaves in the granodiorite and tonalite has already been described. (pp 81) (Plate VI A, VII B). They will now be described petrographically.

Rather rarely, xenoliths obviously derived from semi-pelitic Moine schist which has been reconstructed and enriched in biotite are associated with the dioritic xenoliths. Of this type is the schist xenolith enclosed in tonalite from a locally derived boulder on the beach of Loch Garth near Migovie. An analysis (no. D) of the xenolith is given on p. 123(overleaf) It is a dark grey, semi-pelitic schist somewhat enriched in biotite and further modified by the development of thin tonalitic veinlets along its foliation planes. In thin section the rock is found to consist largely of small, lozenge-shaped feldspars -- mainly oligoclase, but with subsidiary orthoclase, and abundant biotite with sphene and black iron-ore. The biotite is pleochroic from pale to dark brown and is very fresh. The flakes are aligned with the foliation of the schist. Along the margin of one of the tonalitic veinlets are abundant groups of irregular grains of black ore, each grain surrounded by granular sphene. The margin of the xenolith is welded to the enclosing tonalite, which is slightly more quartzose than the type rock. The schist has apparently undergone feldspathisation -- indicated by the high content of soda and by the increase in the amount of feldspar present as compared with an unaltered schist of this type.

Analysis D.

Percentage	Molecular Proportion	Norm	von Wolff values
SiO ₂	52.44	8731	Q = 5.95
Al ₂ O ₃	21.97	2155	Or = 4.00
Fe ₂ O ₃	3.04	190	Ab = 41.92
FeO	4.18	582	An = 28.10
MgO	1.60	397	C = 2.77
CaO	5.94	1059	Hyp = 5.08
Na ₂ O	4.96	800	Mag = 4.41
K ₂ O	1.68	72	Il = 5.06
H ₂ O+	0.72		Ap = 0.53
H ₂ O-	0.16		Water = 0.88
CO ₂	none		<u>99.73</u>
TiO ₂	2.66	333	
P ₂ O ₅	0.23	16	
MnO	<u>0.13</u>	18	
	<u>99.71</u>		

(D) Feldspathised schist inclusion in tonalite. From a locally derived block, Loch Garth shore, Migovie. no.D 6 Foyers plutonic complex.
Analyst. W.H.Herdsman

Analysis E

Percentage	Molecular Proportion	Norm	von Wolff values
SiO ₂	51.73	8621	Or = 15.68
Al ₂ O ₃	20.85	2045	Ab = 33.64
Fe ₂ O ₃	1.73	108	An = 25.83
FeO	5.62	782	C = 1.96
MgO	3.78	945	Hyp = 11.21
CaO	5.94	1058	Ol = 3.18
Na ₂ O	3.96	642	Mag = 2.50
K ₂ O	2.62	282	Il = 3.50
H ₂ O+	0.78		Ap = 1.53
H ₂ O-	0.27		Water = 1.05
CO ₂	none		<u>99.88</u>
TiO ₂	1.80	230	
P ₂ O ₅	0.63	43	
MnO	<u>0.16</u>	23	
	<u>99.87</u>		

(E) Basic dioritic inclusion in tonalite. Loch an Ordain. no.4291 Foyers plutonic complex
Analyst. W.H. Herdsman

In Torr Shelly quarry, where a sheet of tonalite, crowded with basic inclusions, cuts siliceous and semi-pelitic schists and injection rocks, there are also a few xenoliths which appear to be obvious derivatives from schist fragments. They are rather more altered than the Migovie specimen. In hand specimen, one such xenolith (562b) retains a schist-like appearance, though it is much enriched in biotite. The contact of the xenolith with the tonalite is marked by a selvage of large, lustrous plates of biotite. In thin section, the xenolith is found to have lost much of its original granulitic texture. The quartz, orthoclase and sparse oligoclase still form a mosaic, but the individual grains are slightly elongated parallel to the foliation of the biotite. The latter is pleochroic from pale yellow to dark olive-brown; that of the selvage is pleochroic from nearly colourless to slightly reddish brown. Accessory apatite occurs as colourless granules, often clustered into groups which seem to be coalescing to form larger, single crystals.

The more typical basic inclusions at Torr Shelly (6) however, are medium-grained, usually showing only a faint foliation (Plate VII B, XVII A). This type, of which an analysis is given on p.125 (no. F) consists of quartz, orthoclase, oligoclase, hornblende and biotite with accessory apatite, sphene and iron-ore. The quartz (rather abundant), oligoclase (near An_{25}) and orthoclase are all typically granoblastic in their development. The quartz sometimes occurs as blebs inside the feldspars, but myrmekitic intergrowths appear to be absent. Some of the plagioclase forms small porphyroblasts. Both hornblende and biotite are abundant. Hornblende occurs in rather ragged crystals,

Analysis F

Percentage	Molecular Proportions	Norm	von Wolff values
SiO ₂	56.98	9487	Q 3.95
Al ₂ O ₃	15.82	1552	Or 21.31
Fe ₂ O ₃	0.78	49	Ab 27.73
FeO	5.26	732	An 17.80
MgO	4.37	1084	Diop 9.16
CaO	6.23	1111	Hyp 14.19
Na ₂ O	3.28	529	Mag 1.14
K ₂ O	3.61	383	Il 2.12
H ₂ O+	1.58		Ap 0.71
H ₂ O-	0.12		Water 1.70
CO ₂	none		99.81
TiO ₂	1.12	140	
P ₂ O ₅	0.32	23	
MnO	0.34	48	
	<u>99.81</u>		

L = 65.08
M = 30.86
Q = 4.05

(F) Basic inclusion in tonalite sheet cutting schists, Torr Shelly quarry, Errogie. no. 6. Foyers plutonic complex.

Analyst. W.H.Herdsman

Analysis G

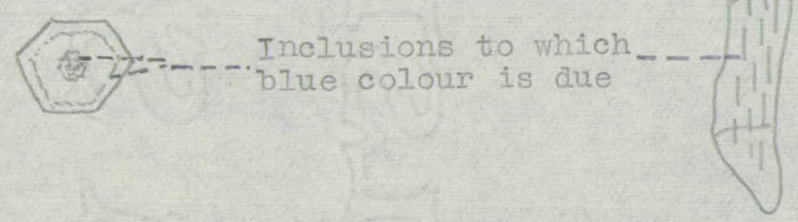
Percentage	Molecular Proportions	Norm	von Wolff values
SiO	62.92	10476	Q 16.58
Al O	17.15	1682	Or 17.92
Fe O	0.64	40	Ab 31.40
FeO	4.34	604	An 12.70
MgO	3.26	809	C 3.09
CaO	2.78	496	Hyp 14.27
Na O	3.71	599	Mag 0.93
K O	3.03	322	Il 1.74
H O+	0.78		Ap 0.41
H O-	0.12		Water 0.90
CO	none		99.94
TiO	0.92	115	
P O	0.18	13	
MnO	0.12	17	
	<u>99.95</u>		

(G) Part of the tonalitic sheet enclosing the xenolith (F). Torr Shelly quarry, Errogie. no. 476(1). Foyers plutonic complex.

Analyst. W.H.Herdsman

the cores of which are sometimes poikilitic. The pleochroism is X = pale yellow ; Y = olive-green and Z = green. Some of the cores of the crystals are slighter in colour and seem to be relics of pyroxene. The biotite is pleochroic from yellow to a rather reddish brown and contains a few inclusions of zircon. The accessory sphene is fairly abundant; it forms poorly shaped crystals sometimes moulded on the scarce iron-ore. Accessory apatite is abundant, both as tiny needles scattered through the rock and as larger, stouter prisms. Some of the apatite, both large and small, is clear and colourless, while some of it is a smoky blue. The colour appears to be due to rod-like inclusions, lying parallel to the length of the crystals and sometimes zonally arranged. These blue apatite crystals have been only observed in the basic enclaves, in some of the alsbachite dykes (p. 104) and, rather rarely, in the appinite (p. 120).

Cross-section



Arrangement of inclusions in blue apatite crystals

The xenolith becomes rather poorer in hornblende as the contact with the enclosing tonalite is approached. The contact line is very irregular in thin section, though in hand specimen it appears to be fairly sharply defined. The larger crystals of the tonalite appear to be developing around the finer-grained material composing the xenolith. Away from the contact, the large feldspars of the tonalite still contain blebs of quartz and small flakes of biotite, similar to those of the xenolith.

The tonalite of the Torr Shelly intrusion (Analysis G, p. 125) is slightly more quartzose than the type rock, and rather poorer in sphene. The plagioclase seems to be dominantly oligoclase(An_{20}), but is zoned from more calcic cores which range from sodic labradorite (An_{55}) to calcic andesine(An_{45}). The biotite and hornblende are similar to those found in the xenoliths. The analysis, mentioned above, refers to a slightly ~~basic~~ more basic patch in this tonalite. It contains slightly more hornblende and biotite and has a somewhat streaky appearance. It is found bordering basic xenoliths or as "ghost"-like patches where xenoliths may have originally been. (Plates VII B, XVII B)

The majority of the basic inclusions in the tonalite of the main complex in the L^och an Ordain--Errogie--Farraline district are coarser in texture than the Torr Shelly xenoliths, but there is much variation. Most of the them are very noticeably rich in sphene, which occurs in large crystals, up to 3mm in length, and of a light brown, or honey colour. The xenoliths are all rich in hornblende and biotite, both identical in pleochroism with the corresponding minerals of the enclosing tonalite. Moreover, the porphyroblasts of white plagioclase, which are found in many of them, are similar to the plagioclase of the tonalite. Several typical examples will now be described. (Plate VI A).

A xenolith from the same detached block (p.122 from Migovie, is a dark, compact and of medium grain. It contains abundant plates of biotite and blades of hornblende, aligned parallel to the lineation of the enclosing tonalite. A few small porphyroblasts of white plagioclase are developed. The

xenolith is composed of calcic oligoclase (An_{24}), biotite and hornblende with accessory quartz, apatite, sphene and iron-ore. The feldspar forms subhedral crystals, elongated parallel to the foliation and is unzoned. The porphyroblasts, however, are zoned, the rim consisting of calcic oligoclase and core of andesine ranging from An_{40} to An_{45} . In some individuals the twinning lamellae are slightly curved. The margins of the porphyroblasts are generally embayed against the other minerals, though they tend toward a general prismatic shape. They enclose small inclusions of quartz, biotite, sphene and apatite. Brown biotite, which lacks the red "hornfels"-type colour, is in excess of green hornblende. Sphene occurs as ragged crystals, sometimes developed around iron-ore. In some cases sphene and iron ore are concentrated along particular bands suggestive of original heavy residue layers. Apatite is an abundant accessory and is found as numerous tiny needles and as subsidiary colourless prisms of larger size.

Other xenoliths from the Loch an Ordain district are rather coarser in grain and show a better development of porphyroblasts. The porphyroblasts often tend to be arranged parallel to each other and the foliation. The hornblende prisms are frequently strongly aligned also. One inclusion of rather striking appearance from the moss between Errogie and Loch an Ordain (244) shows lenticular eyes of white feldspar and brown sphene. The sphene has a markedly skeletal habit (Plate XVI **C**). The photograph also shows the abundant needles of apatite and the irregular shapes of the green hornblendes. The feldspar-sphene "eyes" are elongated parallel to the lineation of the rock.

Another, rather coarser type of xenolith is rich in larger, lustrous plates of biotite and long blades of hornblende (Plate XVI D). An analysis is given on p. 123, no. E . The rock (429c) consists of oligoclase-andesine, hornblende and biotite with accessory apatite, sphene and iron-ore. Sphene is very abundant, both as well shaped crystals and in more irregular form, moulded on the ~~xxxx~~ iron-ore. The texture of this specimen is typical of most of these enclaves -- most of the minerals tend to a poikiloblastic and rather irregular habit. In this particular xenolith hornblende is sometimes moulded on the biotite, and sometimes plates of biotite are enclosed in the hornblende together with granules of iron-ore. Both biotite and hornblende are very fresh and show the same pleochroism as that of the corresponding minerals in the enclosing tonalite. Small feldspars are sometimes enclosed in biotite and hornblende, and one large sphene was seen with a feldspar inclusion. Quartz appears to be absent, though it is present as a sparse accessory in most of the basic xenoliths.

These basic inclusions are most abundantly developed in the tonalite, but they are also found in the granodiorite. An example from the granodiorite quarries in the Dell Marsh near the Upper Falls of the Fechlin (Plate XVI B) is a dark, lens-shaped enclave (45) of finer grain than the enclosing granodiorite. It is composed of oligoclase, orthoclase, quartz and biotite and hornblende with accessory magnetite, sphene and apatite. Orthoclase is subsidiary to plagioclase and sometimes encloses blebs of quartz. Quartz is rather sparsely distributed. Like the inclusions in the tonalite, the xenolith is richer in hornblende and biotite than the surrounding granodiorite; unlike them the constituent minerals tend to be more nearly euhedral

The hornblende crystals are, however, sometimes poikilitic.

A coarse-grained xenolith, consisting predominantly of biotite and hornblende with subsidiary oligoclase, orthoclase, quartz, sphene, apatite and iron-ore (33), was found in the granodiorite near Fairyburn Farm, a short distance from the contact of the granodiorite with the siliceous schists of Loch Bran. The inclusion formed a round ball, some 6" in diameter. The biotite and hornblende resemble those in the granodiorite. The hornblende occurs in part as large crystals enclosing poikilitically, some of the quartz and feldspar.

These basic inclusions appear to be eventually made over into the enclosing tonalite or granodiorite (p. 81). Both tonalite and granodiorite sometimes show peculiarities of crystallisation which seem to be attributable to incorporation of these inclusions. Hornblende is frequently sieved with quartz, more especially in the cores of the crystals. The large feldspars very frequently enclose smaller feldspars, quartz blebs and sometimes biotite and hornblende. Myrmekite is common in the tonalite and granodiorite, but is not so characteristic of the enclaves. The discussion of the petrogenesis of the complex as a whole will however, be deferred to the next section. (p.131)

E. PETROGENESIS & MODE OF EMPLACEMENT OF THE FOYERS PLUTONIC COMPLEX

i. Summary of the evidence

The evidence relating to the mode of emplacement and the genesis of the Foyers Plutonic Complex may be summarised under the following headings:-

1. The Complex is later than the regional "injection" of the Moine schists. It cuts permeation schists and contact-alters them.
2. The country rock into which the complex is intruded consists of predominantly siliceous schists with some permeation gneisses and migmatites belonging to an older phase of plutonic activity. Pelitic schists outcrop some short distance from the complex at Killin and Glen Doe. Calc-silicate bands are prominent at Killin. Hornblende-schists are sparsely distributed throughout the whole series.
3. The Foyers plutonic complex consists of four principal types, emplaced in the following order:-
 1. Appinite.
 2. Tonalite.
 3. Granodiorite.
 4. Granite.
4. The appinites occur as a few satellite intrusions in Knockie Forest and Gleann Liath, but in the main complex they are only preserved as sparse xenoliths.
5. The general arrangement of the chief members of the complex (tonalite-granodiorite-granite) is concentric relative to both walls and roof.
6. The contact between tonalite and granodiorite is sometimes fairly sharp, sometimes grading. The granite forms a series of anastomosing sheets and dykes cutting both tonalite and granodiorite, with which its contacts are always sharp. At one point only, on Carn Choire Riabhaich, is the granite in contact with the roof of the complex.
7. The granodiorite contains large, pink, porphyritic crystals of perthitic orthoclase. They frequently enclose blebs of quartz and small plagioclase crystals. Both tonalite and granodiorite tend to have a poikilitic textures, which seem to be symptomatic of the incorporation of the basic enclave material as cited below.

8. The complex is definitely transgressive to the surrounding schists.
The schists at the contact are vertical or highly inclined. The contacts between the different members of the complex and the schists are always sharply defined.
9. Although the complex is transgressive to the schists, the regional strike of the Moine schists has been deflected to conform to the margin of the complex. At one locality, Carn Gairbhthinn, this deflection is accompanied by the formation of an "intrusion-breccia" of schist fragments.
10. Tonalite, granodiorite and granite all vein the surrounding schists. The veins tend to be parallel to the schistosity, but are frequently transgressive.
11. The tonalite and granodiorite are rich in xenoliths. The granite is nearly free from them. The xenoliths consist of:-
1. Sparse inclusions of appinite.
2. Basic dioritic xenoliths.
3. Moine schist xenoliths.
12. The tonalite and the granodiorite both show a fairly well marked foliation or alignment of their components. The granite does not.
13. The foliation of the granodiorite and tonalite, the foliation of the basic dioritic xenoliths, the strike of the schist xenoliths and the strike of the neighbouring Moine schists at the contact are all practically in parallel.
14. There is no mappable aureole of contact-metamorphism round the complex. It is likely that the siliceous schists would not show the effects of superposed contact-alteration very clearly. They sometimes have a glazed appearance due to the coalescence of contiguous quartz grains. The more pelitic types, however, develop andalusite, sillimanite and cordierite and are probably also somewhat enriched in biotite.
15. The schist inclusions are sometimes very large. Some of them occur as long arcuate strips up to $\frac{1}{2}$ mile in length. The pelitic types show marked contact-alteration, with development of abundant red biotite of hornfels type, andalusite, sillimanite and cordierite. Andalusite persists right up to the contact with the enclosing tonalite.
16. Very rarely, some of the schist inclusions, usually only a few inches in length, show enrichment in biotite and feldspathisation. (Analysis D).
17. The dioritic inclusions are best developed in the tonalite between Loch an Ordain and Meall Donn in the north-east part of the complex. These dioritic rocks are composed of sodic plagioclase (usually near oligoclase-andesine), hornblende and biotite, with accessory orthoclase, quartz, sphene ~~and~~ apatite and iron ore. Sphene and apatite are very abundant.

The dioritic enclaves vary in texture from fine-grained varieties of the type found in the Torr Shelly tonalitic sheet, outside the main complex (Analysis F) to coarser-grained varieties (Analysis E) which grade into the finer-grained varieties of tonalite.

Many of the minerals of these enclaves are characteristically poikiloblastic (ref. Plates I6 C,D). Frequently, porphyroblastic plagioclases are developed in them, similar to those found in the enclosing tonalite.

18. The tonalite and granodiorite are rich in sphene. The tonalite is apparently richest in sphene near the basic inclusions at Loch an Ordain. Its foliation is most marked near the inclusions. Myrmekitic intergrowths are typical in all three types of the plutonic complex.

19. The contacts between tonalite and basic enclave are normally fairly sharp, but sometimes one can trace the basic material through a stage of finer-grained tonalite into definite and typical tonalite. Analysis G refers to this intermediate type as developed in Torr Shelly quarry; the type Torr Shelly tonalite is more quartzose than most of the tonalite of the main complex, and is perhaps nearer that of Strontian (Analysis 2). The hornblende and biotite of the enclaves are of the same types as those found in the tonalite and granodiorite.

20. It is not possible to trace the dioritic enclaves back to existing country rock at the contacts. There appears to be a perfectly sharp and sudden break between the two. There is apparently no evidence along the margin of the plutonic complex of granitisation of the schists at the present level of erosion.

21. A few schist inclusions of the type of Analysis D have selvages of large plates of biotite. Some of the appinite inclusions in the Cnoc Carrach type of granodiorite show similar selvages of hornblende crystals.

22. Pegmatite veins cutting the granitic complex or the surrounding schists are rare, and where they do occur, are developed on a small scale. Aplite veins are not very abundant. Alsbachite veins are the most common, cutting the granite and the schists in the north-eastern part of the complex.

23. Apatite is abundant in the schists, permeation schists, basic inclusions and tonalite and granodiorite. In the basic inclusion the tonalite, the appinites and the alsbachite dykes, it may sometimes have a blue colour, due to numerous rod-like inclusions. The apatite crystals in the schists never show these inclusions. The blue apatite crystals are most typically developed in some but not all of the basic xenoliths, and the alsbachites.

24. The alsbachites, in thin section, have features suggestive that they are felspathised schists. In the field, they occur as typical dykes.

The analyses, all new, of the type rocks of the Foyers plutonic complex are tabulated at the end of this section on pp. 144-5. A series of analyses of Moine schist types similar to those found in Strath Errick is quoted on pp. 147-8, together with an analysis of ~~the~~ one of the Sutherland Ach'uaine hybrids. On p. 146, for comparison with the Foyers complex, are a series of analyses of the Morvern-Strontian plutonic complex.

The analyses have been plotted on the accompanying von Wolff diagrams (pp 138a, 139a): the Foyers type rocks are also shown on a silica variation diagram (p.134 a)

ii. The Origin of the Foyers Plutonic Complex

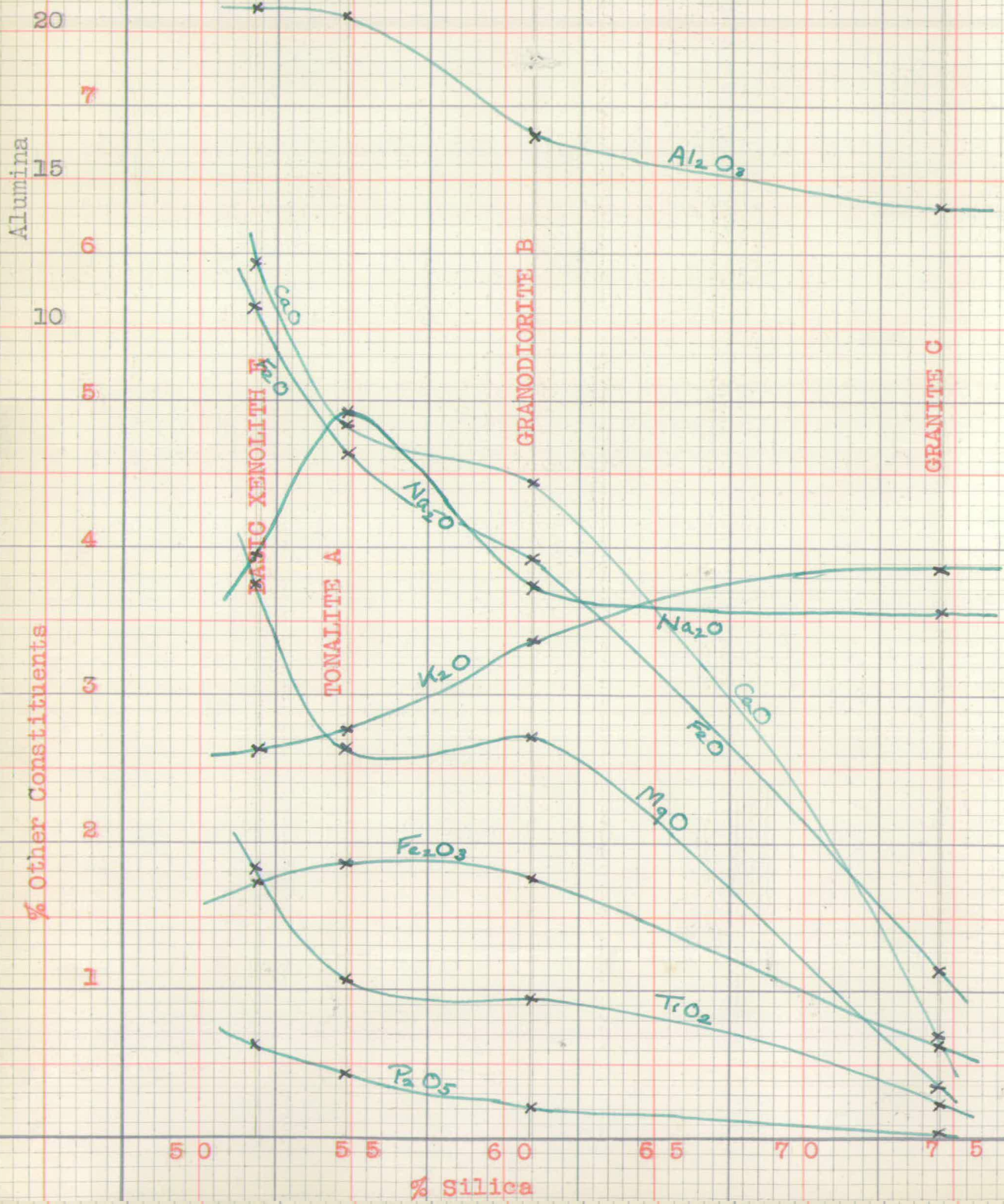
There are three principal hypotheses to be discussed in relation to the problem of the origin of the Foyers plutonic complex. They are:-

a) That the complex was formed by crystal differentiation.
b) That the complex was formed in depth, perhaps from granitised schists, and then pushed up, in diapir fashion, to its present position.

c) That the complex was formed by the granitisation of pre-existing country rocks, very near to the position in which it now occurs.

The relative adequacy of these three hypotheses to explain the facts as they exist in the Foyers complex will now be discussed in turn.

Silica variation diagram to show the relations between the basic dioritic inclusions-tonalite-granodiorite-granite in the Foyers Plutonic Complex.



a) Crystal differentiation

If the Foyers plutonic complex had been formed by crystal differentiation, the initial magma would have had to be at least as basic in composition as appinite, and the tonalite, granodiorite and granite would then represent successive differentiates produced by separation of crystals and liquid. The chemical analyses of the tonalite, granodiorite and granite do not support this view. In the series tonalite-granodiorite-tonalite-granite (represented by analyses A-B-G-C) it will be seen in the series formed by the first three (tonalite-granodiorite-tonalite) that magnesia rises with increase of silica, whilst soda decreases. In the same three analyses, potash is highest in the granodiorite (B), falling off again in the Torr Shelly tonalite (G) which contains a higher percentage of silica.

Further, mineralogical evidence is at variance with the hypothesis, eg. the observation that the granodiorite locally contains more hornblende than the tonalite (p. 94) and that the granite commonly contains more quartz than the amount corresponding to the quartz-feldspar eutectic (p. 100)

These chemical and mineralogical results are obviously inconsistent with the variation to be expected if crystal fractionation had been the controlling process at work.

Nor does the crystal differentiation hypothesis afford any explanation of the poikilitic textures found in the plutonic complex. It does not explain the sieving of the hornblende with quartz, nor the blebs of quartz and plagioclase in the large orthoclases of the granodiorite, textures which suggest growth in a solid or highly viscous medium. Such crystalloblastic textures and their significance have been discussed by Dr. D. L.

Reynolds (1936 pp 345-348). She shows that these textures are a result of ~~xxxx~~ recrystallisation during the metasomatic reconstruction of rocks invaded by migrating emanations. It is not possible to explain such textures as a result of normal crystallisation from a magma.

Moreover, the crystal differentiation hypothesis would not, by itself, satisfactorily explain either the textures of the basic inclusions in the tonalite or their transitions into the tonalite. Nor would it explain the feldspathisation of schist inclusions of the type of Analysis D (p. 122).

The parallelism of the foliation of the tonalite, granodiorite, schist enclaves and country rock also seems to be inconsistent with the crystal differentiation hypothesis. There is finally the all-important space problem. A roofed complex such as this, with the roof in continuity with the surrounding schists, can only have made room for itself ~~with~~ by stoping. The xenoliths would then be sunken roof blocks frozen in, and the presence of the basic inclusions and feldspathised schists is not explained. Further, the inclusions gradually die out in depth, since they are practically absent in the granite. Yet the granite should have been emplaced by stoping granodiorite and tonalite, and inclusions of these types would therefore be expected in it. This evidence suggests that, even on the stoping hypothesis, the inclusions should be still present, the material having lost its original form by being made over into the plutonic types. Thus on this hypothesis, the space problem remains unsolved.

It appears therefore that the evidence in the Foyers plutonic complex is definitely adverse to any hypothesis

of its genesis by crystal differentiation.

b) The Diapir hypothesis _

It is possible that the Foyers complex, having been formed in depth, as a mass more mobile or plastic than its surroundings, would then respond to tectonic pressure by being pushed up, in diapir fashion, to its present level. Supporting this idea are the facts (a) that the basic inclusions, which may represent basified relics of the country rock, cannot be traced back to the country rocks now exposed at the contacts, and (b) that there is a sharp, transgressive break at the margins of the complex.

The schists at the contacts of the complex are highly inclined, but they are not faulted, as they might well have been if the complex had been pushed up from great depths. The problem of the means by which the strike of the Moine schists was swung round to conform to the margin of the complex is still largely unworked. The "intrusion-breccia" and the considerable veining of the schists at Carn Gairbhthinn suggest that there may have been actual mechanical fracture in that area. It is difficult to see how the strike of the roof and wall rocks could have been so extensively deflected, unless there had also been considerable recrystallisation.

* The continuity of the roof with the surrounding schists and the fact that the xenoliths of schist contained in the complex are obviously the same as those forming the country rock indicate that any upward movement in diapir fashion can hardly have been of the order of several miles. The schist xenoliths, if the complex had been generated at great depths, would be expected to

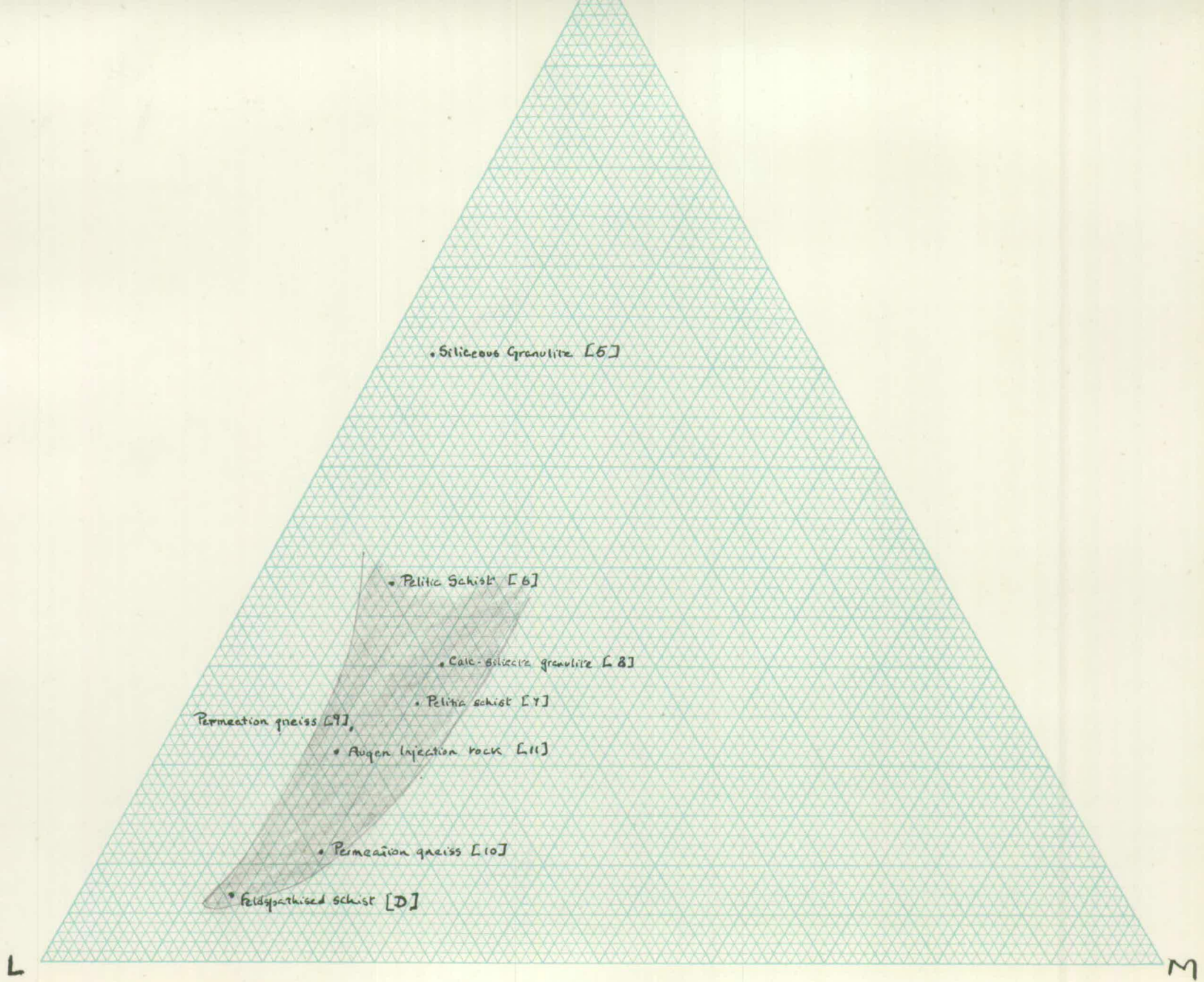
differ from the schists now exposed in the immediate vicinity of the complex.

Moreover, if the complex had been intruded from great depths, volcanic activity would have been expected. The fact that much of the roof is still preserved makes it improbable that there was any volcanic activity associated with the complex, though it does not altogether rule out this possibility. Further, no pebbles of volcanic rock have, as yet, been found in the overlying Middle Old Red Sandstone conglomerates.

Nor is the space problem solved by a hypothesis of diapir intrusion from great depths. If however, the depths from which the complex was intruded were not great, the space problem is not so serious and need not involve stoping. It seems that a diapir hypothesis is necessary to explain some of the phenomena observed in Strath Errick, but that the amount of upward movement must have been strictly limited. The complex cannot have formed at great depths below its present position. This modified diapir hypothesis, together with the hypothesis of granitisation will be further developed in the next section.

c) Granitisation

The idea that appears to conform best with the observed facts is that the Foyers plutonic complex may have been formed by the granitisation of the surrounding Moine schists and associated country rocks, not for the most part, in situ, but not far beneath the existing erosion level. Sufficient movement must have taken place for the production of sharp contacts with the surrounding schists, and for the change of foliation direction in the latter. Moreover the plutonic rocks must have become



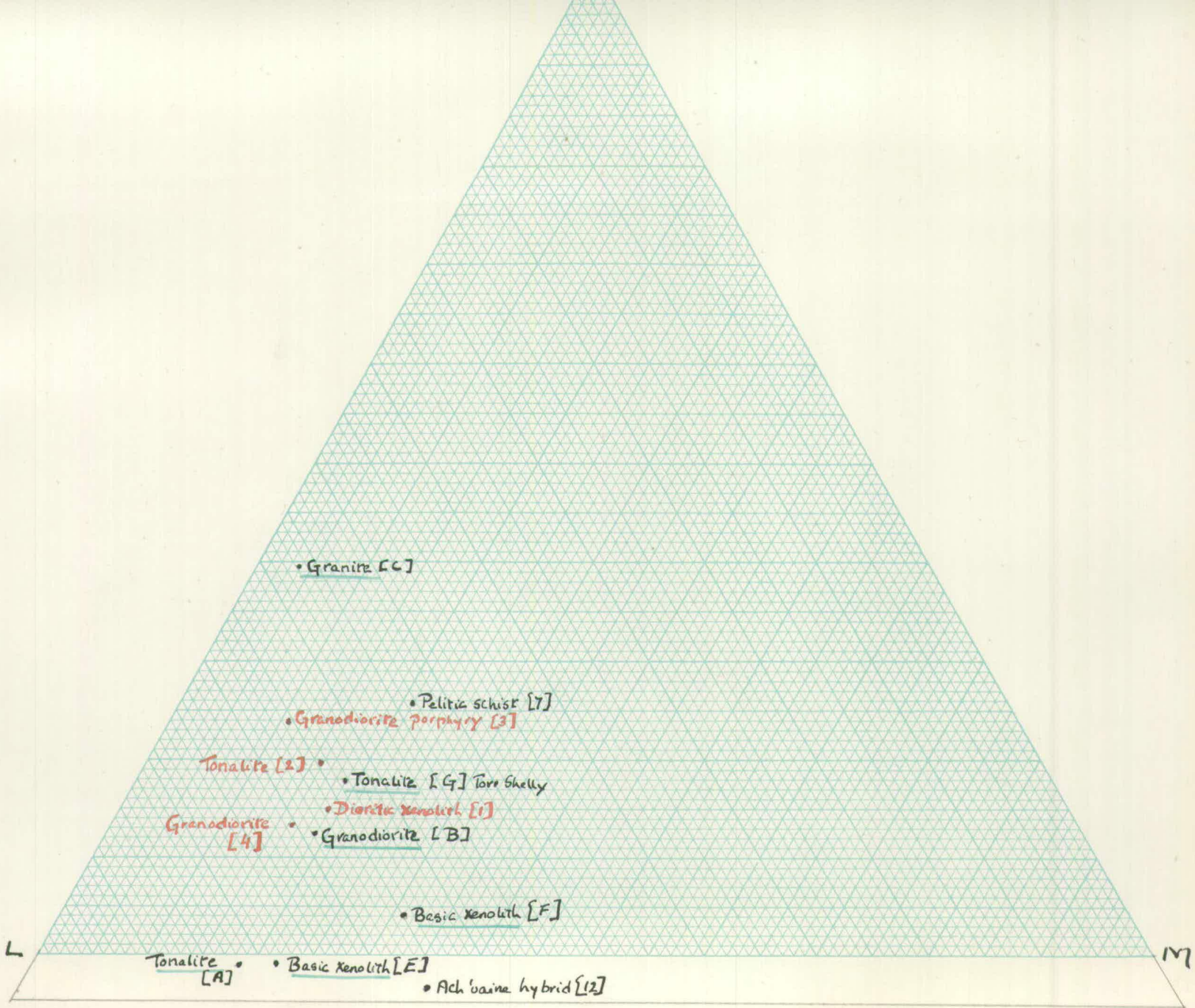
sufficiently mobile to vein the schists of the roof and walls.

On this hypothesis, the basic enclaves are regarded as basified relics of the country rock, in process of being made over into the tonalite and granodiorite.

On the first von Wolff diagram, 1, p.138a, there are plotted the points corresponding to the chemical analyses of a series of typical Moine schists and three typical permeation gneisses from Sutherland, together with the feldspathised schist from Strath Errick. The analyses are listed on pp 145,147,148. In the formation of the permeation rocks from ordinary Moine schist the content of soda rises, whilst the ratio of potash to the total content of alkalies falls. Lime also increases but iron and magnesia decrease in amount. Silica and alumina remain fairly constant (Read 1931, p.147)

The Strath Errick feldspathised schist (Analysis D) is not formed from one of the "injection" rocks of that district but probably represents an ordinary pelitic Moine type modified during the development of the Foyers complex. It does not show the increase of muscovite and biotite found in the Sutherland permeation rocks, but it has been obviously enriched in soda and lime resulting in a rise in the content of plagioclase. Potash and magnesia would be liberated in the formation of the feldspathised pelitic schist, and these constituents may be in part represented by the selvages of biotite found around some of the xenoliths of feldspathised schist.

The points corresponding to the basic dioritic enclaves, and one of the pelitic Moine schists, together with the plutonic rocks from Foyers are plotted on the second von



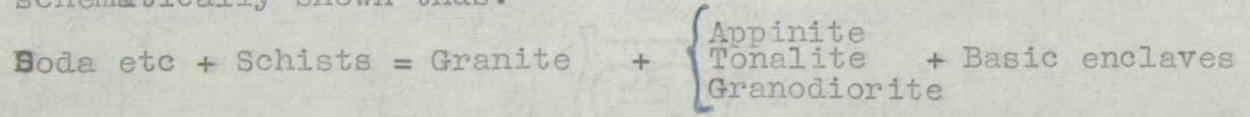
Wolff diagram, 2. p.139 a. The corresponding Strontian plutonic rocks are plotted in red on the same diagram (analyses listed on pp.144-5-6). It is suggested that the basic enclaves represent pelitic schists in which there has been a general increase in the calcemic constituent and in soda. These basic inclusions appear to correspond with the diabrochites of Dunn (1942 p.231-238). Dunn defines diabrochites as schistose rocks that have recrystallised under the influence of migrating solutions, but which differ from migmatites in that the added material is not obviously granitic. In the Indian examples, mentioned by Dunn, the dominant feldspar of the diabrochites is sodic plagioclase.

However, the point of special significance in relation to the present investigation is that Fe and Mg have been driven out from loci of granitisation and that they have been added to the outer zones of replacement, where they appear in rocks that have been enriched in biotite and/or hornblende. Dr.D.L.Reynolds (1944 p.244) has adopted the term diabrochite for "rocks which have resulted from the basification and desilication of hornfelsed sediment, dependant on the fixation of material expelled during granitisation".

The process seems to be primarily started off with soda by introduction of migrating emanations (or ions of Na) as the predominant constituent (Point A on the diagram on p. 142). Assume that in the first place, this results in the formation of feldspathised schists of the type of Analysis D, shown on the von Wolff diagram p. 138a. Then the range of material to be "granitised" includes ordinary Moine schists, feldspathised schist and permeation rocks of earlier date. This field is shown by the shaded area on the diagram, p.138a. Granitisation requires the

addition of chiefly soda, silica and potash. Sufficient silica for the less siliceous rocks is probably available from the more siliceous Moine schists; potash is liberated during the feldspathisation of some of the schists, and soda is being added from a deep-seated source. The resulting granitisation of the rocks would then necessarily liberate alumina, iron, magnesia and lime (Point B on the diagram p.142). These constituents would be driven ahead to form appinites and to basify the schists. The latter are now represented by the basic dioritic enclaves which are probably merely relics of an originally more extensive basified roof. The alumina and calcemic constituents liberated would also be required in part for the formation of tonalite and granodiorite.

The suggested changes are shown diagrammatically overleaf, p. 142, on a von Wolff triangle. In this diagram, the composition of the schists which became granitised is indicated by the shaded area on each side of the line AS, the process being initiated by the introduction of soda etc. from A. Granitisation, with production of material represented by G, then results in the liberation of calcemic constituents represented by points such as B. This material, combined with soda etc. from A provides migrating emanations with a composition such as C which moves ahead of the zone of granitisation proper, and produces basic xenoliths, appinite, tonalite and granodiorite according to the degree in which they are fixed by the material traversed. All of these products lie along a belt of which GC is the axis. In other words, the addition of new material from depth, mainly soda, stimulates a kind of metamorphic differentiation of the schists, schematically shown thus:-



dioritic enclaves of the same type as those found in the Foyers complex are also prominent in the Strontian complex.

Dr. D. L. Reynolds (1943 p. 231-267) describing the granitisation of hornfelsed sediments in the Newry granodiorite at Goragewood, shows how complementary zones of mafic enrichment were formed around the loci at which granitisation was taking place in the hornfelsed sediments. At Goragewood, sodic, soda-potassic and potassic "granite" bodies are developed; the sodic types are of earlier formation than the potassic ones -- the latter being commonly developed from the former. Dunn (1942 pp 231-238) states that the enrichment in soda and other constituents necessary to form diabrochite may be followed by subsequent enrichment in potash during granitisation, the potash having been liberated as a by-product of an earlier stage of feldspathisation. At Foyers, a complete series from schists through basic diabrochite types into granite has not been traced, though there is ample evidence of various stages. Consequently, any hypothesis concerning the genesis of the complex can, at present, be no more than tentative. But the facts appear to accord best with a hypothesis of granitisation and limited upward intrusive movement; the basic inclusions being regarded as schists enriched in soda and calcium constituents, and the "granitic" series as products that became subsequently enriched in potash.

	(A)	(B)	(C)
SiO ₂	54.95	60.77	74.72
Al ₂ O ₃	20.57	16.44	14.17
Fe ₂ O ₃	1.87	1.77	0.63
FeO	4.68	3.92	1.17
MgO	2.68	2.71	0.36
CaO	4.82	4.44	0.68
Na ₂ O	4.84	3.73	3.58
K ₂ O	2.75	3.39	3.84
H ₂ O+	0.72	1.53	0.33
H ₂ O-	0.13	0.05	0.07
CO ₂	none	none	none
TiO ₂	1.09	0.95	0.22
P ₂ O ₅	0.43	0.25	trace
MnO	0.26	0.26	trace
	<u>99.79</u>	<u>100.21</u>	<u>99.77</u>

- (A) Tonalite. Foyers plutonic complex. From old quarries in field immediately south of Wester Aberchalder Lodge.
Analyst W.H.Herdsman
- (B) Tonalitic granodiorite. Foyers plutonic complex. Dell Marsh quarries, $\frac{1}{2}$ mile SW of Upper Falls of Foyers.
Analyst. W.H.Herdsman
- (C) Biotite-granite. Foyers plutonic complex. Flank of Creag a'Chliabhain, about $\frac{1}{2}$ mile SE of Easter Aberchalder Farm.
Analyst W.H.Herdsman.

	(D)	(E)	(F)	(G)
SiO ₂	52.44	51.73	56.98	62.92
Al ₂ O ₃	21.97	20.85	15.82	17.15
Fe ₂ O ₃	3.04	1.73	0.78	0.64
FeO	4.18	5.62	5.26	4.34
MgO	1.60	3.78	4.37	3.26
CaO	5.94	5.94	6.23	2.78
Na ₂ O	4.96	3.96	3.28	3.71
K ₂ O	1.68	2.62	3.61	3.03
H ₂ O+	0.72	0.78	1.58	0.78
H ₂ O-	0.16	0.27	0.12	0.12
CO ₂	none	none	none	none
TiO ₂	2.66	1.80	1.12	0.92
P ₂ O ₅	0.23	0.63	0.32	0.18
MnO	0.13	0.16	0.34	0.12
	<u>99.71</u>	<u>99.87</u>	<u>99.81</u>	<u>99.95</u>

(D) Feldspathised schist inclusion in tonalite. From a locally derived block, Loch Garth shore, Migovie.

Analyst. W.H.Herdsman

(E) Basic dioritic inclusion in tonalite. Loch an Ordain.

Analyst W.H.Herdsman

(F) Basic inclusion in tonalitic sheet cutting schists. Torr Shelly quarry, Errogie.

Analyst. W.H.Herdsman

(G) Part of the tonalitic sheet enclosing the xenolith (F) at Torr Shelly quarry, Errogie.

Analyst. W.H.Herdsman

	(1)	(2)	(3)	(4)
SiO ₂	63.70	66.58	68.83	63.53
Al ₂ O ₃	15.10	14.84	14.29	16.08
Fe ₂ O ₃	1.14	0.15	0.84	1.39
FeO	3.10	2.94	1.72	2.54
MgO	2.73	2.22	1.60	2.58
CaO	4.24	3.58	2.78	4.08
Na ₂ O	4.26	4.48	4.35	4.64
K ₂ O	3.52	2.87	3.88	3.43
H ₂ O+	0.30	0.68	0.48	0.45
H ₂ O-	0.06	0.14	0.08	0.07
CO ₂	0.00?	0.00?	0.00?	0.00?
TiO ₂	1.23	1.04	0.79	1.14
P ₂ O ₅	0.42	0.49	0.65	0.41
MnO	0.07	0.05	0.07	0.06
FeS ₂	0.09	0.18	0.09	0.09
Cr ₂ O ₃	0.00?	none	none	none
	<u>99.96</u>	<u>100.24</u>	<u>100.45</u>	<u>100.49</u>

- (1) Fine-grained dioritic rock, cut by granodiorite-porphry dyke and probably enclosed in granodiorite of the Morvern-Strontian granite complex. Coast, 300 yds N of Eilean a' Mhuirich.
Analyst. B.E. Dixon
- (2) Tonalitic granodiorite. Outer member of plutonic intrusive complex (Morvern-Strontian granite complex). In burn 900 yds W. 30° S. of Bellsgrave Lodge (at the site of the old Middlehope Mine)
Analyst. B.E. Dixon
- (3) Granodiorite porphyry. Broad dyke or sheet cutting granodiorite of Morvern-Strontian granite complex. Coast 300 yds N. of Eilean a' Mhuirich.
Analyst. B.E. Dixon
- (4) Granodiorite. Member of plutonic complex intervening between an outer tonalite and an inner granite (Morvern-Strontian granite complex). Quarry, 300 yds E.N.E. of Eilean a' Mhuirich.
Analyst. B.E. Dixon.

The above analyses of the Morvern-Strontian granite complex are taken from the Geological Survey Summary of Progress for 1933, Part I. pp 90-91

	(5)	(6)	(7)	(8)
SiO ₂	82.79	67.77	59.54	62.55
Al ₂ O ₃	6.90	16.42	19.55	15.75
Fe ₂ O ₃	1.41	1.37	0.81	1.56
FeO	0.64	3.68	6.03	3.26
MgO	0.44	1.50	2.73	2.88
CaO	1.44	1.23	1.85	9.39
Na ₂ O	1.75	2.28	1.88	0.93
K ₂ O	3.63	3.58	3.68	1.54
H ₂ O ⁺	0.45	0.74	1.80	0.64
H ₂ O ⁻	0.06	0.04	0.10	0.15
CO ₂	0.07	---	0.01	trace
TiO ₂	0.42	1.04	1.01	0.79
P ₂ O ₅	0.06	0.15	0.30	0.30
MnO	0.17	0.33	0.08	0.28
FeS ₂	nt. fd.	---	0.13	---
(NiCo)O	nt. fd.	0.04	trace	0.04
BaO	0.08	0.06	0.09	trace
Li ₂ O	trace	?trace	nt. fd.	trace
SrO	---	---	---	0.05
C	---	---	0.29	---
	<u>100.31</u>	<u>100.23</u>	<u>99.88</u>	<u>100.11</u>

- (5) Typical siliceous granulite of 1st Sheet 102. 1000 yds SE of Glencassley Castle. 3⁷/₈ miles NNE of Rosehall House, Glen Cassley, Sutherland. Analyst. E.G. Radley. Mem. Geol. Survey. Strath Oykeill & Lower Loch Shin p 134
- (6) Garnetiferous muscovite-biotite-schist, on hill ³/₄ miles south-west of Glencalvie Lodge. Analyst. W. Pollard. Mem. Geol. Survey. Ben Wyvis, Carn Chuinneag & Inchbae p. 112
- (7) Pelitic schist of Corriemulzie district. 500 yds W. 29°N of Upper Letters Cottage, Ross-shire. Analyst. F.R. Ennos. Mem. Geol. Survey. Strath Oykeill and Lower Loch Shin. p. 136
- (8) Garnetiferous zoisite-hornblende-granulite on hill ³/₄ mile S.W. of Glen Calvie Lodge. Analyst. W. Pollard. Mem. Geol. Survey. Ben Wyvis, Carn Chuinneag & Inchbae p. 45

	(9)	(10)	(11)	(12)
SiO ₂	61.11	59.25	62.28	53.25
Al ₂ O ₃	18.33	18.48	17.69	14.20
Fe ₂ O ₃	1.14	1.24	1.09	2.94
FeO	5.47	6.78	5.25	3.60
MgO	1.75	2.30	1.67	5.40
CaO	1.66	2.51	2.29	7.44
Na ₂ O	2.64	3.78	3.25	3.20
K ₂ O	4.41	3.64	3.60	5.00
H ₂ O+	1.51	0.72	1.43	0.88
H ₂ O-	0.13	0.12	1.13	0.16
CO ₂	0.00?	---	---	2.01
TiO ₂	1.15	1.18	1.08	1.26
P ₂ O ₅	0.08	0.08	0.08	0.52
MnO	0.11	0.08	0.07	0.31
F	0.00?	---	0.00?	---
FeS ₂	0.22	0.00?	0.04	0.04
Fe ₇ S ₈	0.12	0.00?	---	nt.f.d.
Cr ₂ O ₃	0.02	0.00?	0.02	trace
(NiCo) ₂ O	---	---	---	nt.f.d.
BaO	0.06	0.05	---	nt.f.d.
	<u>99.91</u>	<u>100.21</u>	<u>99.97</u>	<u>100.21</u>

- (9) Muscovite-biotite-gneiss (Permeation gneiss with pelitic foundation), $2\frac{1}{4}$ miles S.E. by S. of Klibreck Farm, Altnaharra, Sutherland. Analyst. B.E. Dixon Mem. Geol. Survey. Central Sutherland pp 126-127 Analyses (10) & (11) are also quoted from this memoir, pp 126-127
- (10) Sillimanite-garnet-muscovite-biotite-gneiss (Permeation gneiss with pelitic foundation). $2\frac{1}{2}$ miles S.E. of Klibreck steading, Altnaharra, Sutherland. Analyst. B.E. Dixon
- (11) Muscovite-biotite-gneiss with augen of oligoclase (Augen-injection rock with pelitic foundation) $2\frac{3}{8}$ miles S.E. by S. of Klibreck Farm, Altnaharra, Sutherland. Analyst. B.E. Dixon
- (12) Intermediate hybrid of Ach'uaine type. Summit of Cnoc a'Choire Bhuidhe, 1300 yds W.N.W. of Ach'uaine, Sutherland. Analyst E.G. Radley. Mem. Geol. Survey. Strath Oykeil & Lower Loch Shin p163

VI. THE MIDDLE OLD RED SANDSTONE

A. DISTRIBUTION & UNCONFORMITY AT THE BASE OF THE OLD RED SANDSTONE

In the Strath Errick district, the Middle Old Red Sandstone forms a narrow strip bordering Loch Ness-side and finally dying out at Carn Dearg (Foyers). During the present research the outcrop has been studied from Loch Dun Seilcheig to Carn Dearg; that is, from the southern margin of one inch Sheet 83, surveyed by the Geological Survey, to the point at which the formation dies out, on the southern side of Loch Ness. Further outcrops of Middle Old Red Sandstone occur as outliers on the other side of Loch Ness (Sheet 73), the most notable of which builds up Mealfuarvonie, a mountain which dominates Strath Errick from across Loch Ness. The Middle Old Red Sandstone of Mealfuarvonie has not been studied in any detail geologically, but my own observations in the cuttings of the new road on the north side of Loch Ness point to its being of a very similar character to that developed in the Foyers district.

The Middle Old Red Sandstone, traced north-east from Loch Dun Seilcheig, rapidly broadens out into a much wider outcrop in the Inverness district and in Strath Nairn. In these districts, the formation has yielded fossils of Middle Old Red Sandstone age (Peach 1923, pp 65-76; Horne 1914 pp 66-68). The Nairnside fish-bed is represented in a diminished form at Lochan an Eoin Rudha near Loch Dun Seilcheig, by red and dark-grey shales with limestone nodules which have yielded fish remains. The

south-western continuation of the Old Red Sandstone in Sheet 73, appears to be unfossiliferous for the most part. During the present research a fragmentary fossil, apparently part of a fish, was found at Castle Kitchie.

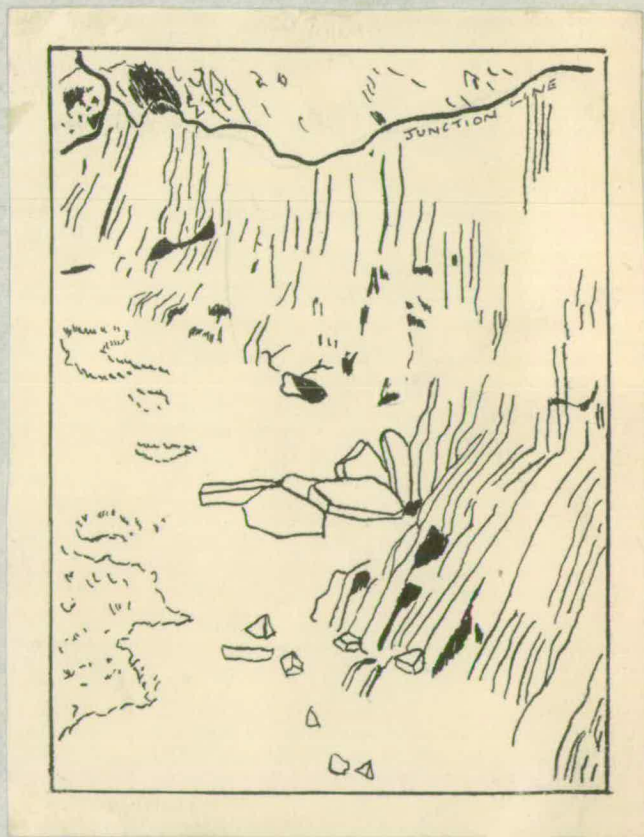
The Middle Old Red Sandstone of the Foyers district consists predominantly of coarse conglomerates overlying the basal breccias, with subsidiary thin-bedded, red sandstones and arkoses. It rests with marked unconformity upon the Moine schists, the Foyers plutonic complex and the Gleann Liath Series, and the character of the basal breccias varies markedly with the underlying formations, from which it was directly derived. The unconformable junction has been traced from Leiterchullin on Loch Dun Seilcheig to Creag Dhearg and Crag nan Clag; thence to Torness School and along the base of Creag a'Chupain to the River Farigaig below its waterfalls. The boundary then runs along the Loch Ness flank of Dun Garbh to the hollow between Dun Garbh and Dun Deardail, crossing the Pass of Inverfarigaig some way above the monument to James Bryce. The junction can then be traced along the top of the ridge between Gleann Liath and Loch Ness to the vicinity of the Upper Falls of the Fechlin and to Carn Dearg, where the breccias appear to be banked up on either side of the hill. They die out on the south-west flanks of Carn Dearg. No Middle Old Red Sandstone has been recognized beyond the Allt a'Mhinn, which flows into Loch Ness from Dearg Lochain at the south-west end of Carn Dearg.

The prominent escarpment formed by the Middle Old Red Sandstone in the Crag nan Clag district, and the marked change in the scenery as one passes from Moine schists to conglomerates have already been described (pp. 8-10). The actual unconformity below the Middle Old Red Sandstone is well

exposed at a number of localities -- of which the best is Crag nan Clag.

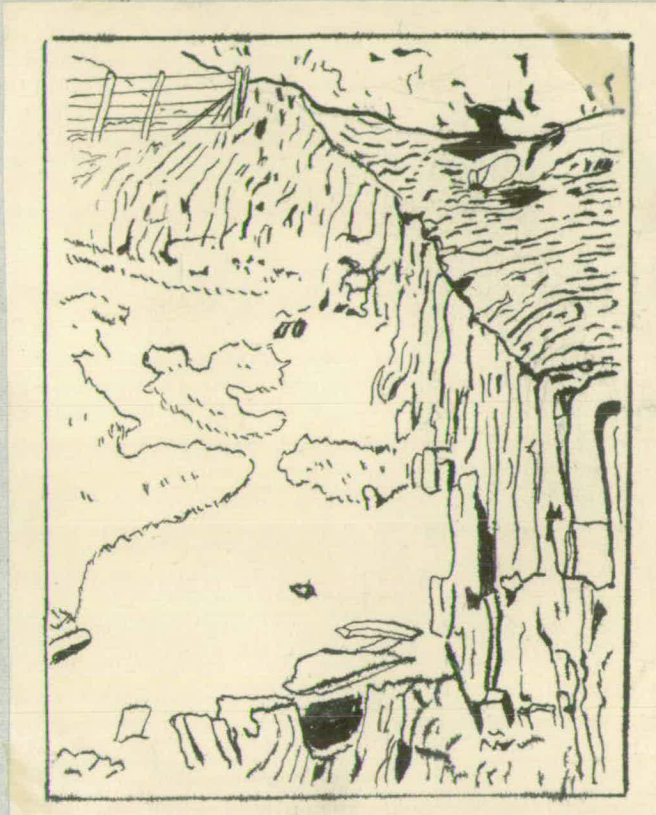
Crag nan Clag (Plate X A) is a vertical crag of Middle Old Red Sandstone conglomerates, facing the south end of Loch Dun Seilcheig and the west end of Loch Ruthven. The crag is weathered into rounded, buttress-like forms. The Moine schists, cut by pink felsite dykes, are seen to pass under the Old Red Sandstone on the south-east side of the crag. The schists are here nearly vertical, and can be seen (cf. photograph Plate X A) forming the more gently sloping, heather-covered hillside in the foreground. The actual junction surface is laid bare along the top of the crag for some 200 yards, ~~at~~ the south-east end. It here forms a shelf, floored by the schists, with an overhanging cliff of

conglomerate. This is shown ~~in the~~ in the accompanying sketch taken from a photograph. The vertical flaggy Moine schists are seen to form an irregular surface on which ~~rest~~ rest the basal breccias of the Middle Old Red Sandstone. The breccias are formed of angular schist fragments, cemented by a red, gritty matrix, and are obviously screens resting very nearly on the rocks from which they were derived.



At the north-east end of the exposure of the unconformity, the

phenomena are rather different. The second sketch (below) attempts to show the structure. Along the base of the Middle Old Red Sandstone, the vertical Moine schists are folded over so that they come to lie horizontally immediately beneath the basal breccias. The effect on the eye is one of two superposed unconformities.



Overhanging cliff of conglomerate.

Horizontal schists.

Fold passing into line of fracture.

Vertical Moine granulites.

The schists are not folded back along the strike, but slightly on the skew, toward the south end of Loch Dun Seilcheig. In some cases the rock has broken along the line of the folding, and there may have been a little horizontal movement; but elsewhere individual bands of the flaggy granulites, and a quartz vein cutting them, can be traced up, round the curve of the fold and then horizontally beneath the basal breccias.

Above the horizontal schists come the basal breccias of the Middle Old Red Sandstone, obviously scree material resting on the rocks from which it was derived. It consists of flaggy schists, still lying horizontally, but broken up into short lengths,

PLATE X



A. Crag nan Glag. Cliffs of Middle Old Red Sandstone breccia and conglomerate. Moine schists outcrop in the foreground -- the unconformable junction between the two is exposed on the face of the cliff to the left.



Unconformity →

B. Creag Dhearg and Loch a'Choire. The escarpment of the Middle Old Red Sandstone is to the left, it rests unconformably on Moine schists and injection gneisses.



A. Exposure of the unconformable junction of the Middle Old Red Sandstone on Moine schists. Tom na h-Iolaire, Dunchia.



B. Intensely compacted conglomerate, chiefly composed of boulders of pink granite, with some fragments of Gleann Liath mica-schists. Middle Old Red Sandstone, above unconformity on Gleann Liath Series; near Glenlia village.

separated by a red, gritty matrix, introduced between the broken fragments. In some cases, a schist fragment has been rolled over, but it often appears possible to trace the discontinuous fragments of a particular layer in the schists along the crag of basal breccia. The total thickness of the breccia is some ~~101~~ 10-15 ft. Higher up on the crag, it passes into the conglomerate, with fairly well rounded boulders, which forms the main cliff face of Crag nan Clag.

Along the junction line between the Moine schists and the Middle Old Red Sandstone, several inches of calcareous tufa is frequently found; this has been leached out of the conglomerate by water dripping down the crag face. Its presence makes photography of the Crag nan Clag exposure of the unconformity, difficult.

The hill, of which Crag nan Clag is the steep north-east termination, is called Dun Chia, and consists of Moine schists surmounted by a flat, pancake-like cap of Middle Old Red Sandstone conglomerate. Along the south-east flank of Dun Chia, these conglomerates form an escarpment rising from the smooth, grassy slope of the schists, along the base of which the unconformable junction is frequently exposed. It can, in fact, be traced from near Tom na Croiche, almost continuously to Crag nan Clag, a distance of about three-quarters of a mile (Plate II A,B). The schists are nearly vertical, and the basal breccias rest on their irregularly eroded edges (Plate XI A). The overfolding of Crag nan Clag is not, however, repeated.

The schists below the unconformity at Crag nan Clag can best be explained as a local fold in the Moine schists, which happened to coincide with the old land surface on which the Middle Old Red Sandstone was laid down. It is difficult to

visualize any natural agency acting sub-aerially, which could have overturned them. On the other hand, most of the outcrops of Moine schist, have vertical dips and the beds are not folded in this way. At Crag nan Clag, the schists, both vertical and horizontal are cut by a felsite dyke, the top of which is rather broken and weathered, where it is overlain by the basal breccias and this observation appears to confirm the idea that the horizontal schists are merely a local fold in the Moine series.

The margin of the Middle Old Red Sandstone north-east of Crag nan Clag is obscured under peat until Creag Dhearg is reached. Here the Old Red Sandstone again forms a prominent escarpment -- a high, red crag of conglomerate rising from the grey "injection" gneisses of the Moine series at Loch a' Choire and near Leiterchullin (Plate X B). The actual unconformity is, however, only exposed for a short distance at the western end of Creag Dhearg, in the "nick" on the hillside, between the steep conglomerate crags to the north-east, and the schists of the rounded heather-clad Tom na h-Iolaire to the south. The schists dip steeply to the north, and the conglomerate rests on an irregular surface eroded in them. In this exposure, unlike that of Crag nan Clag and the other exposures of the unconformity near Foyers, there is no development of a basal breccia; and the conglomerate rests directly on the schists. The conglomerate is very rich in pebbles of felsite, sheets and dykes of which cut the schists immediately below the unconformity on Tom na h-Iolaire.

South-west of Crag nan Clag, the next exposures of the unconformity are found in the course of the River Farigaig and between Dun Garbh and Dun Deardail, though a close

approximation to the boundary of the Old Red Sandstone between these points is possible because of the development of the characteristic basal breccia. The Farigaig-Dun Deardail exposures are somewhat complicated by the presence of the Gleann Liath crush-line, which has given rise to crush-breccias (p.83) in the underlying granodiorite, almost identical with the Old Red Sandstone breccia. It is often difficult to pin-point the exact line of junction. The basal breccias are composed predominantly of fragments of granodiorite and of the red granite found in small outcrops in the Cos an t-Sionnaich and below the Falls of the Farigaig (p.102). It is probable that this rock originally had a much less restricted outcrop, judging by the number of boulders it has yielded to the basal breccias of the Old Red Sandstone.

The unconformity may also be studied where the Middle Old Red Sandstone rests on the Gleann Liath series. The best exposures are above the Foyers limestone quarries near Glenlia. Here the basal breccia is composed almost entirely of fragments of the Gleann Liath series -- green mica-schists and fragments of calc-silicate rocks and limestone. The breccia is a hard, green rock, almost schistose in places, and the fragments are angular. Limestone fragments are in a minority, and usually weather curiously to form pockets. It is noteworthy that limestone fragments are restricted to the breccias in the immediate neighbourhood of the Foyers and Boleskine limestone quarries.

When this breccia is traced away from the Gleann Liath outcrop, toward Loch Ness, it passes up rapidly into more typical Old Red Sandstone grits and conglomerates. Towards Glenlia the breccia passes laterally into a conglomerate of boulders of

PLATE XII

- A. The Pass of Inverfarigaig looking to Loch Ness from a crag of Foyers tonalite above the bridge at the cross-roads in the pass. Gleann Liath fault line crosses pass just below camera; the upper part of the Pass is in granodiorite; toward Loch Ness it unconformably overlain by Middle Old Red Sandstone breccias, conglomerates and sandstones. The Pass is part of the pre-glacial course of the River Fechlin.



- B. Gleann Liath from Creag an Fhithich looking to the Pass of Inverfarigaig. Creag an Fhithich consists of Foyers granodiorite; the opposite crags are tonalite. The deep valley has been excavated along the Gleann Liath fault line; and is part of the pre-glacial course of the River Fechlin.

pink granite, like that found in situ on Carn Dearg (Foyers) (p.103) (Plate XI B). The principal development of the green basal breccia rich in mica-schist fragments, is at Creag nam Broc. In the exposures between Creag Nighean Iain Duinn and Creag an Fhithich it is usually redder in colour, and contains fewer mica-schist fragments.

The ridge of Carn Dearg (Foyers) appears to be a pre-Middle Old Red Sandstone hill, against which the basal breccias are banked. The outcrop splits into two branches, one of which runs up the hollow on the southern flank of the hill, along the Gleann Liath fault line, forming part of the flank of the hill; the other lies on the north-west flank above Loch Ness. The rock types are predominantly basal breccias, with conglomerate and arkose. It must be remembered that all the rocks of which the ridge is composed have been subjected to very extensive shattering, and it is often difficult to distinguish the sheared Old Red Sandstone from the underlying sheared Moine granulites and the Carn Dearg granite. The Middle Old Red Sandstone boundaries shown in the Carn Dearg (Foyers) district are therefore, to be regarded as approximate only. The outcrop of the Middle Old Red Sandstone, however, does not extend further along Loch Ness side, beyond Carn Dearg. This latter hill is some $2\frac{1}{2}$ miles short of the point opposite Invermoriston, to which the Old Red Sandstone outcrop is shown as extending, on the small-scale geological maps so far published.

B. STRUCTURE & LITHOLOGY

i. Sequence of Formations

The Middle Old Red Sandstone, in the Foyers and Strath Errick district, consists predominantly of conglomerates with subsidiary breccias, arkoses, sandstones and shales. The breccias are restricted to the base of the formation where it rests unconformably on the older rocks. They are succeeded by conglomerates, with thin bands of hard, red sandstone, and less commonly shales. The beds dip at low angles to the north-west. They have all been affected by the Great Glen movements, more especially in the Foyers district itself; and the rocks are often highly compacted and very hard.

ii. Basal breccias

The basal breccia of the Middle Old Red Sandstone, as typically developed where it overlies the Moine schists in the Dunchia district, is a hard, well-compacted rock, composed of angular schist fragments in a matrix of coarse red grit. Since the schist underlying the Old Red at Crag nan Clag are thin-bedded flaggy granulites, the fragments in the basal breccias are usually thin and plate-like in form; one example was actually observed to be bent. The Moine schists are less flaggy in character toward Torness and Creag a'Chupain and the fragments in the overlying basal breccia become more "chunky". The general character of the rock, however, remains unchanged, and it forms a useful guide in the mapping of the boundary of the Middle Old Red Sandstone, where the actual unconformity is not exposed.

Where the basal breccias rest on the Foyers plutonic complex, as at Dun Garbh and Dun Deardail, they locally become almost exclusively formed of fragments of granodiorite and red granite. Loose, weathered-out sphenes have been seen in the matrix.

Overlying the Gleann Liath series, the basal breccias vary from the typical reddish rock, with a few fragments of green mica-schist, to green breccias composed almost entirely of fragments from the mica-schists of Gleann Liath. Sometimes the softer fragments of mica-schist are bent round harder fragments. Above the Foyers limestone quarry, the breccias consist almost entirely of mica-schist fragments, calc-silicate rocks and subsidiary limestone fragments derived from the Gleann Liath series, with only a few fragments from the Moine series and the Foyers plutonic complex.

iii. Conglomerates

The conglomerates, which build up the bulk of the Middle Old Red Sandstone in the Foyers district, are composed of fairly well rounded boulders of locally derived rocks. They often show a rude stratification. The schist boulders tend to be elliptical in shape, with their long axes parallel to the bedding. At Tom Bailgeann, in the north-east, the conglomerate is not very hard, and is much guttered by rain erosion. Landslips have occurred here above the Loch Ce-glais road. At Foyers, however, (Plate **XI** B), the conglomerate is intensely compacted, as a result of effects due to the Great Glen movements, and the whole rock breaks as a unit; it is not possible to separate boulders from matrix, as it is further to the north-east.

The boulders forming the conglomerates are poorly sorted, and range from coarse gravel through boulders up to a foot in length to blocks (less common) which may reach three feet in length. The boulders consist of Moine schists, felsites and Foyers "granite" types. The latter are not so abundant as the Moine schists. Felsite boulders are very common indeed in the Tom Bailgeann -- Loch Dun Seilcheig country. Boulders of volcanic types indicating volcanic activity due to the Foyers complex have not been observed. The Moine schist boulders are usually of the more siliceous types, but pelitic types are also present. On Tom Bailgeann, coarse mica-schist fragments are quite usual, and range up to about 18" in length. The Conagleann "injection" gneiss is also represented. There does not seem to be much variation in the composition of the conglomerates as they are traced from the base upwards.

iv. Arkoses, grits and sandstones

Arkosic grits are well developed in the Foyers district, where they occur interbedded with the conglomerate above the basal breccias. The grits are well exposed in the quarry in the Pass of Inverfarigaig (Plate XII A) at the monument to James Bryce. Specimens from this quarry were subjected to a Lovegrove attrition test (p. 160) no. 154.

The arkoses are hard, red, highly compacted rocks composed of angular fragments with subsidiary coarser bands containing more rounded pebbles of Foyers "granite" types. Normally, they contain scattered, more or less intact, crystals of very fresh, pink, perthitic orthoclase, weathered out of the Foyers granodiorite. Biotite flakes are also common in the grits. The

Tests by E.J. Lovegrove (pp 22-25)

Ref. No.	H or M broken	Chips detached from parent stones		Dust % of loss		Specific average Gravity
		<u>dry test</u>	<u>wet test</u>	<u>dry test</u>	<u>wet test</u>	
251	H	0.68	3.12	8.74	13.33	11.03 2.68
254	H	0.00	0.00	4.98	8.10	6.54 2.65

Tests by Logan Waller Page (pp 70-71)

Ref. No.	Water absorbed per cubic foot	Hardness	Toughness	Cementing Value
251	0.12	18.8	15	14
254	0.23	19.0	25	13

----- .

- 251. Feldspathic grit or arkose, approaching a conglomerate. Falls quarry, on S.E. side of Loch Ness by Falls of Foyers
- 254. Arkose. Pass quarry, 1/2 mile S.W. from Glenlia (East) Quarry. This is the quarry, now disused, at which the monument to James Bryce stands, in the Pass of Inverfarigaig.

For a note on these attrition tests, see p. 98.

bedding planes often exhibit rather peculiar pits caused by the impress of the orthoclase crystals in the underlying bed.

Immediately above the basal breccias, thin-bedded, red sandstones are usually developed on a small scale. The sandstones, red or chocolate in colour, ~~are~~ are unfossiliferous. They are fairly coarse in grain, and grade into the arkoses. The sandstones in the Loch Ce-glais district are rich in flakes of muscovite derived from the pelitic Moine schists to the east.

The bedding planes show ripple marks and, near Loch Ashie, well developed sun-cracks. They also show much more irregular markings, in the form of puckering, due perhaps to small rills of water breaking up original ripple prints.

v. Shales

Green and purple shales and mudstones are exposed in a small quarry at Castle Kitchie on the Torness-Inverfarigaig road. One fragmentary fossil fish was found in this quarry. Perhaps the rocks represent a diminished lateral extension of the Lochan an Eoin Rudha fish bed.

The shales show rain prints, and the interbedded ribs of sandstone show ripple marks. There are also a few, poorly developed sun-cracks; as well as more irregular puckers, and on the shales, tiny, crowded raised points.

vi. Conditions of Deposition

The basal breccias of the Middle Old Red Sandstone in the Foyers district evidently represent local scree formations resting on the rocks from which they were derived. The individual fragments are not weathered and probably

accumulated rapidly in a climate in which chemical weathering was not in evidence.

Shallow lakes were then formed in which the sandstones overlying the breccias were deposited. These lakes must have been liable to frequent drying-out, when the sun-cracked and ripple-marked surfaces were formed. Their character is shown in the exposures at Dun Deardail. Here the basal breccias pass up into a few feet of chocolate sandstone, above which come more breccias. The overlying breccias, composed predominantly of fragments from the Foyers granodiorite, have evidently slumped onto the sandstones while the latter were still moist and pliable. The sandstones have been flexed by the slumping of the scree material, which now rests on their irregularly folded surface.

The conglomerates seem to be torrential deposits, in which the boulders were rounded but not sorted. They seem to have accumulated rapidly, near the source of origin of the majority of their components, eg. large blocks of soft mica-schist are preserved in them. The sandstones occurring higher in the series and developed toward Dores to the north-east of the district under discussion, indicate the subsequent oncoming of lacustrine conditions.

C. EFFECTS OF CRUSHING & SHEARING

The Middle Old Red Sandstone in the Foyers district is much altered and affected by the Great Glen Movements. In the Tom Bailgeann district, to the north-east and further from the line of the fault, the effects on the rocks are not so marked. There, the conglomerate is fairly soft, the pebbles can be separated from their matrix, and the principal signs of movement

are to be found in the boulders themselves, which are fairly frequently sheared across. These features may occur with or without lateral movement. Sometimes lines of movement, cutting straight through the larger boulders, can be traced for some distance in the conglomerate cliffs above Loch Ce-glais.

But at Foyers, the conglomerates become intensely compacted and hardened. It is no longer possible to separate boulders from matrix; the whole has been welded into one single unit. The arkoses, grits and breccias in the same area also become intensely hardened and compacted. In fact, in the crush zones, on Carn Dearg (Foyers), it becomes extremely difficult to distinguish between the hardened and sheared Old Red Sandstone ~~and~~ from the sheared Moine granulites and the granite.

The second effect of the Great Glen movements, perhaps later in time, has been the mechanical shattering of the rocks along particular zones. There are many of these shatter-belts one runs along Loch Ness-side from the Aluminium Factory's road at Foyers, toward Inverfarigaig. In the new road cutting below Foyers' church, there is a good exposure of the shattered, broken rock, stained red with haematite. In the small quarry behind Foyers school, on the same line of crush, the conglomerates have been so shattered, that quartzite pebbles, on handling, readily crumble into small pieces.

The Middle Old Red Sandstone only rarely shows the thin lines of micro-breccia so commonly developed in the Foyers plutonic complex, and is never epidotised. The movements producing these effects are therefore considered to be earlier than the Middle Old Red Sandstone.

VII. THE GREAT GLEN FAULT

Glen More nan Albyn, the Great Valley of Scotland, is excavated along the line of a great fault zone, which extends from the Moray Firth in the north-east to the southern end of Mull in the south-west. It is also commonly held to extend into Islay as the Loch Gruinart Fault.

Along the line of the Great Glen fault, the rocks are greatly shattered. The movement is certainly of many different ages, and is still taking place, for earthquake shocks occur at intervals along the glen. During the present research on the south-east shore of Loch Ness, evidence has been found to suggest pre- and post- Old Red Sandstone periods of movement.

The most recent major shocks felt in the Great Glen area were those of the Inverness earthquakes of 1901 and 1890 (Davison, 1891 p.168; 1902 p. 377). The second series of shocks in 1901 definitely originated along the Great Glen itself, but the 1890 evidence pointed to movement along a branch fault lying about 6 miles south-east of Inverness and reaching Loch Ness about 5 miles from its southern end. This supposed movement line is very close to the Gleann Liath fault line mapped during the present research.

It is here suggested that the deep fissures on Carn Dearg(Foyers), may be connected with some of the earthquake shocks. These fissures cross the lower ridges of the hill on the Loch Ness side, and are up to 20 ft. deep with vertical walls. They are partly concealed under deep heather and are said to have

been the cause of several deaths.

From the evidence afforded by the Middle Old Red Sandstone in the country between Inverness and Loch Dun Seilcheig, the minimum downthrow is known to be 6000 ft. (Horne, 1914 p.66-69). Whilst in the above district, the Great Glen Fault brings Middle Old Red Sandstone down against Moine schists ; in the Inverfarigaig-Mealfuarvonie district, Middle Old Red Sandstone rocks of identical types outcrop on both sides of Loch Ness.

In the Loch Linnhe region of the fault, the schists on the north-west side of the fault show a higher grade of metamorphism than those on the south-east side; but this does not apply to the Moine schists on either side of Loch Ness (Peach & Horne, 1930, p.198).

Recently, Professor W.Q. Kennedy (1945 p.) has suggested that the Great Glen Fault is a wrench (or transcurrent) fault with a lateral displacement of 65 miles. He believes that the Strontian and Foyers "granites" belong to the same complex. The wrench-fault hypothesis also connects the two permeation complexes - that round the Foyers complex and that in the Strontian district. Kennedy regards the Loch Skerrols thrust in Islay as the continuation of the Moine thrust, and considers that the Great Glen fault lies to the north-west of Islay, ~~where it crosses~~ ^{part of it} The hypothesis thus brings the Moine thrust in Islay into line that ~~it~~ further north.

The Foyers plutonic complex certainly resembles the Morvern-Strontian complex (Kennedy & MacGregor 1932 p 105-119) much more closely than it does the neighbouring complexes of the Findhorn and Moy.

The members of the Morvern-Strontian complex have a general concentric arrangement relative to the walls, like



A. Strontian from Sron na Saobhaidhe. The foreground is in the schists, the middle distance in the Strontian granodiorite and tonalite; beyond which rise the schists on the other side of the intrusion, forming the mountains on either side of Glen Tarbert.

B. Strontian. Injection gneiss in road-cutting on Strontian-Salen road, near Sron na Saobhaidhe.

cf. Plate IV. B



that of the Foyers complex. There are three principal rock types, tonalite, granodiorite and granite, with earlier appinites preserved in large xenolithic masses; and with subsidiary dykes and sheets of granodiorite porphyry cutting tonalite and granodiorite, but not the granite. The permeation gneisses and other schists into which the complex has been intruded have had their foliation deflected to conform to the trends of the margin of the complex, and at certain points --- for instance, near Bellsgrove Lodge, intrusion "breccias" have been formed. The lineation of the tonalite is roughly parallel to ~~the~~ the strike of the surrounding schists. Inclusions are abundant. As well as appinite, basic dioritic inclusions (Plate VI B) , like those of Foyers are common; and so are inclusions of Moine schist. In the northern part of the complex, a long arcuate strip of Moine schist is found in the tonalite, reminiscent of the long arcuate strips found in the Foyers complex.

The appinites are more varied in type and more widely distributed than at Foyers, but individual types can be exactly matched. The maximum development of appinites in both complexes is on the western side.

The tonalites and granodiorites are very similar to one another; the Strontian rocks are slight coarser than those developed at Foyers and the tonalite is of more uniform character, and less rich in basic enclave material. In places the tonalite of Strontian is riddled with aplite veinlets. This last feature cannot be matched at Foyers.

The Strontian biotite-granite is quite different from that found at Aberchalder in the Foyers complex. It is a biotite-granite, with small porphyritic pink, orthoclase crystal

It is richer in both biotite and orthoclase than the Foyers granite and less quartzose. It does not contain any hornblende. These characters may indicate that the Strontian granite is at a deeper level of granitisation than the Foyers rock.

The granodiorite-porphry can be matched at Foyers in a few small intrusions near Loch Kemp; the orthoclase phenocrysts, however, never reach the dimensions of those at Strontian(where they range up to 3" in length).

The contacts between the individual members of the Strontian complex resemble those found at Foyers, eg. the tonalite-granodiorite contact is fairly sharply marked, but sometimes grading; whilst the biotite-granite always shows sharp contacts. The biotite-granite frequently forms a complicated series of sheets and dykes cutting tonalite and granodiorite, and the surrounding schists. This habit of occurrence is similar to that of the Foyers biotite-granite.

If the two complexes are the same, the Strontian type of biotite-granite may be represented by the few outcrops of badly sheared red granite along the line of the Gleann Liath fault, but these specimens are too badly crushed for certain correlation.

The Moine rocks into which the Strontian Complex is emplaced are chiefly permeation schists, which are in general rather like those of Strath Errick. The Conagleann permeation gneiss can be exactly matched(Plate XIII B & IV B) with examples from the Strontian complex. The Strontian complex definitely cuts the permeation gneisses, in the same manner as does the Foyers complex.

No contact metamorphism due to the Møvern-Strontian complex has been observed in the Moine schists. This is even more remarkable than the paucity of contact-effects at Foyers,

where considerable alteration has locally affected some of the pelitic layers. Pelitic layers are also present at the contacts of the Morvern-Strontian complex, but they are quite unchanged.

A series of analyses of the Strontian rocks is given on p. 146. for comparison with the Foyers rocks.

If the two complexes are really one and the same, separated by a wrench-fault, the Foyers part must be at a much higher level in the complex than that seen at Strontian, for Foyers still retains part of the roof; and the rock types are of a finer grain and less regular in their development. The present erosion level of the Strontian complex must be at a much deeper level relative to the complex, for no parts of the roof now remain, and the rock types are relatively coarser. Moreover, as already pointed out, the granite is more potassic and the tonalite is freer from xenoliths. This inference implies that Foyers is on the down-throw side of the Great Glen Fault, which agrees with the evidence afforded by the Middle Old Red Sandstone in the Inverness district.

The general likeness of the Foyers and Strontian complexes, and the correlation of the two permeation complexes in the Moine schists on both sides of the Great Glen provide rather strong evidence for interpreting the Great Glen fault as a wrench fault. The theory is further supported if the correlation of the Loch Skerrols thrust in Islay with the Moine thrust is correct. The adverse evidence includes the minor differences between the Foyers and Strontian complexes, noted above, but it is probably of less weight than the points in favour. The Gleann Liath series constitute a more serious objection, for they form a faulted inlier

between Loch Ness and part of the roof of the Foyers complex, in a position where, if the Foyers and Strontian complexes were originally a single mass, one would expect to find either, more of the roof-schists, or the granite. It must also be remembered that, at Loch Ness, the Moine schists are much alike on either side of the Great Glen Fault, and that Lewisian inliers exist in them - eg. at Glen Urquhart. A minor point is the presence of Middle Old Red Sandstone on either side of the Great Glen at Foyers and Mealfuarvonie.

It appears to the writer, however, that before anything approaching final conclusions concerning the Great Glen fault can be drawn, the middle stretch of the valley must be geologically surveyed in detail.

VIII. SUMMARY

The district which has been investigated during the present research extends from Loch Dun Seilcheig in the north-east, along the shore of Loch Ness, to Beinn a' Bhacaidh. The Foyers plutonic complex occupies a large part of this district. It is intruded into Moine schists and overlain, unconformably, by the Middle Old Red Sandstone.

The Plutonic Complex consists of three principal types -- tonalite, granodiorite and granite, emplaced in that order, with subsidiary appinites earlier than the tonalite. The plutonic rocks tend to be emplaced concentrically with relation to the walls. The junctions with the schists are highly inclined or vertical. The regional strike of the Moine schists has been forced into conformity with the trends of the margin of the complex, either mechanically or by flowage and recrystallisation, and at some places, intrusion "breccias" have been formed in the schists. There is local contact alteration of the country rock.

The complex contains numerous xenoliths, mostly either Moine schists or basic dioritic enclaves, but sometimes belonging to the appinite series. It is here suggested that the basic dioritic enclaves may represent basified relics of country rock.

The Moine schists are principally siliceous types, but pelitic schists and gneisses are also present. The series includes permeation rocks and migmatites, of earlier age than the Foyers plutonic complex. In Gleann Liath, a quite

different series of gneisses and limestone occurs, and it is suggested that these rocks may be of Lewisian age. There are also mica-schists in the Glen Doe district, near Fort Augustus, which appear to closely resemble typical Dalradian mica-schists.

The Middle Old Red Sandstone rests unconformably on the schists and on the Foyers complex, and consists predominantly of conglomerates formed of boulders derived from the underlying formations. The unconformable junction of the Middle Old Red Sandstone on the older rocks is very well exposed at a number of localities.

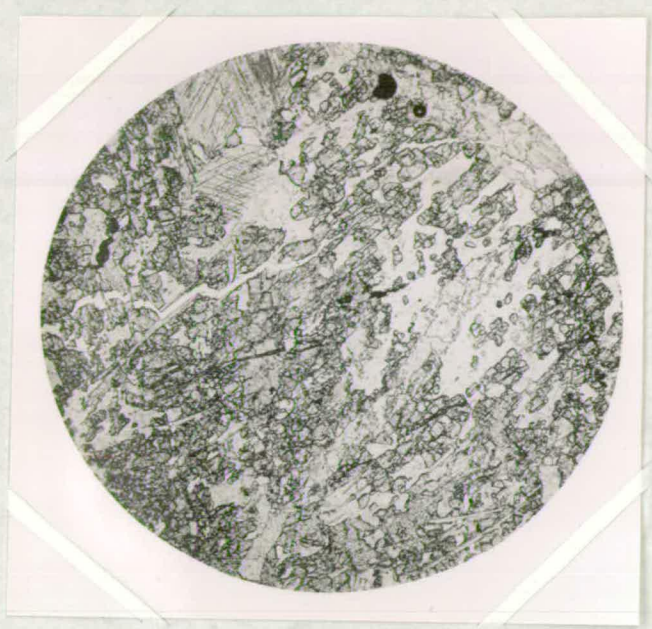
IX. ACKNOWLEDGEMENTS

In conclusion, I must express my warmest thanks to Professor Arthur Holmes and Dr. Robert Campbell, both of the Grant Institute of Geology, for much valuable assistance during this research : to the Carnegie Trust for a grant to defray the cost of chemical analyses : and to Mr. Anderson, Fasnagruig, Inverfarigaig, who rendered me much assistance in the field. The microphotographs are the work of Mr. Fisher, of H.M. Geological Survey, Edinburgh.

PLATE XIV

- A. Gleann Liath Series. Calc-silicate band in limestone, Foyers Limestone Quarry. Principally diopside, with subsidiary feldspar, calcite, zoisite (bottom left), a little sphene (top right), and some blades of colourless mica. Ordinary light x 30
- B. Gleann Liath series. Gleann Liath gneiss, from crags to NE of Foyers limestone quarry. Clear quartz and cloudy feldspars (orthoclase and plagioclase). The layer of partly chloritised biotite also includes subsidiary muscovite, and small colourless garnets (right) and colourless apatite (left). There is a little black iron ore. Ordinary light x 30
- C. Moine calc-silicate granulite, Loch Killin. Granulitic quartz (clear) and feldspar (slightly cloudy). Large sieved pale pink garnet in centre of field. Also shown are shreds of pale green hornblende and small granular sphenes. The very small clear crystals, with high relief, are apatite. Ordinary light x 30
- D. Augen siliceous granulite of Loch Bran type. Head of inlet, Loch Garth, between Migovie and Garthbeg. Granulitic quartz, plagioclase and orthoclase, with aligned flakes of brown biotite. In the lower part of the field a large orthoclase is seen enveloping parts of the finer-grained matrix of the rock. A large quartz, enclosing biotite, is seen at the top of the field. Crossed Nicols x 30

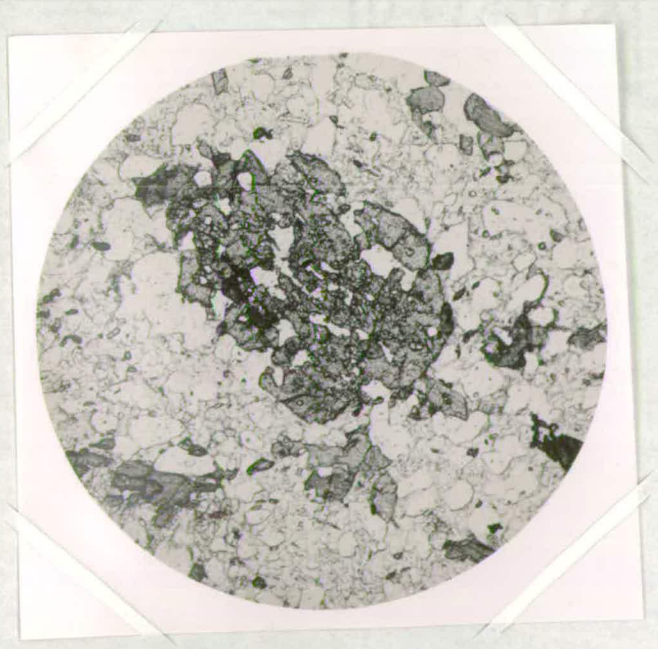
PLATE XIV



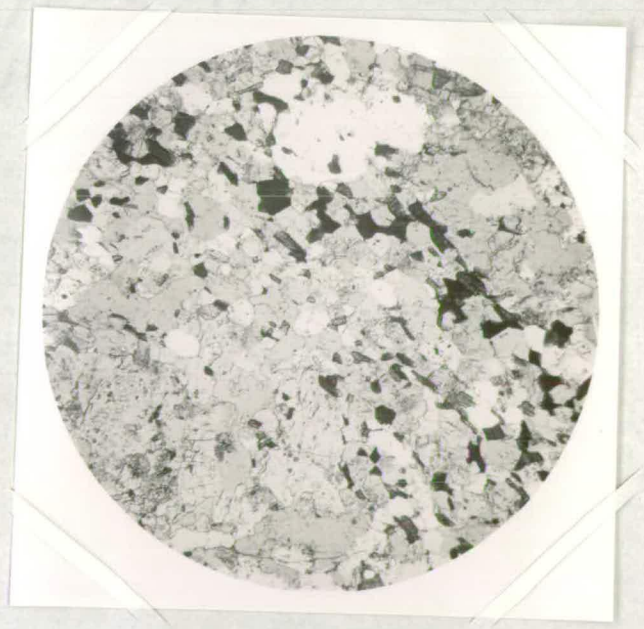
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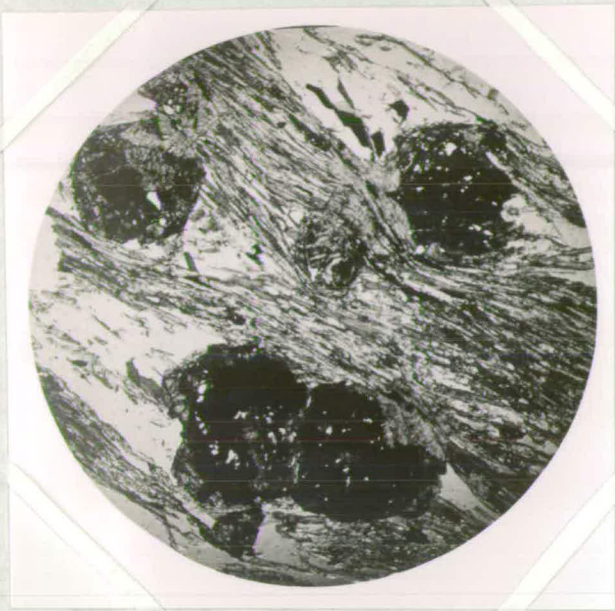


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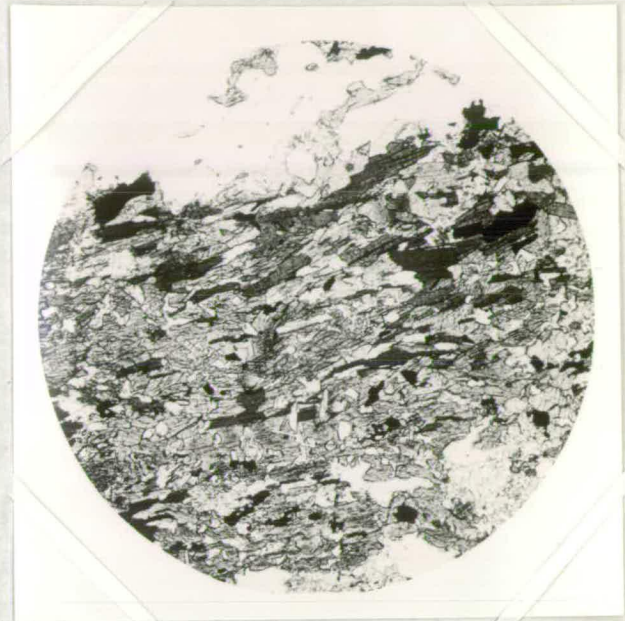
PLATE XV

- A. Garnetiferous mica-schist, Glen Doe bridge. Flakes of muscovite and subsidiary brown biotite sweep round "snowball" garnets with spirally arranged inclusions. Each garnet has a "tail" of quartz on either side. Some of the garnets are partly altered to chlorite. Ordinary light x20
- B. Hornblende-schist, Tom Mor, Oldtown. Field shows aligned green hornblendes with a little reddish biotite. There is subsidiary quartz and sericitised feldspar. Black patches are iron ore. There is a small, concordant vein of quartz at the top of the field, probably related to a neighbouring pegmatite vein. Ordinary light x 30
- C. Tonalite, Foyers Plutonic Complex. Old quarries in field behind Aberchalder Lodge. Field shows green hornblende, brown biotite (some of which is slightly altered) and feldspar. The feldspar is chiefly plagioclase, but a little orthoclase is also present. The inclusions in the biotite in the bottom left-hand corner are apatite. Large crystals of sphene are seen on the left. Ordinary light x 20.
- D. Granodiorite, Foyers Plutonic Complex. Dell Marsh quarries. Clear quartz, perthitic orthoclase (mottled effect), plagioclase, biotite and hornblende with several sphenes. Black patches are iron ore. Note small accessory, hexagonal sections of apatite. Ordinary light x 20.

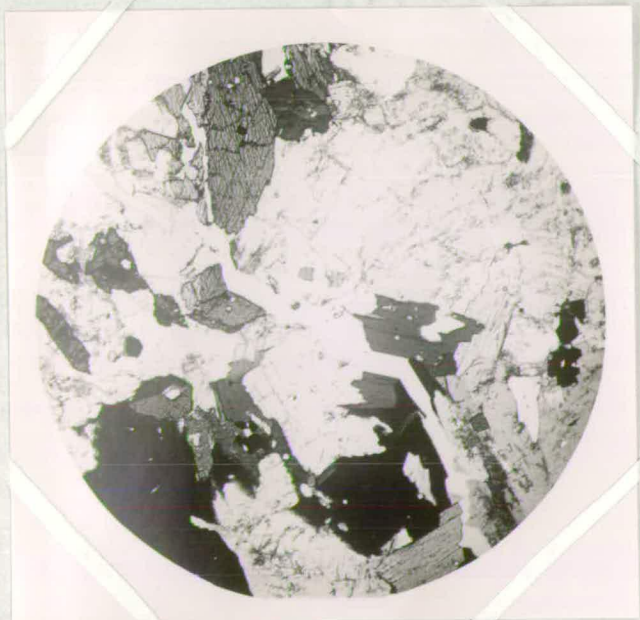
PLATE XV



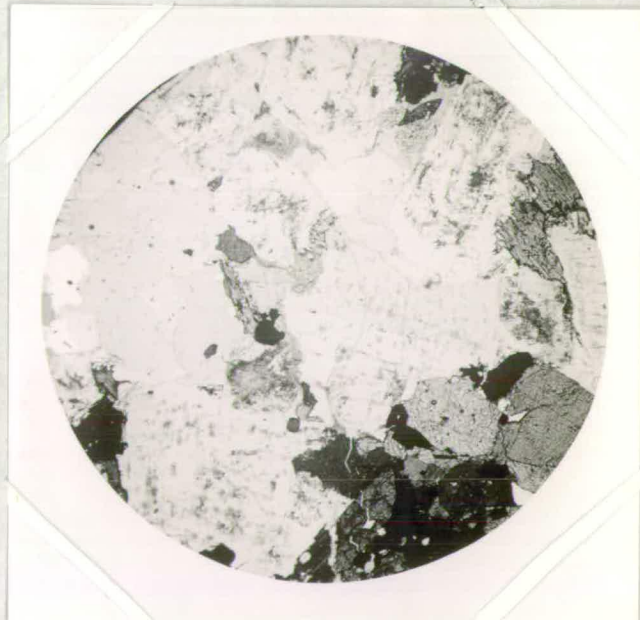
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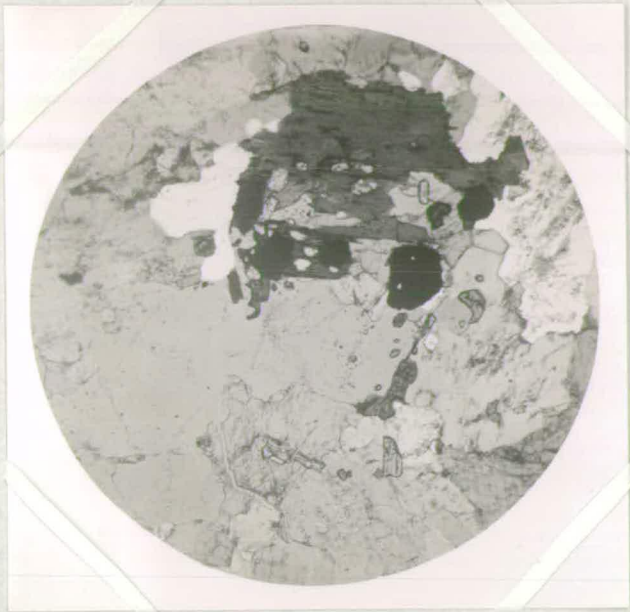


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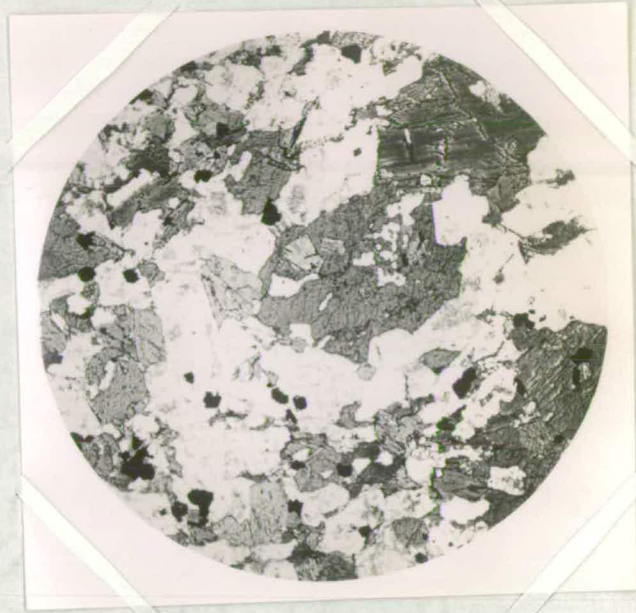
PLATE XVI

- A. Biotite-granite, Foyers plutonic complex. Below Chalder Falls in Aberchalder Burn. Abundant clear quartz, crossed by lines of tiny inclusions; orthoclase and subsidiary plagioclase. Note myrmekitic intergrowth of quartz and plagioclase in lower part of field. Large, dark plate is brown biotite, with iron ore (black) and apatite in numerous clear crystals. A little ragged sphene is associated with the iron ore to the left of the group. The small irregularly shaped crystals in the lower half of the field are green hornblendes. Crossed Nicols x 30
- B. Basic inclusions in granodiorite, Dell Marsh quarries. Abundant green hornblende (note sized example in centre of field) and green biotite, in a plexus of plagioclase crystals with a little subsidiary orthoclase. Accessory iron ore (black) and a little apatite (hexagonal outlines). Ordinary light x 20
- C. Basic inclusion in tonalite, Loch an Ordain. Plexus of rather ~~ragged~~ irregularly shaped oligoclase crystals, large ragged sphene, brown biotite and a ragged green hornblende (top right). Feldspar is slightly sericitised. Numerous needles of apatite, and a little black iron ore. Ordinary light x 30
- D. Basic dioritic inclusion in tonalite, Loch an Ordain. Coarse-grained type, rich in biotite and hornblende. Feldspar in field illustrated is predominantly plagioclase. The large plates are brown biotite; the hornblende crystal (top) encloses fresh biotite. The black spot above the hornblende is iron ore, with clear apatite beside it -- to the right is sphene (dark) and another apatite crystal. Ordinary light x 20

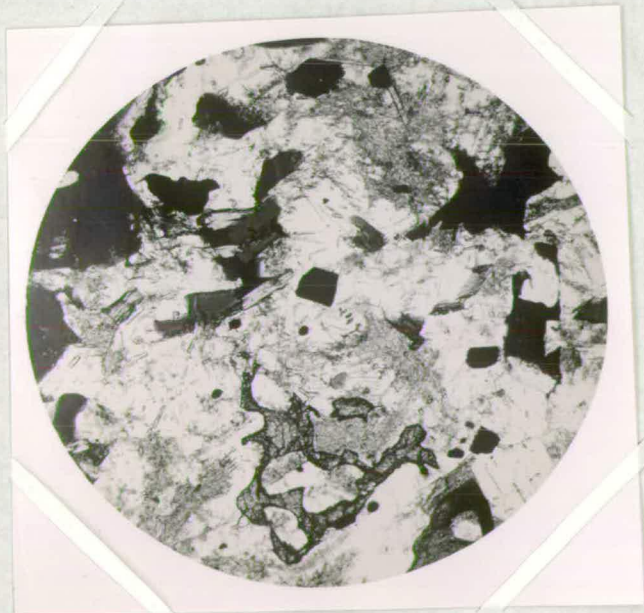
PLATE XVI



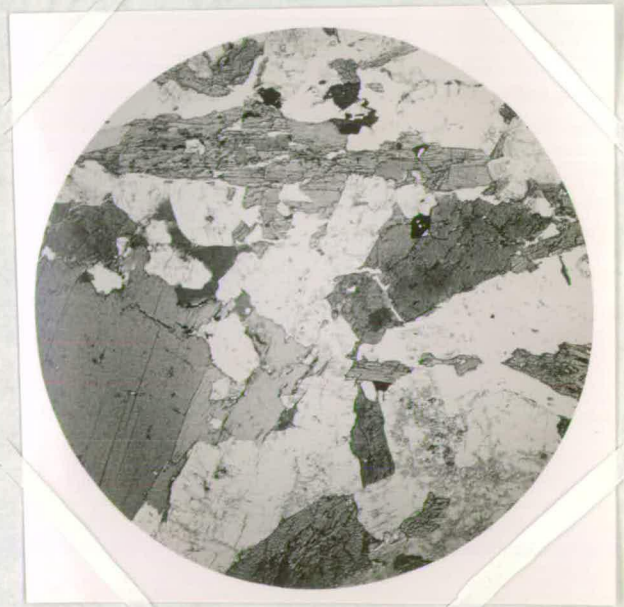
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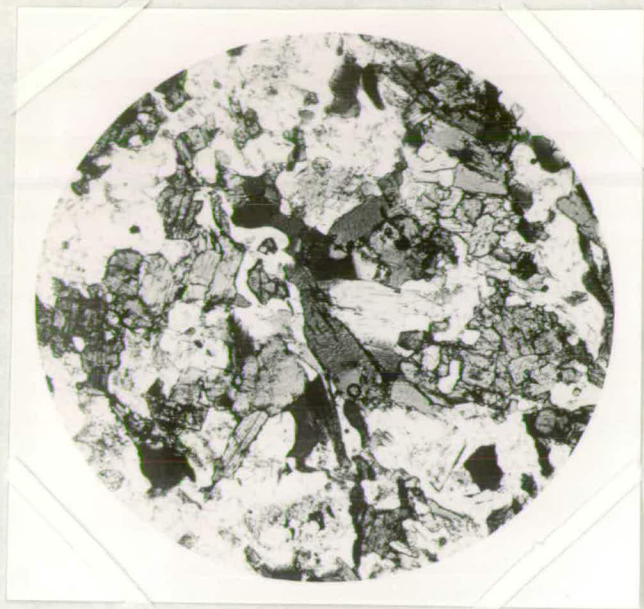


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PLATE XVII

- A. Xenolith in tonalite, Torr Shelly quarry (cf. Plate VIIB) Field shows the interlocking crystals of partly sericitised oligoclase, in which lie irregularly shaped biotites of a slightly reddish colour, and green hornblendes. Apatite is abundant both as stout prisms and as needles. There are a few irregularly shaped sphenes. Ordinary light x 30
- B. Part of the tonalite enclosing the xenolith illustrated above. The field is of a slightly more basic part of the rock than that forming most of the Torr Shelly intrusion. It shows sericitised plagioclase and clear quartz, with a group of green hornblende and reddish biotite crystals (not well differentiated). The black patch in the middle of the group is iron ore; biotite lies to the right hand margin. The darker part of the main group is hornblende, with associated partly chloritised biotite photographing in lighter tints. Note zircon with halo in hornblende to left side of group. Ordinary light x 20
- C. Sillimanite-andalusite-biotite-cordierite-hornfels. Xenolith in tonalite above Dell reservoir. Large andalusite crystal at top, group of sillimanite needles at the bottom, with blades of muscovite just above. Clear background is cordierite. The dark plates are biotite. Specks of iron ore are disseminated through the whole rock. Ordinary light x 30
- D. Conagleann injection gneiss, showing contact-alteration due to the Foyers tonalite. Waterfall in Allt Conagleann below An Fhail. Rock consists of quartz (clear) plagioclase and orthoclase (cloudy) and flakes of reddish biotite with a little muscovite. In the top centre, blades of sillimanite occur in a patch of sericite after cordierite. There are a few dark spots of iron ore. Ordinary light x 20.

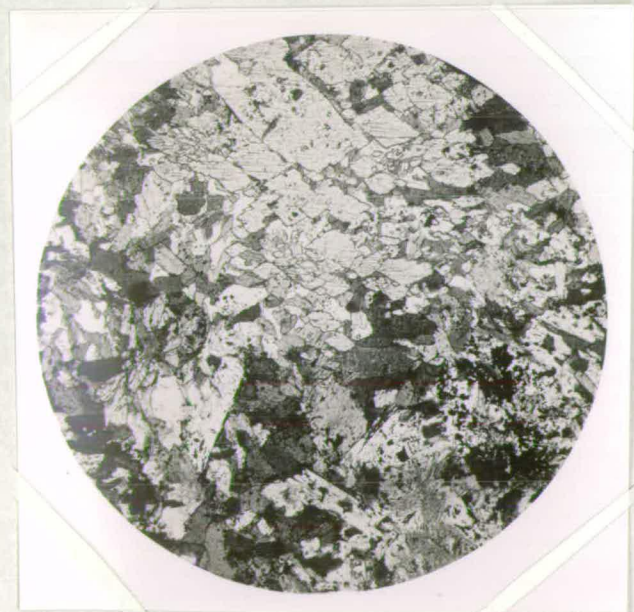
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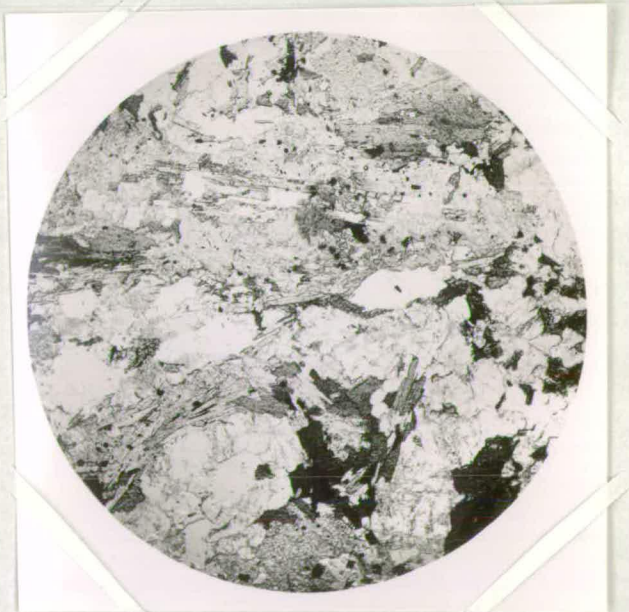
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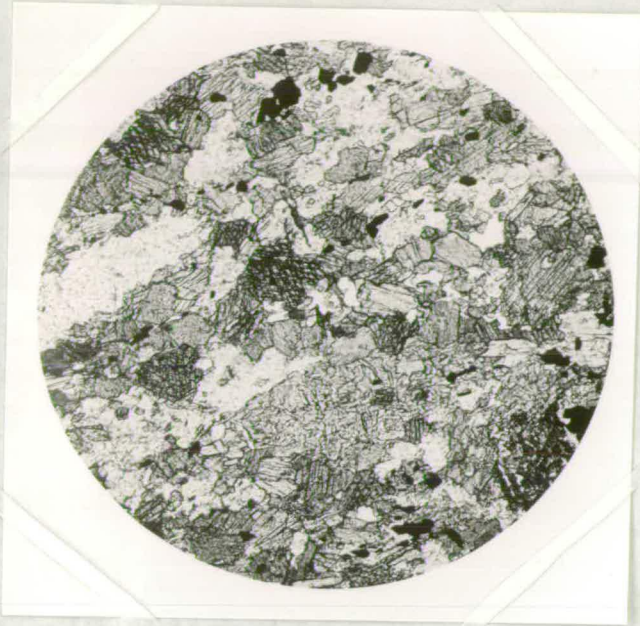


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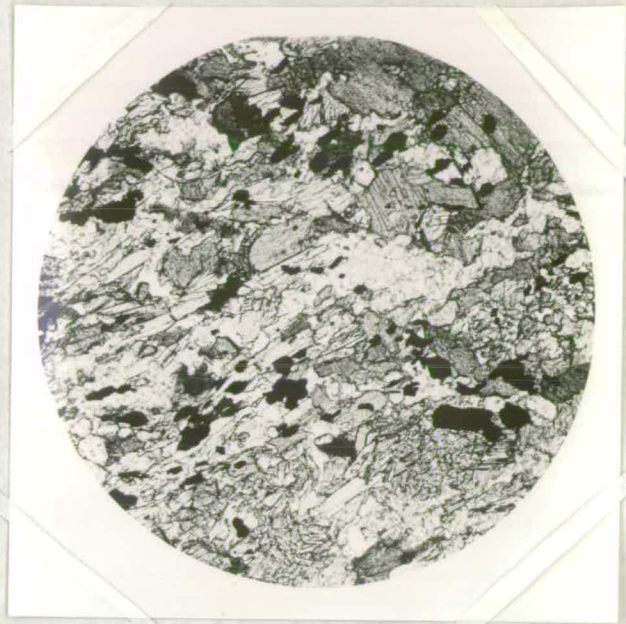
PLATE XVIII

- A-D Xenolith of epidiorite veined with white aplite and enclosed in tonalite. Moss between Loch Scristan and Creag Mhor. All ordinary light x 30
- A. The epidiorite. Green hornblende, some in large, sieved crystals. Clear material is quartz, the mottled is partly sericitised feldspar. There is a little black iron ore, and one or two blades of reddish biotite (eg right edge of field wedging into large sieved hornblende). There are one or two small, clear apatite crystals.
- B. As the vein of aplite is approached, the hornblende is pseudomorphed by biotite. The line separating biotite from hornblende crosses the field from top left to bottom right. Note also numerous apatite crystals.
- C. Within $\frac{1}{4}$ " of aplite vein. Rock here contains only reddish biotite and hornblende is absent. Biotite retains the typical shapes of the hornblende.
* Accessory apatite and iron ore.
- D. Contact of the biotite zone with the aplite vein. Aplite consists of quartz (clear) and plagioclase (slightly cloudy) with a little orthoclase.

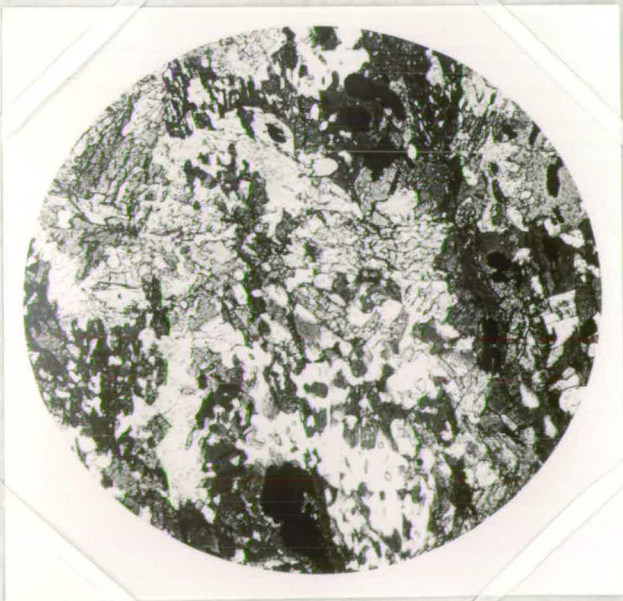
PLATE XVIII



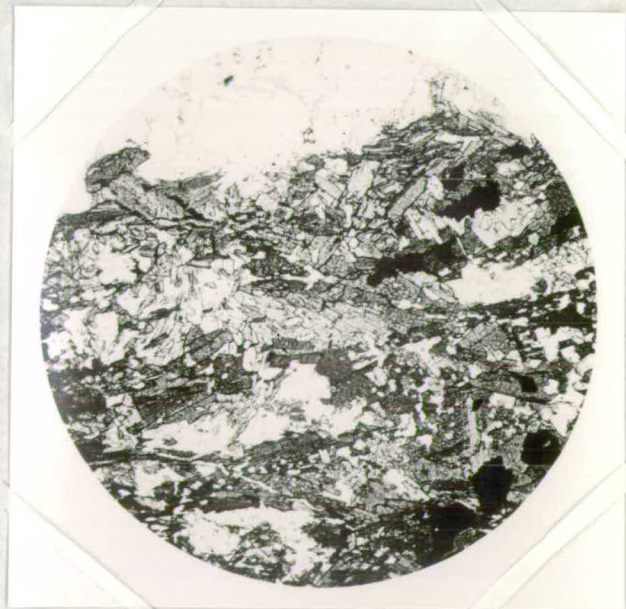
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GLOSSARY OF GAELIC PLACE NAMES

- Aber Mouth or confluence of a river.
- Aberchalder The mouth of the Chalder Burn. The whole stream is now incorrectly, called the Aberchalder Burn.
- Allt A small stream. Equivalent to Lowland Scots Burn and English brook.
- Allt a'Mhinn The stream of the kid.
- Allt na Goibhre. The stream of the goats. Wild goats used to live on the neighbouring Dun Deardail.
- Beinn a'Bhacaidh Probably the mountain of the shelter.
- Beinn Bhuraich The mountain of the roar.
- Beinn Dubhcharaidh. The mountain of the black corrie.
- Beinn Sgurrach The rocky mountain.
- Beinn Mheadhoin. The middle hill
- Blar Nighean a'Mhinisteir . The minister's daughter's bog.
- Boleskine According to the Old Statistical Account, Boleskine is derived from Bail-os-cion -- the town lying above the loch.
The New Statistical Account, however, derives it from Boile-eas-ceann -- the summit of the raging cataract. I am inclined to agree with the earlier derivation. Boleskine lies above the loch and is some way from the Falls of Foyers.
- Carn an Dubh-ghlaic. The hill of the dark hollow
- Carn an t-Suidhe. The hill of the resting place.
- Carn Bhreabag. Probably the speckled or brindled carn.
- Carn Choire Riabhaich. The hill of the brindled corrie
- Carn Dearg }
Creag Dhearg } The red hill/crag
- Carn Gairbhthinn. The rough hill.
- Carn Liath The grey hill.

- Carn Liathdoire. The hill of the grey grove
- Carn na Glaice Moire. The hill of the big hollow
- Carn na Saobhaidhe The hill of the fox's den.
- Carn Suidhe ghoiril. The resting place of (?) the goat.
- Cnoc an t-Sithein. The fairy hill.
- Cnoc Carrach The scruffy hillock.
- Conagleann The glen of the dogs.
- Cos an t-Sionnaich. The hollow of the fox.
- Creag Alasdair mhic Sheumais. The crag of Alastair, son of James.
- Creag a'Ghiubhais. The crag of the pines
- Creag an Fhithich The raven's crag.
- Creag Mhor The big crag.
- Crag nan Clag The crag of the bells.
- Creag Nighean Iain Duinn. The crag of Black Jack's daughter.
- Creag Ruadh The ruddy crag.
- Druim Teampuill. The ridge of the temple. "Druidical" circles, according to the New Statistical Account used to exist on the ridge - they were removed to clear the fields for easy cultivation.
- Dun Chia The fort off the mist
- Dun Deardail. Perhaps a fortified hill. But also said to be named after the beautiful Dearduil (Deirdre), the wife of Naois.
- Dun Garbh The rough fort
- Dunmaglass Possibly a fort near a stream
- Fuaran an Eich Bhan. The spring or fountain of the white horse.
- Garth An enclosure.
Garthbeg -- the smaller
Garthmore -- the larger -- now a ruin, whilst
Garthbeg is still inhabited.
- Glac nan Uan. The hollow of the lamb
- Gleann Liath. The grey valley. The village at the Fechlin end is usually spelled, English fashion, Glenlia.

Hills	Gaelic names form . Gaelic is remarkably rich in descriptive names for hills. The principal ones are:-
<u>Beinn</u>	a mountain. Originally Beann, a top, horn or peak.
<u>Carn</u>	Cairn. Round, rocky hill.
<u>Cnoc</u>	A round hillock, a hillocky crag.
<u>Creag</u>	a rock, a crag
<u>Druim</u>	A ridge. Usually spelled Drum
<u>Dun</u>	A fort
<u>Meall</u>	A lump, a rounded hill
<u>Monadh</u>	Hill-mountain, mountain range.
<u>Sgurr</u>	A sharp rock, a rocky peak .
<u>Tom</u>	A rounded, humpy hillock
<u>Torr</u>	A conical hill, a heap, a rocky version of tom.

Inver The mouth of a river.
eg. Inverfarigaig.

Leachd nan Cisteachan. Locally said to refer to the Moine schist outcrops on the top and to mean tombstones. I rather incline to the view that it refers to the kist-like shape of the whole mountain.

Leiterchullin. The hillside of the holly.

Lochan an Eoin Rudha. The pool of the red bird (grouse)

Lochan na Leitrich. The pool on the hillside.

Lochan nan Dealra. The loch of the leech.

Loch an Ordain. The lake of the little round hillocks

Lochan Torr an Tuill. The pool in the hollow on the crag.

Loch ~~Baan~~ (?) The loch of the raven

Loch Ce-glais The lake of the misty hollow

Loch Dun Seilcheig. The loch of the fort of the snail. Usually spelled phonetically either Duntelchaig or Duntelchaik.

Loch Knockie The lake of the hillocks

Loch Mhor The large lake (the combined Lochs Garth & Farralin

Loch nan Losganan. The lake of the frog. Usually called Loch Paddock.

Loch na Sgorthaich. The loch of the rocky crags.

Loch Ness Supposed to mean the Loch of the Cataract. But may be after Naois.

- Loch Tarff The lake of the bull
- Meall a'Bhuailt. ? the hill of the fold.
- Meall Donn The round, brown mountain
- Mealfuarvonie. Properly Meall Fuar-mhonaidh . The round hill of the cold upland.
- Meall nan Aidhean. The round hill of the hind
- Meall na Targaid The rounded hill of the target.
- Monadh Dubh Knockie. The mountain of the black rocky knolls.
- River E Perhaps from the Norse, Ey -- an island.
- Sgor(Tom)na h-Iolaire. The eagle's crag.
- Suidhe Sui-chuiman. Cummin's resting place.
- Tomnan Tarsuim. The little transverse hillock. This hillock is transverse to the direction of the neighbouring crags on the ridge between Gleann Liath and Loch Ness.
- Tom a'Mhoid The hillock of the mod or assembly
- Tom na Croich. Gallows hill
- Torr an t-Sagairt. The priest's hill.
- Torr Dhonnachaidh Donald's crag.
- Torr Paiteag The rocky hump.

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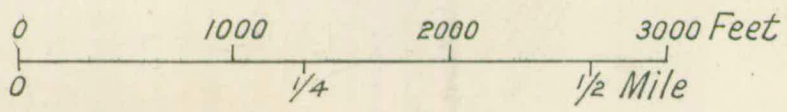
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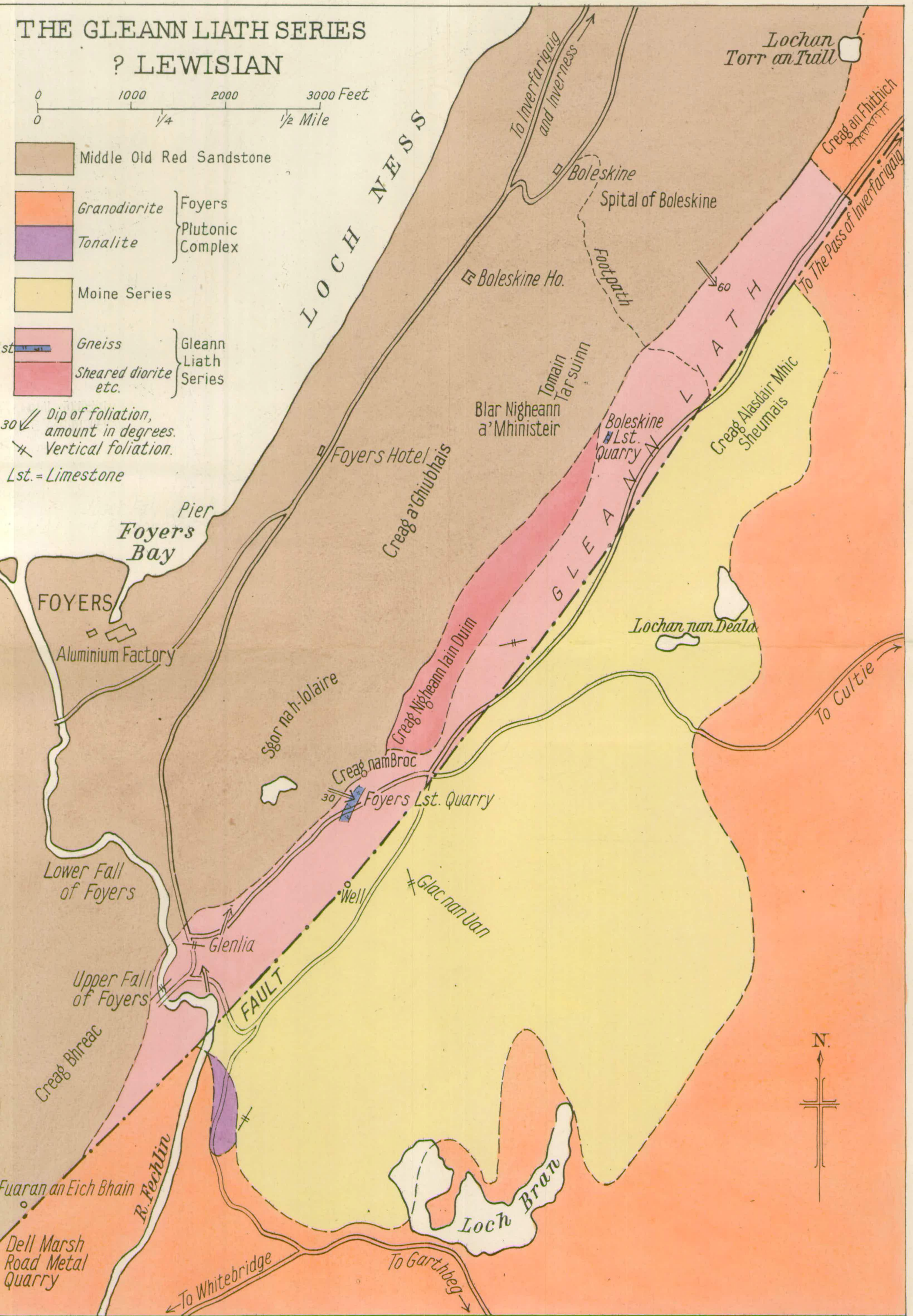
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THE GLEANN LIATH SERIES ? LEWISIAN



- Middle Old Red Sandstone
 - Granodiorite
 - Tonalite
 - Moine Series
 - Gneiss
 - Sheared diorite etc.
- } Foyers
 } Plutonic Complex
 } Gleann Liath Series

30 ↘ Dip of foliation, amount in degrees.
 ✕ Vertical foliation.
 Lst. = Limestone



THE MORVERN-STRONTIAN

PLUTONIC COMPLEX

ENLARGED FROM BRITISH REGIONAL GEOLOGY
"THE NORTHERN HIGHLANDS" page 68

SCALE: ONE INCH = ONE MILE



Red	Biotite - Granite
Purple	Granodiorite - Porphyry
Blue	Granodiorite
Green	Tonalite
Grey	Appinite
White	Moine schists

Inclined } Foliation of schists
Vertical }
----- Faults



BIOTITE - GRANITE
AND GRANODIORITE
LOCH LINNHE

GREAT GLEN FAULT ZONE

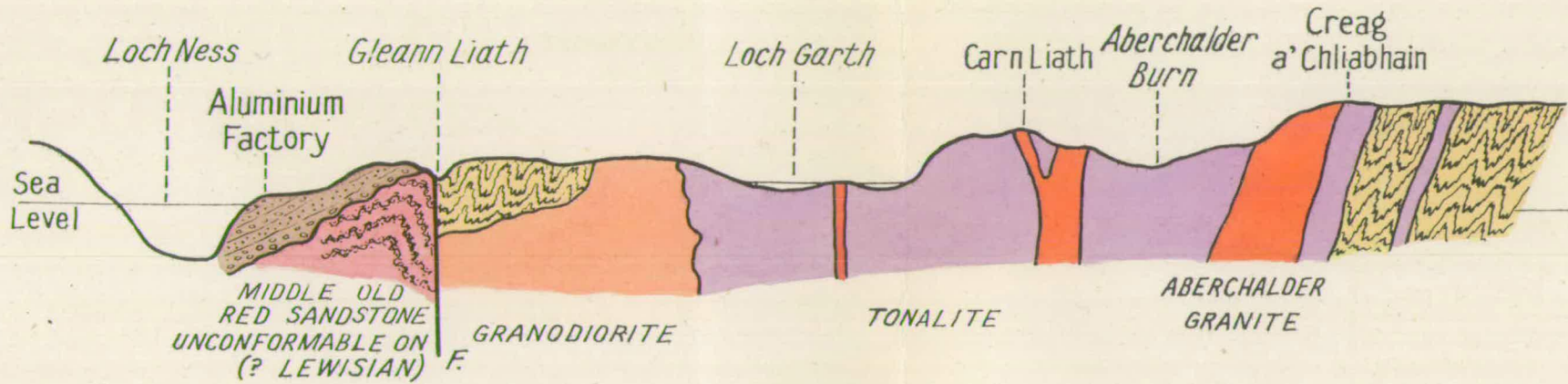
TERTIARY BASALTS
AND OLDER SEDIMENTS

Rudha an Ridine

N.W.

S.E. | S.W.

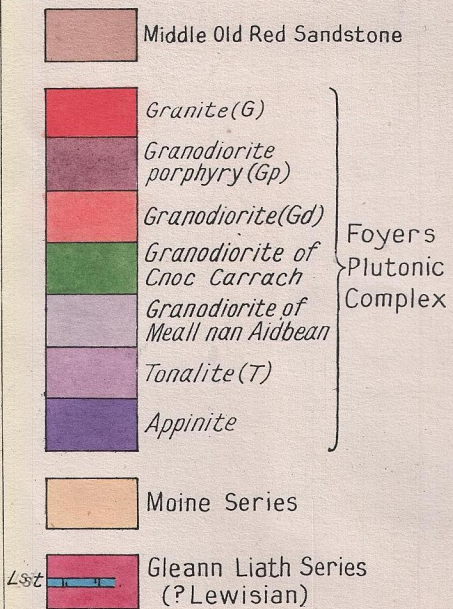
N.E.



Horizontal Scale
0 1 2 Miles
(Vertical Scale = twice the horizontal)

THE GEOLOGY OF THE FOYERS PLUTONIC COMPLEX AND THE SURROUNDING COUNTRY

0 1/2 1 2 3 4 Miles



Foyers Plutonic Complex

