Chapter 2 Lewisian Complex of Coll

Introduction

Coll is made up of highly crystalline metamorphic rocks cut by much later minor intrusions that have escaped metamorphism. The metamorphic rocks have always been grouped by geologists as a southern continuation of a prevalently gneissose complex, which constitutes practically the whole of the Outer Hebrides and much of the North-West Highlands. To this complex the name Lewisian is now commonly given. The correlation of the Coll complex with the Lewisian is based partly upon the nature of the rocks and partly upon their geographical position, and is not likely to be questioned. The following features may be cited as characteristic of Coll and also of the type regions, farther north:

1. The great bulk of the complex is thoroughly crystalline and metamorphic.
2. A large proportion consists of metamorphosed calc-alkali igneous rocks, basic, intermediate, and acid. In Coll, all these compositions are well represented, with a predominance of hornblende-biotite-gneiss, a type of frequent occurrence elsewhere.
3. Metamorphosed sediments can be locally distinguished. In Coll these include magnesian-marbles; in Tiree, immediately to the west, there are not only magnesian-marbles, but also graphite-rich schists. These two types of sediment are found in association again in Harris in the Outer Hebrides, and at Loch Maree in the North-West Highlands.
4. There are many examples of so-called flinty crush-rock in Coll, Tiree, the Outer Hebrides, and the neighbourhood of Loch Maree.

The Lewisian Complex in the North-West Highlands is often unconformably overlain by a group of sediments, named Torridonian. and this, again unconformably, by fossiliferous basal Cambrian, The Torridonian unconformity is particularly impressive and, as a detail, it may be added that it is of later date than the many zones and veins of flinty crush-rock which have been recognized in the Loch Maree district. On this account the analogous flinty crush-rocks of Coll are classed in the present chapter as part of the Lewisian Complex.

Major interbanding of ortho- and para-gneisses

The igneous and sedimentary rocks in the Lewisian of Coll are, in spite of their metamorphism, sufficiently distinct to allow of their being separately mapped. As a result it has been found that they are interbanded with one another on a large scale, and, moreover, that the bands are isoclinally interfolded. The following major bands or zones have been distinguished:

1. Western Zone of grey orthogneiss: in two detached outcrops west and east of Feall Bay.
2. Feall Bay Zone of paragneiss: in two semi-detached outcrops at Feall Bay and Hogh Bay.
3. Ben Hogh Zone of pinkish granite or granodiorite-orthogneiss.
4. Gorton Zone of paragneiss.
5. Eastern or Arinagour Zone of grey orthogneiss.

It is conceivable that this succession of zones may have resulted in part by duplication due to folding: that the Ben Hogh granite-gneiss (3) may be in the core of an isoclinal fold, and that the flanking Zones 2 and 1 may be fold-repetitions of 4 and 5. The lithological resemblances of the two flanking series of zones is sufficiently close to allow of this suggestion. For instance, it is practically certain that the paragneiss zones (2 and 4) belong to a single stratigraphical system. On the other hand, Zone 2 is very much thicker than Zone 4, and it therefore appears probable that Zones 2 and 4 are not fold-repetitions but that they have been separated from one another by the intrusion of the Ben Hogh granite-gneiss (3).

However we regard this particular case, it remains practically certain that Coll furnishes instances of two kinds of interbanding, the one due to intrusion and the other to subsequent interfolding. As an example of interbanding by intrusion let us consider the Feall Bay paragneiss (2). This paragneiss separates, in its Hogh Bay outcrop, two easily distinguished zones of orthogneiss, (1) the Western zone of predominantly grey banded hornblende-biotite-gneiss and (2) the pinkish Ben Hogh granite-gneiss; and at each junction there appear to be intrusive contacts. As an example of interbanding by isoclinal folding we may take that portion of the Western outcrop of the grey orthogneiss of Zone 1 which separates the paragneiss outcrops of Feall Bay and Hogh Bay from one another, though both belong to Zone 2. The inclination of the banding of the rocks is steep and isoclinal, roughly speaking, towards the east. Followed to the south coast the orthogneiss outcrop narrows down to nothing and allows the bordering paragneisses to come together. This may be ascribed to folding because a well-marked band of dark orthogneiss, which locally occurs at the junction of the grey orthogneiss and the paragneiss, continues in this position round the end of the grey orthogneiss outcrop.

Somewhat similar to the last-mentioned case, but not so pronounced in its development, is the fold-deflection of the Feall Bay outcrop of paragneiss westwards into Gunna. Here one sees clearly that the course taken by the outcrops is parallel with that of the banding, alike in the igneous and the sedimentary rocks.

A concealed fold-termination is indicated by a dotted line in (Figure 1), north of Feall Bay. This is inserted because, where folding takes paragneiss from Loch Breachacha by Caolas Soa and Eilean Tumala to Crossapol Bay, it leaves the Ben Hogh granite-gneiss out at sea somewhere west of Soa. Accordingly the two outcrops of grey orthogneiss that flank the paragneiss between Crossapol Bay and Feall Bay belong to folded repetitions of a single zone; and, unless there is a change of pitch, their outcrops will unite north of Feall Bay.

Two bands of igneous material, intercalated among the paragneiss that outcrops between Hogh Bay and Loch Breachacha, are almost as broad as the Gorton zone of paragneiss which has been included in our enumeration of the major zones of the Coll succession. One of these intercalations consists of dark orthogneiss traceable for a mile southwards from Hogh Bay, and the other of grey orthogneiss which has been followed for two miles northwards from Loch Breachacha. The outcrop of the dark gneiss is· nearly 200 yards broad, and that of the grey gneiss is about zoo yards. In both cases exposures are too discontinuous to decide if the bands continue along their strike right across the island. Other examples of interbanding of igneous and sedimentary material will be noted in the sequel. Still, the zones classed as igneous include only an exceedingly small proportion of recognizable sedimentary material and *vice versa.*

It may be added that there is nothing at the junction of the sedimentary and igneous rocks of the Coll Lewisian to correspond with what is commonly called contact alteration. The metamorphic sediments are either gneisses or schists, not hornfelses.

There is another aspect of the structure of Coll to which a few words may be devoted. The succession of zones from the Western grey orthogneiss (r) to the Eastern or Arinagour grey orthogneiss (5) is structurally an ascending sequence, although this relation may have only a very limited and local significance. The Western orthogneiss Zone r protrudes as two outcrops southwards into the outcrop of the Feall Bay paragneiss (2). The more westerly of these protrusions extends westwards from Crossapol Bay into Gunna. It is of anticlinal form as shown by the dip of the orthogneiss banding, so that Zone 1 structurally underlies Zone 2 in this particular locality. Unfortunately, in the eastern outcrop of Zone 1 between Crossapol Bay and Hogh Bay, the banding-dips are so constantly in one direction as to furnish no information regarding the order of superposition. From the Hogh Bay outcrop of Zone 2, north-eastwards to the end of Coll, banding-dips are directed to some point of the compass between north-east and south-east, and accordingly Zones 2, 3, 4, and 5 follow one another in ascending sequence in this direction. Additional weight attaches to this observation because the banding-dips in the Eastern or Arinagour grey orthogneiss zone (5) are often at quite moderate angles, even under 20°. Moreover, the banding south of Cliad Bay is thrown into a well-defined syncline pitching north-eastwards.

Petrology

Orthogneisses

Pinkish granite-gneiss

The Ben Hogh granite-gneiss, Zone 3, furnishes the only important example of its kind in Coll. Other minor occurrences will be mentioned at the end of this account.

The analysed specimen (Anal. I, (S23020) [NM 1701 5810] is fresh and is a good representative of much of the Ben Hogh zone, though a little more basic than the average. In the hand-specimen this can be seen to consist mainly of colourless quartz and felspar, streaked with dark biotite and hornblende; while a very occasional pink orthoclase appears like a relatively undeformed phenocryst. The microscope shows that the main minerals are oligoclase and quartz, aggregated for the most part in allotriomorphic crystals measuring about z mm. across; subordinate minerals are orthoclase, biotite, and hornblende; accessories are iron-ore, including pyrites, and apatite. The biotite is pleochroic from light to dark brown, and the hornblende from green to brownish-green. The orthoclase occurs as irregularly bounded patches and has partly passed over to microcline.

(Table 1)

	I	A	II	III	B	IV	C	V	D	E	VI
	Igneous	Igneous	Igneous	Sedimentary	Igneous	Sedimentary	Igneous	Sedimentary	Sedimentary	Sedimentary	Sedimentary
Metamorphic or Non-metamorphic	Met.	Non Met.	Met.	Met.	Non Met.	Met.	Non Met.	Met.	Non Met.	Non Met.	Met.
SiO_2	68.97	67.00	66.19	81.89	79.19	76.15	63.03	64.23	67.92	59.96	18.29
Al_2O_3	14.66	15.19	15.58	9.10	9.88	5.55	1772	15.87	12.89	16.52	2.77
Fe_2O_3	1.36	1.98	1.38	0.17	0.21	0.87	2.27	0.03	3.73	2.37	1.11
FeO	1.92	2.17	2.90	0.16	0.63	0.82	1.92	3.84	2.42	3.20	nt. fd.
MgO	1.88	1.76	2.11	0.02	0.55	6.48	3.63	3.32	2.69	2..47	15.52
CaO	4.28	3.55	4.20	0.64	0.00	678	5.97	5.06	3.84	5.32	31.44
Na_2O	4.18	3.88	3.64	0.11	0.66	0.49	3.92	2.86	1.82	5.00	0.05
K_2O	1.42	2.99	2.18	7.11	7.68	0.66	1.06	1.68	1.59	2.82	0.78
H_2O+105° C	0.47	077	0.63	0.21	0.54	0.46	—	0.84	0.89	1.27	4.01
H_2O –105° C	0.03	—	0.04	0.03	0.03	0.08	0.44	0.05	0.17	0.15	0.51
TiO_2	0.38	0.51	0.54	0.06	0.00	0.12	—	0.67	0.82	0.59	0.09
P_2O_5	0.13	0.13	0.13	0.07	0.00	0.45	—	0.13	0.06	0.24	0.22
MnO	0.38	0.07	0.37	0.26	0.00	0.30	—	0.42	0.10	0.09	0.42
CO	0.13	–	0.39	0.28	0.64	0.95	—	0.10	1.28	trace	24.84
FeS_2	nt. H.	–	nt. fd.	nt. fd.	–	nt. fd.	—	0.88	—	—	nt. fd.
S	—	—	—	—	—	—	—	–	0.05	0.00	—
Cr_2O	—	—	—	—	—	—	—	trace	0.00	—	—
(Co, Ni)O	nt. fd.	—	nt. fd.	nt. fd.	—	0.03	—	nt. fd.	—	—	nt. fd.
BaO	nt. fd.	—	nt. fd.	0.03	—	nt. fd.	—	0.04	—	—	nt. fd.
Li_2O	nt. fd.	—	nt. fd.	trace	—	trace	—	trace	—	—	trace
Cl	—	—	—	—	—	0·03	—	—	—	—	—
	100.19	100.00	100.28	100·14	100·01	100.22	99·96	100.02	100.27	100.00	100.05

nt. fd. = not found.

I. ((S23020) [NM 1701 5810]; Lab. No. 813.) Acid hornblende-biotite-gneiss (acid granodiorite-gneiss), representative of the granite-gneiss ' of Ben Hogh (Lewisian). Shore cliffs, 375 yds. W. 11° N. of Ballyhaugh farm, Coll. Anal. E. G. Radley.

A. Mean of 17 analyses of various types of quartz-diorites of which 5 have been called granodiorite in original descriptions. From A. Osann (H. Rosenbusch), Elemente der Gesteinslehre, 1923, p. 188.

II. ((S23019) [NM 1846 5980]; Lab. No. 811.) Hornblende-biotite-gneiss (granodiorite-gneiss), representative of the more acid of the 'grey orthogneisses' of Coll (Lewisian). Shore cliffs, 1155 yds. N. 25° E. of Clabhach Church, Coll. Anal. E. G. Radley.

III. ((S23026) [NM 1461 5523]; Lab. No. 815.) Quartz-orthoclase (microcline)-granulite with a little muscovite (metamorphosed arkose) from Ben Feall outcrop (Lewisian). Shore cliffs, 358 yds. N. 10° E. of Trigonometrical Station, Ben Feall, Coll. Anal. E. G. Radley.

B. Felsite porphyry, Bahia Rodriguez, Patagonia. Anal. M. Dittrich. Quoted from P. Quensel, Bull. Geol. Inst. Upsala, vol. xii., 1914, p. 28.

IV. ((S23025) [NM 1794 5915]; Lab. No. 812.) Quartz-(pale) amphibole-scapolite-rock with accessory apatite (metamorphosed dolomitic sandstone) from Clabhach outcrop (Lewisian). W. side of small bay, 280 yds. N. 33° W. of Clabhach Church, Coll. Anal. E. G. Radley.

C. Hypersthene-andesite, Mount Shasta, California. Anal. W. H. Melville. Quoted from J. S. Diller, U.S. Geol. Surv. Bull., 150, 1898, p. 228.

V. ((S23027) [NM 1616 5716]; Lab. No. 814.) Biotite-hornblende-andesine-quartz-granulite with an unusual proportion of hornblende (metamorphosed impure sandstone) from Hogh Bay outcrop (Lewisian). Shore cliffs, 1100 yds. N. 33° W. of Totronald, Coll. Anal. E. G. Radley.

D. Green sandstone of Old Red Sandstone (Devonian). Polletind, Norway. Anal. A. Vindenes. Quoted from C. F. Kolderup, Bergens Museums Aarbok, 1924–5 (1925), p. 33.

E. Green sandstone of Old Red Sandstone (Devonian). Bleien, Norway. Anal. A. Vindenes. Quoted from C. F. Kolderup, Bergens Museums Aarbok, 1924–5 (1925), p. 33.

VI. (S23028) [NM 1674 5425]; Lab. No. 816. Forsterite (serpentinized)-phlogopite-marble (metamorphosed impure dolomitic limestone) from Clabhach–Gorton outcrop (Lewisian). N.E. of garden, inside roadside fence, 333 yds. S. 37° W. of Uig, Coll. Anal. E. G. Radley.

The structure of the gneiss is such as could easily be developed by squeezing a well-crystallized granite under conditions that allowed of plastic flow. The ferromagnesian minerals are streaked out into lamina, but these are very impersistent and do not give rise to bands.

Analysis I agrees closely with Analysis A given by Osann as the mean of 17 analyses of quartz-diorite types, including 5 that were classed as granodiorites in the original descriptions. General usage seems to favour a silica percentage of about 69 as separating granodiorites from granites.<ref>V. A. Eyles and J. B. Simpson, Silica Percentages of Igneous Rocks, *Geol. Mag.,* 1921, p. 438; *see also* E. B. Bailey in The Geology of Ben Nevis and Glen Coe, *Mem. Geol. Surv.,* 1916, pp. 153, 159.</ref> According to this criterion the analysed specimen is a granodiorite, and this agrees well with its content of 428 per cent of CaO and only 1.42 per cent of K_2O.

Other slices from the Ben Hogh Zone (S21303) [NM 1791 5921], (S21305) [NM 1711 5773], (S21308) [NM 1716 5768], (S23285) [NM 1647 5297] differ from the analysed material in showing no hornblende; while the corresponding hand-specimens are in some cases definitely pink, rather than grey with pink crystals. In (S21303) [NM 1791 5921] there is a somewhat pronounced though subangular idiomorphism of the oligoclase; and in (S21305) [NM 1711 5773], (S21308) [NM 1716 5768] the potash-felspar occurs in perthitic intergrowth with oligoclase.

Away from the Ben Hogh Zone, pink granite-gneiss occurs only in a subordinate and often ill-defined fashion, which does not allow it to be shown on the published one-inch Map. A good example of potash-rich granite-gneiss runs as a narrow strip along the coast for half a mile north-east of Eilean nam Muc, east of Arinagour (S22140) [NM 2495 5834]. Though foliated it is associated at one place with an unf oliated syenite-like rock rich in stumpy green hornblende, microcline, and quartz, with secondary epidote and albite — probably something in the nature of a pegmatite (S22142) [NM 2495 5834].

The pink or pinkish orthogneisses here described 'owe their colour to the presence of a fair proportion of potash-felspar. They must not be confounded with altered varieties of the normally grey orthogneisses, in which albitized plagioclase felspar often assumes a pink colour. The distinction between the more acid and the more basic gneisses in such cases is generally apparent, even in the field, because of different concentrations of ferromagnesian constituents.

Grey Orthogneiss

Mostof the rocks of Coll are classed as grey hornblende-biotite-orthogneiss, of more basic composition than the Ben Hogh granite-gneiss. Extensive slicing of material from comparable grey orthogneiss in Tiree has revealed the frequent occurrence of pyroxenic varieties, so it is probable that such rocks may also occur in Coll.

A feature of the grey orthogneisses is the prevalence of banding. This makes it difficult to secure a representative analysis. The material analysed (Anal. II, (S23019) [NM 1846 5980] is a good fresh sample of one of the more acid varieties. It shows a well-marked banding with quartzo-felspathic layers, one or two centimetres thick, alternating with others which, while containing quartz and felspar, are dark with biotite and hornblende. The biotite occurs in flakes up to 2 mm. broad and is orientated approximately parallel to the banding. Under the microscope the quartzo-felspathic grains generally measure between 1and 3 mm. across. Quartz, oligoclase, and orthoclase, passing to microcline, are all well represented with general allotriomorphic outlines. Strongly pleochroic brown biotite flakes bulk more largely than brownish-green hornblende in stumpy crystals. Pyrites and apatite are accessory. The analysis (II) is very close to that of the Ben Hogh granite-gneiss (I), but with lower silica. Some of the extra potash goes, with increased iron and alumina, into biotite.

As compared with other slices of grey orthogneiss from Coll, the analysed material is unusually rich in potash-felspar, for often this mineral is practically absent. The biotite of the analysed rock is more abundant than the hornblende. This feature is quite Common, for it reappears in many slices (S21293) [NM 2095 5860], (S21365) [NM 1624 5331], (S21391) [NM 1264 5221], (S21392) [NM 1264 5211], (S21393) [NM 1265 5200], (S21403) [NM 1044 5125], (S21404) [NM 1564 5659], (S23286) [NM 1573 5694], (S23288) [NM 1576 5697], (S23289) [NM 1815 5923], (S23470) [NM 1544 5518], (S23472) [NM 1062 5185], (S23473) [NM 1094 5169]. Slices with hornblende more abundant than biotite are (S21294) [NM 1811 5913], (S21352) [NM 1772 5338], (S21402) [NM 1040 5113], (S21420) [NM 2400 5671], (S21421) [NM 2258 5612], (S23467) [NM 1502 5516]. One mineral sometimes occurs to the exclusion of the other, but, as a rule, an association of biotite with hornblende is characteristic of the grey orthogneisses. Myrmekitic intergrowth of oligoclase and quartz was noted in one slice only (S21294) [NM 1811 5913].

In addition to a parallel structure, such as may be ascribed to plastic flow of a crystallized dioritic rock (S21421) [NM 2258 5612], there is a very prevalent banding of lighter and darker constituents. Without attempting a full discussion of this banding, it may be pointed out that it is much more prevalent than is flow-banding in ordinary non-metamorphic igneous rocks, and that it can in special cases be traced to the deformation and partial assimilation of xenoliths.

Hornblendic layers in the grey orthogneiss, even where only a foot or two in thickness, may be traced continuously for several yards. These dark layers may be simple or complex, for some consist entirely of slightly banded hornblendic material, while others are freely veined by coarse hornblendic pegmatite. Where veining is the rule it frequently produces intrusion-breccias with hornblendic blocks enveloped in pegmatite, and these blocks as shown by their internal banding have sometimes been markedly deorientated.

Before leaving the subject of the grey orthogneisses, mention may be made of certain deceptive appearances due to alteration. In (S21369) [NM 1498 5520] hornblende is replaced by calcite and chlorite, so that the rock weathers cariously like a ribbed impure limestone. In (S23472) [NM 1062 5185] albitization has given rise to a pink colouration.

Dark orthogneiss

Therocks here classed as dark orthogneiss are of types commonly spoken of as amphibolite and pyroxenegranulite. They are typically composed of about equal proportions of felspar (oligoclase or andesine) and ferromagnesian minerals. The commonest among the latter is brownish-green hornblende (S21368) [NM 1554 5254], (S21401) [NM 0950 5135], (S22141) [NM 2525 5890], sometimes in association with augite (S23287) [NM 1650 5716]. In two slices the predominant ferromagnesian mineral is augite, accompanied by abundant iron-ore (S21374) [NM 1470 5522], (S23469) [NM 1470 5518]. Common accessory minerals are quartz and apatite. Garnet has been noted in various occurrences in the field. It has a sporadic tendency, and is present only in one slice (S21368) [NM 1554 5254]. The hornblende is stumpy and generally under 3 mm. long. The other minerals are rather shorter.

In many quite considerable outcrops these gneisses are very little banded. An augitic rock in the hand-specimen may closely resemble a fine gabbro (S21374) [NM 1470 5522], but hornblendic varieties usually glisten very definitely when broken along their foliation planes.

Sir Jethro Teall<ref>J. J. H. Teall, The Metamorphosis of Dolerite into Hornblende-schist, *Quart. Journ. Geol. Soc., vol. xli.,* 1885, p. 133; *also* Dynamic Metamorphism, *Proc. Geol. Assoc., vol. xxix.,* 1918, p. i.</ref> and other workers have shown that the types here considered result from metamorphosis of basic igneous rocks. This conclusion may be the more readily accepted because a gabbroic composition is indicated (r) by the mineral proportions of the augitic varieties, and (2) by chemical analysis in the case of a typical hornblendic variety selected from Tiree. Comparison of Coll and Tiree slices shows that the augite and iron-ore of the one type must be represented by the hornblende of the other. The hornblende has probably also received material from felspars, rejecting at the same time a certain amount of silica as quartz. Olivine is absent, as is always the case in metamorphic basic igneous rocks that retain felspar. Apparently olivine and felspar under conditions of regional metamorphism tend to react, and to yield either hornblende or garnet.

The material sliced may be grouped according to its field relations as follows:

1. Major bands shown on one-inch Map: Gunna (S21401) [NM 0950 5135]; east of Ben Feall (S21374) [NM 1470 5522], (S23469) [NM 1470 5518]; west of Loch Breachacha (S21368) [NM 1554 5254]; Hogh Bay (S23287) [NM 1650 5716].
2. Minor bands not separately shown on one-inch Map: (S22141) [NM 2525 5890], (S22153) [NM 2377 5642], (S23018) [NM 1818 5937].

The last-mentioned slice (S23018) [NM 1818 5937] comes from a thin band in grey orthogneiss. It is a hornblende-felspar rock quite unusually rich in a hornblende that is of a pale blue-green instead of the usual brownish-green colour.

Felspar free rocks

Felspar-freerocks, associated with the Coll orthogneisses, are only represented by two slices. The first (S21394) [NM 1265 5214] is from a lenticle enclosed in a grey orthogneiss tongue invading paragneiss on the west shore of Crossapol Bay. It consists of pale blue-green hornblende and subordinate hypersthene, the latter furnishing a framework of very complicated character. The second slice (S22152) [NM 2356 5632] is from a 3-ft. band in grey orthogneiss on the east shore of Loch Eatharna, near the entrance of the loch. Its main constituent is strongly pleochroic brownish-green hornblende, but there is also abundant biotite with pleochroism from yellowish to almost black. The Crossapol lenticle has probably resulted from the alteration of an olivine-rich basalt. The considerable potash of the Loch Eatharna rock suggests a possible derivation from lamprophyric material or from dolomitic shale.

Calcified orthogneisses

Three peculiar specimens taken from areas of somewhat calcareous sediment may represent products of interaction between this latter and grey orthogneiss. One (S21318) [NM 1640 5712] comes from a little west of the Hogh Bay dark orthogneiss, the others (S21395) [NM 0925 5096], (S21396) [NM 0920 5107] from a couple of bands at the west end of Gunna. They differ from the normal metamorphosed calcareous sediments of Coll in having aegirine-augite as their main ferromagnesian constituent, and sphene as a conspicuous accessory.

In Tiree this combination is very characteristic of certain reaction products between dark orthogneiss and the. Pink Marble, and can be shown to be dependent upon the association of iron and titanium, so characteristic of igneous rocks. Quartz and potash-felspar are present in all three slices, calcic scapolite in (S21318) [NM 1640 5712], (S21396) [NM 0920 5107], oligoclase in (S21395) [NM 0925 5096], (S21396) [NM 0920 5107], and calcite or carbonate in (S21318) [NM 1640 5712], (S21395) [NM 0925 5096]. In several cases the carbonate is rimmed by 'cauliflower' growths of green augite or pale-green diopside which spread out into adjoining felspars and scapolite (p. 24).

A specimen (S21398) [NM 1034 5105] from the dark orthogneiss outcrop mapped with associated marble (S21399) [NM 1040 5113] on the south shore of Gunria consists of green diopsidic augite and calcic scapolite, along with abundant accessory sphene. The colour of the augite is intermediate between that of the aegirine-augite of the last specimens and the diopside commonly met with in the calcareous sediments. The rock exactly reproduces the characters of some of the reaction products between dark orthogneiss and the Pink Marble of Tiree.

Pegmatites

Thereare many irregular highly felspathic intrusions in Coll to which the name pegmatite may be applied, although graphic structure is absent or very subordinate. These pegmatites show little or no foliation and generally measure only a few feet or yards across. They may be quite unorientated, or they may run in lenticular fashion along the banding of their host. The nature of these pegmatites varies fairly consistently according to the nature of their associates. In the grey orthogneiss the main minerals are oligoclase, potash-felspar, and quartz, with subordinate biotite. The crystallization is coarse and the colour may be white or pink. In the pegmatites of the dark orthogneisses large idiomorphic crystals of dark hornblende are frequently met with, and sometimes garnet is present. With the micaceous paragneisses west of Hogh Bay a distinctive compact white pegmatite is common. Among the paragneisses on the west shore of Loch Breachacha there are cross-cutting bands of quartzo-felspathic rock, which carry subordinate biotite and garnet, and exactly resemble some of the apparently bedded quartzo-felspathic material of neighbouring exposures. Similarly, white garnetiferous pegmatites are a feature of the paragneiss outcrops west of Feall Bay and at the west end of Gunna. It therefore seems certain that the various country rocks have contributed a considerable proportion of the substance of the pegmatitic intrusions.

Supposed quartz vein of Clabhach–Gorton Paragneiss Zone

On the shore of Clabhach Bay, and at intervals across the island along the course of the Gorton sedimentary zone, there are exposures of an extremely pure translucent quartz-rock that has a. somewhat frosted appearance on fracture. Quite possibly the outcrop of this rock is continuous under the cover of superficial deposits. At Clabhach the band is only 15 ft. broad, but at the roadside at Acha it measures 200 ft. Under the microscope there is seen a minute stress-granulitization of what must at one time have been very large individual crystals (S21296) [NM 1801 5911], (S26296) [NM 1801 5911]. There are numerous little needles, possibly rutile; and in hand-specimens pink felspar crystals are occasionally seen. The rock is shown on the one-inch Map as a quartz vein, but it is possibly a metamorphosed sandstone of exceptional purity. If the latter alternative were proved it would add greatly to the interest of the Gorton sedimentary zone, for it would show that its course is parallel to original bedding.

Paragneisses

The metamorphosed sediments of Coll show a variety of types, including highly quartzose granulites, magnesian marbles, biotite-granulites, and many interesting intermediate varieties. Thoroughly aluminous material is unrepresented, as is shown by the extreme rarity of muscovite, the very moderate development of garnet, and the apparent absence of sillimanite or kyanite. The biotite-granulites of Coll seem to have originated from very impure sandstone rather than shale. In Tiree metamorphosed shale occurs, and is often richly garnetiferous, but, even so, it is abnormal owing to absence of muscovite.

The main minerals of the Coll sediments are quartz, felspars (never more basic than andesine), biotite (including phlogopite), pyroxenes (including diopside and hypersthene), amphiboles (typically pale-green), pink garnets, carbonates, forsterite (pseudomorphed), and calcic scapolite. Apatite and pyrites are the commonest accessories.

In the short descriptions that follow, very little attention can be paid to secondary changes. A general note is therefore given here on the common occurrence of prehnite in the paragneisses of Coll. In a very few slices, mentioned again in the sequel, prehnite builds considerable crystals or groups of crystals, probably in part replacing felspar and in part of independent formation. Prehnite with this habit occurs in a quartzo-calcareous sedimentary rock (S21299) [NM 1794 5915] in the Clabhach Bay outcrop, and also in specimens (S21306) [NM 1711 5773], (S21310) [NM 1716 5768] representing xenoliths or xenolithic material picked up by the Ben Hogh granite-gneiss. In two of these slices (S21299) [NM 1794 5915], (S21306) [NM 1711 5773] the prehnite has another mode of occurrence, for it figures prominently in pseudomorphs after biotite, and it is in this fashion that most of the prehnite of Coll occurs. Typically it grows as a lenticle prising open the cleavage of the biotite, which may remain fresh but often passes to chlorite. The basal cleavage of the prehnite generally runs parallel with that of the biotite, but there is a strong tendency for the prehnite to form divergent growths. Good examples of prehnite wedging open biotite are afforded by (S21317) [NM 1640 5712], (S21323) [NM 1613 5704], (S23284) [NM 1646 5302], (S21387) [NM 1282 5304], (S26298) [NM 1794 5915], (S26300) [NM 1794 5915]. In (S21355) [NM 1769 5339], (S21361) [NM 1648 5325] both prehnite and yellow epidote occur with similar habit and sometimes in actual association. There seems little doubt that prehnite is much more often developed in the calcareous sedimentary rocks of Coll than in the orthogneisses. Its formation probably dates from the Lewisian period and is unconnected with subsequent weathering.

Quartz-granulites

Quartz-granulite, or quartzite, is developed on a very big scale in Ben Feall on the east side of Feall Bay. The outcrop is a quarter of a mile broad and the dip of the banding is eastwards at angles of about 45°. This banding is more regular than that of the grey orthogneisses, and may with confidence be considered as bedding, since the rocks in which it occurs are of sedimentary composition. There are variations of composition within the Ben Feall mass: most of it is somewhat felspathic, calcareous, and micaceous, while intercalated bands represent what were once calcareous or, more precisely, dolomitic shales. There is no better exposure for realizing, almost at a glance, that sediments enter largely into the Lewisian Complex.

Another exposure of quartzose granulite occurs in Hogh Bay immediately west of the mapped dark orthogneiss. In this case the outcrop is only 70 yds. broad, and has so pronounced a calcareous tendency that little of it is as quartzitic as the main mass of Ben Feall. Elsewhere in the disconnected exposures of Coll sedimentary types there are many bands of highly quartzose rock, but they are of small bulk.

The most quartzose types are represented by slices from Ben Feall (S21376) [NM 1435 5450], (S23291) [NM 1461 5523], from Hogh Bay (S21315) [NM 1640 5712], and from Clabhach Bay (S23290) [NM 1794 5915], (S26299) [NM 1794 5915]. Quartz is predominant, making more than half the material. Potash-felspar is a frequent associate, but plagioclase felspar is rare. Calcareous minerals, calcite, tremolite, or calcic scapolite (S23290) [NM 1794 5915], (S26299) [NM 1794 5915], are generally found. Muscovite and chloritized biotite are also common. The quartz usually occurs in exceedingly irregular grains measuring two or three millimetres across. In the scapolite-bearing slices the texture is coarser. Here somewhat rounded prisms of scapolite, up to 3 mm. long, and stout flakes of mica, generally of smaller size, lie in and among irregular quartz grains that may reach 15 mm. in length. The scapolite is sometimes very irregularly intergrown with oligoclase. In (S23290) [NM 1794 5915] most of the mica is pale biotite; in (S26299) [NM 1794 5915] it is muscovite. Other examples of scapolite-bearing rocks from Clabhach Bay, including analysed material, will be described presently under the heading quartzo-calcareous rocks.

Quartz-felspar-granulites

Quartzose types rich in potash-felspar are represented by analysed material from the Ben Feall outcrop (Anal. III; (S23026) [NM 1461 5523]. In the hand the rock looks like a medium-grained, non-metamorphic sandstone of very pale pinkish tint. Under the microscope it appears as an equiproportioned mosaic of quartz and potash-felspar, in allotriomorphic grains generally measuring less than I mm. Much of the felspar shows microcline-twinning. Muscovite is an accessory, and one flake, moulded on other constituents, is 1 mm. long. The analysis agrees with the microscopic appearance. There is enough potash to combine with a third of the silica as potash-felspar, and this would account for almost all the alumina. Such a composition can easily be matched amongst arkoses. It can also be paralleled amongst igneous rocks, as is evident from Anal. B; but igneous rocks with more than 80 per cent. of SiO_2 (alaskites and ultra-acid porphyries) are rare and are generally of vein or dyke habit. The Coll specimen with its more quartzose and quartzo-calcareous associates is part of a great mass of bedded aspect, and may unhesitatingly be interpreted as of sedimentary origin. Specimens still richer in potash-felspar come from bands on the west of Crossapol Bay (S21388) [NM 1280 5304], (S21389) [NM 1262 5190]. Plagioclase is present as perthitic intergrowths, or as independent crystals (oligoclase). Highly pleochroic biotite, and garnet, reddish-brown in the hand-specimen, are characteristic accessories. The oligoclase sometimes shows myrmekitic intergrowth with quartz (S21388) [NM 1280 5304]. It is doubtful whether such rocks can be distinguished lithologically from cross-cutting pegmatites in neighbouring exposures.

Quartzo-calcareous rocks

The analysed specimen (Anal. IV, (S23025) [NM 1794 5915] from Clabhach Bay is shown by its composition to be a metamorphosed dolomitic sandstone. In the hand-specimen it looks like a rather fine-grained pale diorite. Under the microscope it is seen to be about half composed of quartz, while the remainder consists of pale-green amphibole and lime-scapolite, with accessory apatite. Individual crystals may be 3 mm. long, and the structure is markedly parallel but not banded.

Similar rocks can easily be collected at Clabhach Bay (S21297) [NM 1794 5915], (S26295) [NM 1794 5915], (S26297) [NM 1794 5915], (S26298) [NM 1794 5915], (S26300) [NM 1794 5915]. The main individual differences are due to presence or absence of diopside and biotite, and there is also doubt as to the interpretation of certain sericitic pseudomorphs, some of which may represent scapolite and others plagioclase felspar. Fresh lime-scapolite is well shown in (S26298) [NM 1794 5915].

Quartzo-calcareous rocks from a little west of the Hogh Bay dark orthogneiss are represented by two slices. In one (S21316) [NM 1640 5712] the main minerals are quartz and biotite with sericitic pseudomorphs almost certainly after scapolite; pale bluish-green hornblende also occurs. In the other (S21317) [NM 1640 5712] quartz, biotite, potash-felspar, plagioclase, and lime-scapolite are all important constituents, the last two being mostly decomposed.

There are beds in the Ben Feall quartz-granulite series in which the chief minerals are quartz, diopside, and biotite, along with a certain amount of pale-green hornblende (S21380) [NM 1439 5492], (S21382) [NM 1429 5478]. Cloudy apatite, pink in the hand-specimen, is a characteristic accessory. These rocks represent an approach to metamorphosed dolomitic shale, and are associated with quartz-free or quartz-poor analogues which will be described presently.

An unusual type from Clabhach Bay (S21299) [NM 1794 5915] consists of quartz, pale-green amphibole, prehnite and accessory apatite, and a few grains of a mineral resembling zircon. The prehnite appears to be replacing both felspar and biotite.

Quartzo-felspathic calcareous rocks

A small proportion of the quartzo-calcareous rocks are rich in potash-felspar. Presumably some of them were dolomitic arkoses in which the proportion of felspar to quartz has been increased during the formation of diopside or amphibole. In (S21377) [NM 1426 5471] from the Ben Feall quartzitic outcrop, quartz is the most abundant mineral, but diopside, potash-felspar, and calcite are all well represented. In (S21385) [NM 1351 5306] from Crossapol Bay, quartz is no more abundant than potash-felspar, while diopside accompanied by a little pale-green amphibole is dominant, and calcite is quite subsidiary. In (S23292) [NM 1471 5524] from the outcrop mapped as marble east of Ben Feall, quartz and potash-felspar are accompanied by abundant trernolite associated with epidote.

It is impossible to decide in many cases how far the colrfposition of the Lewisian rocks has been modified during their complicated history. For example, a specimen from a junction of marble and pegmatite, at the north end of Soa, consists mainly of potash-felspar and orientated biotite, with subordinate diopside and accessory blue apatite (S23471) [NM 1554 5518]. Similar extreme material comes from the calcareous belt mapped as marble east of Ben Feall (S21373) [NM 1470 5522].

Marbles

Probably half the sedimentary rocks of Coll are noticeably calcareous; but actual marble, though widely distributed, is restricted to occasional bands that perhaps never exceed 50 ft. in thickness. All the marbles are magnesian, like the analysed material (Anal. VI, (S23028) [NM 1674 5425], from east of the square-walled garden half a mile east of Breachacha Castle, in which the main minerals are calcite, which makes about 55 per cent., forsterite, represented by serpentine pseudomorphs, and phlogopite. The two last are in about equal proportions, while apatite is a minor accessory. The pseudomorphs after forsterite occur as rounded grains, and the phlogopite as stout flakes, in each case 1 to 2 mm. long. The calcite builds allotriomorphic crystals up to about 3 mm. in length. The serpentine is of the very lowly birefringent type that usually replaces forsterite. The phlogopite is practically colourless, but is easily distinguished from muscovite by its uniaxial nature. All the three main constituents show clearly in the hand-specimen: the calcite as a white base, the serpentine as green translucent grains, and the phlogopite as glancing colourless flakes see also (S21364) [NM 1674 5425].

Closely similar marbles outcrop at Loch Gorton (S21356) [NM 1767 5352], (S21358) [NM 1767 5352], (S23293) [NM 1767 5352], (S23294) [NM 1767 5352] and south-south-west of Lonban (S21313) [NM 1715 5583], also in the islands of Soa (S21366) [NM 1557 5190] and Gunna (S21399) [NM 1040 5113]. Diopside is a fairly frequent mineral in these marbles and tends to segregate in nodules (S21314) [NM 1715 5583], (S21367) [NM 1556 5184]. Tremolite is occasionally present; and one nodule or band consists of diopside grains enclosed poikilitically in crystals of pale bluish-green amphibole sometimes measuring 2 cm. across (S21357) [NM 1767 5352]. This last specimen contains conspicuous accessory apatite, very cloudy in thin slice and bright pink in the hand-specimen.

The phlogopite of the marbles ranges from colourless to pale-brown in thin slices. The coloured variety is best exhibited in a black and white marble from Gunna (S21399) [NM 1040 5113]. Here there occurs a black deposit, apparently magnetite, round several of the mica crystals and also round the serpentinous pseudomorphs after forsterite.

Diopside-amphibole rocks

Wehave mentioned the rather frequent occurrence of diopside nodules, sometimes with pale-green amphibole, in the Coll marbles. Similar material is common as thin beds associated with quartzo-calcareous or biotite-rich members of the suite. The diopside is usually very pale-green in the hand-specimen (medium-green in (S21372) [NM 1470 5522] and has a granular felspathic appearance, with sufficiently marked cleavage to be easily distinguished from quartz. The amphibole tends to be darker, has a more elongated form, and shows its cleavage more conspicuously.

Under the microscope the diopside is nearly colourless, and the amphibole may be colourless or pale-green or, exceptionally (S21372) [NM 1470 5522], fairly dark-green. Accessory minerals are quartz, felspar, and calcite. The main constituents are generally under 3 mm. in cross section, and, as a rule, build independent crystals.

Rocks of this character occur: in Clabhach Bay (S21301) [NM 1794 5915], (S21302) [NM 1794 5915]; south of the Hogh Bay dark orthogneiss (S21319) [NM 1640 5712], (S21320) [NM 1640 5712]; as a belt in biotite-granulite south of Rudha nan Uan (S21323) [NM 1613 5704]; in the outcrop mapped as marble east of Ben Feall (S21372) [NM 1470 5522]; and near the west end of Crossapol Bay (S21386) [NM 1309 5298].

Biotite-rich calcareous bands

Occasional thin dark beds intercalated in the Ben Feall quartz-granulite glitter with flakes of black mica, between which pale-green grains of diopside can be seen (S21381) [NM 1429 5478]. The mica under the microscope is brown and strongly pleochroic. Magnetite is an accessory. Incoming of quartz (S21382) [NM 1429 5478] gives rise to a type of quartzo-calcareous rock already described.

Another specimen (S21371) [NM 1475 5523] comes from the calcareous outcrop east of Ben Feall, in contact with dark orthogneiss. The hand-specimen shows twisted chlorite, after biotite, curving about little eyes of oligoclase. Under the microscope much pale blue-green amphibole is seen in stout crystals that sometimes have a colourless interior.

Non-calcareous quartzose biotite-granulites

In the sedimentary series of Coll there are several pale bands, in which about half the rock consists of quartz and the remainder of felspar and orientated biotite with accessory apatite. Specimens come from Clabhach Bay (S21298) [NM 1794 5915], (S21300) [NM 1794 5915] and Gorton Bay (S21355) [NM 1769 5339].

Biotite-granulite

The rocks here grouped together as biotite-granulites are dark-grey, often unbanded, of rather fine texture, and conspicuously rich in orientated flakes of biotite which measure about 1, mm. across. The biotite is evenly distributed in a matrix. mainly composed of oligoclase or andesine, which gives the whole a uniform granulitic texture, modified, of course, by the schistose orientation of the biotite. Quartz is present in variable proportions, Pink garnet, hypersthene, and green hornblende are often met with, though they are more commonly absent. Apatite and pyrites are frequent accessories.

This type makes up about a third of the bulk of the rocks for which a sedimentary origin is claimed in the Coll complex. If it stood alone its interpretation would be a matter of uncertainty, for its composition lies about the border line separating typical igneous rocks from typical sediments. The hornblendic members certainly occupy this indecisive chemical position, as has been proved by analysis of the most hornblendic material obtainable (Anal. V, (S23027) [NM 1616 5716]. In it the main mineral is andesine, accompanied by a fair proportion of quartz. Brown pleochroic biotite and distinctly green hornblende are both abundant. Apatite and pyrites are accessory. The chemical analysis shows that if the rock is igneous in origin it has an unusually low proportion of alkali for its 64 per cent. of silica. At the same time it can be matched in this and other respects among superior analyses of igneous rocks listed by Washington (cf. Anal. C). If, on the other hand, the rock is of sedimentary origin, it differs from typical argillaceous rocks in having: very little more alumina than would combine with its lime and alkalis to give felspar; less magnesia than lime; and less potash than soda. Accordingly it cannot be a metamorphosed shale, but, as comparison with Analyses D and E suggests, it may be a metamorphosed impure sandstone. The last interpretation is adopted because:-

1. The analysed material must be considered along with its more normal associates that constitute the bulk of the Coll biotite-granulites. These are rich in biotite, free from hornblende, and in some cases garnetiferous (S21324) [NM 1608 5702]. They obviously have a composition much more readily interpreted as sedimentary than igneous.
2. The biotite-granulites are an easily recognizable type in Coll, largely on account of their fine texture, so that their distribution is thoroughly known. With trifling exceptions, wherever biotite-granulite occurs, more obvious sedimentary types, such as various grades of quartzose and calcareous rocks, are also found. The association takes the form of apparent interbedding, and there are many intermediate passage rocks.

The best exposure of biotite-granulite lies west of Hogh Bay. Among specimens from this locality two (S21321) [NM 1625 5715], (S21322) [NM 1625 5715] contain biotite as their only ferromagnesian mineral; while the analysed sample already described (S23027) [NM 1616 5716] carries biotite and hornblende; and another (S21324) [NM 1608 5702], from near the orthogneiss on the south-west, biotite and garnet. In (S21321) [NM 1625 5715] there is a considerable proportion of potash-felspar.

Biotite occurs without any other ferromagnesian in (S21295) [NM 1810 5909] from the eastern limit of the Clabhach Bay exposures. It is accompanied by insignificant hornblende in two specimens (S21397) [NM 0994 5094], (S21400) [NM 1032 5110] from Gunna; and by a fair proportion of hypersthene and accessory garnet and hornblende in (S21354) [NM 1769 5339] from Gorton Bay; and by abundant garnet and hornblende in a band beside the burial-ground on the west side of Crossapol Bay (S21387) [NM 1282 5304]. Other occurrences will be noticed later in describing the marginal relations of the ortho- and paragneisses.

The zones and their marginal relations

Zone 1

The western grey orthogneiss has two outcrops, one on either side of Feall Bay. Exposures are good. Most of the outcrop consists of banded grey orthogneiss, with here and there intercalations of dark orthogneiss of sufficient importance to be shown on the one-inch Map. As already indicated the inclination of the banding of the orthogneiss in the outcrop west of Feall Bay is anticlinal, and in the eastern outcrop it is mostly isoclinal towards the east. Pegmatites are common, especially in Gunna.

Three minor occurrences of biotite-granulite or allied gneiss have been noted within Zone 1:

1. A hundred yards within the boundary of Zone 1 there is exposed by the roadside west of Ballard, between Loch Breachacha and Hogh Bay, a narrow band of typical garnet-rich biotite-granulite. Its outcrop is about 30 yds. wide, and has been traced for 300 yds. along the strike as shown on the one-inch Map.
2. Farther north, 500 yds. north-west of Totronald, and again about 100 yds. inside the boundary of Zone 1, there is a 3-ft. band of biotite-granulite.
3. On the shore 70 yds. north-east of Dimbeic, a third of a mile within the boundary of Zone 1, there is a 4-ft. band (S21405) [NM 1564 5659] which differs from the adjacent grey orthogneiss (S21404) [NM 1564 5659] in being richer in biotite and in carrying garnet in addition to hornblende. This apparently sedimentary band seems to end in lenticular fashion.

These intercalations are interpreted as enclosures in the igneous complex.

Marginal relations of Zones 1 and 2

The best exposure for examining the mutual relations of orthogneiss and paragneiss in Coll occurs half-way up the west shore of Crossapol Bay. The sedimentary rocks here are biotite-granulites often garnetiferous. Their main junction with the grey orthogneiss runs out to sea just west of Port an Duine (a locality named on the six-inch Map, Argyll 50 S.W.). Immediately north-east of this the coast-line takes a rather pronounced bend, and here, about 150 yds. within the boundary of the sediments, there occurs a band, some 20 yds. wide, of typical grey orthogneiss with layers and lenticles of hornblendic material. It can be traced along the sea margin northwards for 400 yds. until the garnet-biotite-granulite closes around its termination. This band envelops many thin layers and lenticles of the biotite-granulites, distinguishable from the hornblendic material already noted. They are commonly three or four inches thick, but occasionally less. There does not seem any room for doubt that the grey orthogneiss has invaded the granulite.

Specimens taken from this complex junction include (S21390) [NM 1265 5237], a biotite-rich gneiss rather than granulite. It carries accessory garnet and represents the invaded sedimentary rock, quite possibly modified to some extent by absorption of igneous material. In (S21393) [NM 1265 5200] from the tongue of invading orthogneiss, the mineral proportions are those of a typical quartz-oligoclase-biotite-diorite with very little orthoclase and accessory apatite. There can be no doubt of the igneous origin of such a rock. A dark lenticular inclusion proved on slicing to consist of green hornblende and hypersthene (S21394) [NM 1265 5214]. Two other slices (S21391) [NM 1264 5221], (S21392) [NM 1264 5211] taken from the invading orthogneiss rather suggest modification by digestion of sediment. In (S21392) [NM 1264 5211] there is a considerable proportion of hypersthene.

Where the junction of Zones 1 and 2 reappears on the northern coast west of Feall Bay the same type of relations is hinted at without clear demonstration. There is a considerable belt of biotite-granulite, sometimes garnetiferous, sometimes hypersthene-bearing (S21384) [NM 1283 5458], for which a sedimentary origin can safely be asserted. Within this are bands that exactly resemble grey orthogneiss, and one of them is indicated on the one-inch Map. It is probable that there has been considerable interpenetration of igneous material. Specimen (S21383) [NM 1298 5452] illustrates what is regarded as a mixed sedimentary-igneous product. It is rich in biotite and big garnets, but has coarse igneous-looking quartzo-felspathic Nothing of special interest has been noticed elsewhere along the junction of Zones 1 and 2.

Zone 2

In Gunna the prevalent paragneiss type is biotitegranulite. Some beds are calcareous, others quartzose. Magnesian marble occurs as thin intercalations in a dark orthogneiss band where exposed on the south shore. Some of the dark orthogneiss here appears calcified, and what has been interpreted as calcified grey orthogneiss occurs in two bands on the west coast of the island. The paragneiss series dips steeply southwards off the grey orthogneiss of Zone 1. Pegmatites are common, and on the west coast they are sometimes richly garnetiferous.

The same rocks are exposed with west-south-west strike in Eilean Bhoramuil. The skerries to the east, including Sgeir nan Garbhanach, are probably partly composed of Zone 2, but have not been visited.

On the west shore of Crossapol Bay the biotite-granulites appear again, where they are intruded by the associated grey orthogneiss of Zone 1 (*see above*). An excellent exposure of interbedded sedimentary types, mainly biotite and quartzo-felspathic granulites, both with garnets, is afforded by the shore near Crossapol burial-ground. Sometimes the garnetiferous quartzo-felspathic material has a cross-cutting (pegmatitic) relation. In the next 100 yds. to the east there are two other very good exposures of interbanded quartzose, biotite-rich, and calcareous material, cut at one place by a conspicuous pegmatite. Beyond this, for three quarters of a mile, the bay shows nothing but sand. Some of the hidden rocks come to view in the headland near Eilean Tumala. They are biotite-granulite, associated with calcareous quartz-granulite and cut by pegmatites, and are separated from the grey orthogneiss of Zone 1 by an important band of dark orthogneiss.

There is no exposure north of Crossapol Bay until the shores of Feall Bay are approached.

On the west of Feall Bay biotite-granulite is the main type, cut by white garnetiferous pegmatite and associated at its eastern side with a band of dark orthogneiss. It has already been pointed out that the separation between biotite-granulite and grey orthogneiss is not always clear in this exposure, probably a result of the intrusion of the latter into the former.

The head of Feall Bay is obscured by sand, but Ben Feall and the adjoining coast east of the bay furnish magnificent exposures. Ben Feall consists of a great mass of quartz-granulite with minor intercalations of biotite-rich calcareous material. The whole has an impressive bedded appearance, with an easterly dip of about 45°. In this direction the quartz-granulite is succeeded by a highly calcareous series associated with dark orthogneiss. The latter is likely a continuation of the band already mentioned east of Crossapol Bay.

It will be seen from looking at the map that the exposures of Zone 2 in Crossapol Bay are sufficiently extensive to demonstrate that there is little but sedimentary material in the intervening sandy hollow. In Coll and Tiree it is the general rule that the orthogneisses are very fully exposed, while the paragneisses from their softer nature are largely concealed in sand-filled hollows.

If we return to Crossapol Bay we find at low tide that garnetiferous granulite is traceable round the southern termination of the dark orthogneiss that here separates the sediments of Zone 2 from the grey orthogneiss of Zone 1. The same garnetiferous granulite with pegmatites continues along the west shore of Loch Breachacha. Two thirds of the outcrop of Zone 2 is obscured by sand at the head of Loch Breachacha, where the only prominent exposure consists of an intercalated band of grey orthogneiss. The eastern boundary of the zone is, however, seen on the east shore of the Loch and at the Sgeirean nan Cuiseag end of the Soa group of islets. In the former locality calcareous rocks are involved with the Hogh granite-gneiss (Zone 3) in a manner that will be discussed presently. In Sgeirean nan Cuiseag there is a good exposure of marble and associated pegmatite.

Little need be said of the inland exposures between Loch Breachacha and Hogh Bay. They show that the median band of grey orthogneiss continues for at least two miles inland; and that as Hogh Bay is approached there is also a band of dark orthogneiss within the series. It is possible the latter is the same as the band or bands seen at the junction of Zones 1 and 2 west of Loch Breachacha and some little distance inside Zone 2 east of Ben Feall. Of the sediments themselves the two most interesting inland outcrops consist of marble. They are situated, the one beside the walled garden half a mile east of Breachacha Castle, and the other 300 yds. south-south-west of Lonban.

The coast section of Zone 2 west of Hogh Bay reads from west to east as follows (distances refer to width of outcrop measured across strike): 200 yds. of biotite-granulite with garnets near west margin, the whole flooded with white pegmatite; 20 yds. of highly calcareous rocks rich in diopside and amphibole; 350 yds. of biotite-granulite at Rudha nan Uan, cut by many white pegmatites; 70 yds. of calcareous quartzose rocks; Hogh Bay dark orthogneiss. Beyond the latter is scarcely an exposure till the margin of the Ben Hogh granite-gneiss, Zone 3, is approached.

Marginal relations of Zones 2 and 3

At the east end of the sand of Hogh Bay there is a small exposure of biotite-gneiss (S21311) [NM 1710 5771]. It resembles the sedimentary biotite-granulites, but is more coarsely crystalline and has quartzo-felspathic veins along the foliation which very likely have come from the Hogh granite-gneiss. The latter is seen a few feet away with its normal characters. In between is a zone of variable grey orthogneiss, which seems to interdigitate and at places to merge with its two neighbours. This border zone is strikingly xenolithic. Most of the xenoliths are dark in the hand-specimen and obviously composed mainly of hornblende. A slice (S21300) [NM 1794 5915] shows a bluish-green hornblende of medium tint accompanied by quite subordinate quartz, apatite and pseudomorphs after biotite. Such a rock is more easily interpreted as of igneous than sedimentary origin. There are, however, a few xenoliths that certainly suggest derivation from a calcareous sediment. A slice from one of these (S21310) [NM 1716 5768] shows two distinct crystallizations, a coarse-grained followed by a fine-grained. The main constituents with the coarse-grained crystallization are very pale-green amphibole, diopside, oligoclase, calcite, prehnite and quite subsidiary quartz. The diopside occurs in stout rounded prisms up to 3 mm. long enclosed poikiloblastically in the other constituents, among which the amphibole individuals sometimes measure 25 mm. across. In the finer crystallization we find small unorientated blades of tremolite and a little epidote partially replacing, in some cases along cracks, earlier calcite and prehnite. The matrix of the xenolithic layer may be normal Ben Hogh granite-gneiss (S21308) [NM 1716 5768], but often the xenoliths are rolled out along with the matrix so that the unbanded granite-gneiss passes into a perfect example of a banded gneiss rich in ferromagnesian minerals such as rather pale-green hornblende with relics of diopside (S21305) [NM 1711 5773], (S21306) [NM 1711 5773], (S21307) [NM 1711 5773]. In one of the slices (S21306) [NM 1711 5773] there are patches largely composed of prehnite, which presumably represent digested calcareous sediment.

Similar phenomena follow the boundary southwards and are best studied on the east shore of Loch Breachacha. Here, opposite the low-water termination of the sand at the head of the loch, a green xenolith was collected a little within the granite-gneiss. On slicing, it proved to consist of green diopside and medium-green hornblende with accessory biotite (S21360) [NM 1662 5369]. The colour was distinctly deeper than in most diopside-amphibole rocks collected from the Coll sediments, for instance (S21357) [NM 1767 5352]. At the same time this colour can be matched with that of a band or lenticle in the Soa marbles (S21367) [NM 1556 5184]. Now the Soa marbles, and also those seen at the walled garden inland from Loch Breachacha, belong to Zone 2 and lie just outside the Ben Hogh granite-gneiss, so that the xenolith is in all probability a calcareous sediment derived from Zone 2, modified possibly by absorption of magmatic iron. It is, however, right to state that diopside-hornblende rocks of similar composition do sometimes occur as plutonic igneous rocks.

On the one-inch Map the boundary of the Ben Hogh granite-gneiss is drawn as a firm line along much of the Loch Breachacha coast. The granite-gneiss continues with normal character (S23285) [NM 1647 5297] to within a few feet of this boundary. It there merges into a grey flaggy series which is often highly calcareous and almost certainly in large measure of sedimentary origin. What is taken to be a reaction border along the edge of the granite-gneiss locally includes types characterized by abundant grains of green diopside (S21363) [NM 1648 5325], (S23283) [NM 1646 5302], (S23284) [NM 1646 5302]. Besides this mineral andesine is well represented with, in (S21363) [NM 1648 5325], pale-green hornblende, biotite, and quartz, and in (S23283) [NM 1646 5302], (S23284) [NM 1646 5302] abundant potash-felspar, sometimes as large crystals. In these last two slices myrmekitic quartz is characteristic; in one of them (S23283) [NM 1646 5302] there is accessory sphene and ' cauliflower ' growths of diopside such as have been described above from certain apparently calcified orthogneisses (p. 13). It will be noted that this supposedly mixed rock from the shore of Loch Breachacha agrees approximately in mineral composition with certain varieties of augite-diorite and monzonite.<ref>A previous record of norite-gneiss in this position was based on a misnumbered slice.</ref> Two slices (S21362) [NM 1648 5325], (S21361) [NM 1648 5325], taken to illustrate the passage from this type into the normal Ben Hogh granite-gneiss, show progressive disappearance of diopside and deepening of the tint of remaining green hornblende.

Zone 3

The great Ben Hogh granite-gneiss appears to be a single intrusion separating sediments, which now are spoken of as belonging to Zones 2 and 4. It forms the highest ground of the island (339 ft.) and everywhere exposures are excellent. Hornblendic xenoliths teased out and incorporated occur here and there but are a very minor feature. Some compact little xenoliths of andesine-biotite-rock are noteworthy on the coastal cliffs northwest of Ballyhaugh. Their foliation, shown in orientation of their biotite previous to crystallization of their andesine (S21304) [NM 1713 5810], (S22089) [NM 1713 5810], usually runs parallel with that of the surrounding granite-gneiss; but in several cases there is a marked discordance. These xenoliths are more felspathic than any of the sedimentary biotite-granulites outside the Ben Hogh granite-gneiss.

Marginal relations, Zones 3 and 4

At Clabhach Bay the marginal relations of the Ben Hogh granite-gneiss are obscured by shearing. At Loch Gorton they are hidden by sand.

Zone 4

The Clabhach–Gorton sedimentary zone dips steeply off the Ben Hogh granite-gneiss in a curved outcrop convex to the east. This outcrop is about 100 yds. wide at Clabhach and 200 yds. wide at Gorton, and its length from coast to coast is 4 miles. Exposures at Clabhach Bay are mainly of calcareo-quartzose rocks, often containing scapolite. At one point these rocks show not only a crystallization parallel to banding, but also a cross-foliation developed parallel to the axes of little folds or crumples. Another feature of interest is a 15-ft. quartz-rock, which, as already mentioned, is considered to be a metamorphosed quartz vein, but is possibly a metamorphosed sandstone of exceptional purity.

Inland the sedimentary zone is generally covered, but it gives rise to a very definite hollow holding two fresh-water lochs. Here and there the quartz-rock is seen as indicated on the one-inch Map, and more locally small exposures of the undoubted sediments occur. The north end of Loch Cinneachan from west to east shows: calcareous quartz-granulite, some beds with pink garnet; dark hornblendic orthogneiss or schist; quartz-rock; biotite-granulite.

Where the road crosses the outcrop at Acha the quartz-rock is thicker than elsewhere, measuring about 200 ft.

At the head of Loch Gorton an exposure of calcareous granulite, including an outcrop of marble, measures 20 yds. in width. South of this, towards the grey orthogneiss of Zone 5, biotite-granulite is encountered.

Marginal relations of Zones 4 and 5

At the eastern limit of the Clabhach Bay exposure of sedimentary rocks, biotite-granulite (S21295) [NM 1810 5909] is cut by many pegmatites. Almost all of these are clean quartz-felspar pegmatites such as are commonly met with in biotitegranulite exposures elsewhere in Coll. One vein, however, has lenticular swellings which enclose veined augen of hornblendic rock in a manner characteristic of countless pegmatitic veins in the neighbouEing grey orthogneiss of Zone 5.

Further evidence suggesting intrusion of the orthogneiss into the biotite-granulite is exposed at half-tide. Ten feet within the orthogneiss a 6-ft. band of biotite-granulite occurs. It can be seen that this band is impersistent, though the exact manner of its ending is hidden.

On the east side of Loch Gorton a junction-rock between biotite-granulite of Zone 4 and grey orthogneiss of Zone 5 is of gneissose texture, with oligoclase, biotite, and quartz as the main minerals, and garnet and pyrites as accessories (S21353) [NM 1769 5339]. The rock is probably an interaction product. There are occasional lenticles or bands of the same type within the neighbouring orthogneiss.

Zone 5

Two thirds of Coll lie east of the Clabhach–Gorton line. In this area exposures are very good, though not continuous. There is a mosaic of peat and rock, the latter rising as a series of moundy hillocks without any particular orientation. The greatest height attained is 259 ft. The country rock almost everywhere is some variant of grey banded hornblende-biotite-orthogneiss. There are numberless bands and lenticles rich in hornblende, and there are also very many cross-cutting intrusions of pegmatite. Subordinate strips of pink acid gneiss occur, as, for instance, north of Eilean nam Muc on the east coast.

The banding runs in simple curves as indicated in (Figure 1). Dips are often quite moderate, as if due to open folding with a northeasterly pitch. South of Chad Bay the banding is thrown into a very definite syncline.

An exceptional igneous type is exposed on the coast north of Meall na h-Iolaire. It is characterized by pink phenocrysts or porphyroblasts of microcline, measuring as much as 6 by 2 inches, set in a medium base of plagioclase and biotite with subordinate quartz. It is possibly a variety of pegmatite.

Flinty crush-rock

The term flinty crush-rock has come into general use among Scottish geologists to denote semi-vitreous products of crushing, characterized among other things by a flinty lustre. It would be out of place to treat the subject at length, but reference may be made to a few standard works by Clough, Holland, Dougal, Shand, Jehu and Craig, and Hall and Molengraaff.<ref>C. T. Clough *in* The Geology of the North-West Highlands of Scotland, *Mem. Geol. Surv., 1907, see* index; T. Holland, The Chamockite Series, a Group of Archaean Hypersthene Rocks in Peninsular India, *Mem. Geol. Surv. India, vol.* xxviii., 1900, pp. 198, 248; J. W. Dougal, Observations on the Geology of Lewis, *Trans. Edinburgh Geol. Soc., vol. xii.,* 1928, p. 14; S. J. Shand, The Pseudotachylite of Parijs, *Quart. Journ. Geol. Soc., vol.* lxxii., 1917, p. 198; T. J. Jehu and R. M. Craig, Geology of the Outer Hebrides, *Trans. Roy. Soc. Edinburgh; vol.* liii., 1922, p. 430; vol. liii., 1925, p. 627; vol. liv., 1926, p. 483; vol. iv., 1927, p. 483; A. L. Hall and G. A. E. Molengraaff, The Vredefort Mountain Land, *Vehr. Konn. Akad. Weten. Amsterdam* (Tweede Sectie), deel xxiv., No. 3, 1925, p. 93.</ref>

In Coll flinty crush-rocks are of insignificant proportions, but are fairly widely distributed. The gneiss of the coast-line north of Loch Eatharna is often shattered and sheared, and in such positions it is common to find little veins, some black and flinty in appearance, and others green and epidotic. Exceptionally individual veins may be as much as a foot wide, but more often they measure half an inch to two inches and have thread-like branches. On Eilean nam Faoileag a belt largely reduced. to the condition of flinty crush-rock actually measures 15 ft. across Occasionally, as for instance, east of Loch Urbhaig, east of Arinagour, an obvious displacement can be detected along veins of flinty crush-rock; but often all that is definitely clear is that the country rock has been intensely sheared along certain planes closely associated with the flinty veins. Viewed microscopically the crushing of the country rock is generally impressive (S21403) [NM 1044 5125], (S21420) [NM 2400 5671], (S22144) [NM 2573 5919], (S22145) [NM 2573 5919], (S22153) [NM 2377 5642], (S22160) [NM 2333 5773]. Dark lines or zones of completely broken material come together at short intervals or cross one another. The dark and pale minerals are twisted and drawn out into lenses of broken material which are often waved. The quartz in early stages shows strain shadows. The final result may look little else than a dirty powder (S22144) [NM 2573 5919].

Specimens were taken from two black veins of flinty lustre traversing relatively uncrushed gneiss 930 yds. south of Arinagour Pier. The veins are two inches thick. Thin sections (S21421) [NM 2258 5612], (S22154) [NM 2258 5612] show a certain amount of the ordinary evidence of crushing; but they also reveal notable powdering, and many of the mineral fragments lie as though in a grit, the quartz without strain shadows, the biotite only slightly bent. Friction could not have produced such a powder, but shock of some sort, possibly connected with explosion, seems to be indicated. Professor Shand has already made this suggestion in regard to certain South African occurrences. The flinty veins in the present case are quite obviously in large measure glass with a detectable beginning of felsitic crystallization. A proportion of the quartz inclusions are rounded.

Flinty crush-rock has very seldom been noted in the northern half of Coll except along the east coast. It is possible indeed that the crush phenomena are connected with a fault which very probably flanks most of the south-eastern coast of Coll. Other evidence for such a fault is supplied by the steepness of the coast and the presence of deep water just off shore. Many hollows in the West Highlands have been eroded along shatter belts.

On the other hand in southern Coll flinty crush-rock is developed more indiscriminately though still on a small scale. There is, for instance, a good example at Calgary Point, at the west end of the island. It is associated here and at other places in this part of the island with a sudden change in the strike of the country rock.

Mention has been made of epidotic crush-veins. The epidote is a green, feebly pleochroic variety (S22150) [NM 2681 6153], (S22159) [NM 2704 6198]. It occurs as crowded crystals, some of which may reach 3 mm. in length. It is associated with exactly the same type of crushing of the country rock as has been noted above, in connexion with which the plagioclase is usually altered to albite and the ferromagnesian minerals decomposed. The epidote veins sometimes run along the crush zones and sometimes cross them, and they include fragments of the crushed material. Subsequent crushing sometimes breaks up the epidote itself. E.B.B., V.A.E., J.B.S.

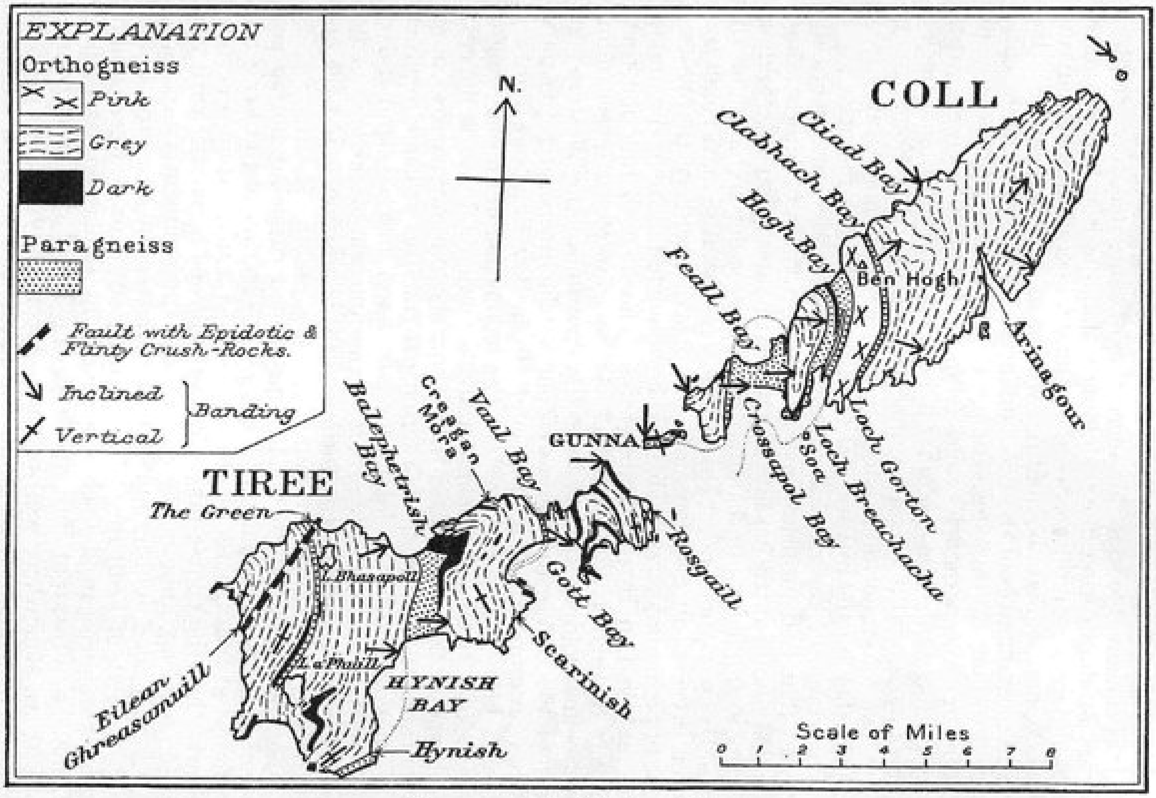

FIG. 1.—*Map of Coll and Tiree.*

(Figure 1) — Map of Coll and Tiree.

TABLE I

ANALYSES

	I.	A.	II.	III.	B.	IV.	C.	V.	D.	E.	VI.	
	Igneous.			Sed.	Ign.	Sed.	Ign.	Sedimentary.			Sed.	
Metamorphic or Non-metamorphic.	Met.	Non-met.	Met.	Met.	Non-met.	Met.	Non-met.	Met.	Non-met.		Met.	Metamorphic or Non-metamorphic.
SiO_2	68·97	67·00	66·19	81·89	79·19	76·15	63·03	64·23	67·92	59·96	18·29	SiO_2
Al_2O_3	14·66	15·19	15·58	9·10	9·88	5·55	17·72	15·87	12·89	16·52	2·77	Al_2O_3
Fe_2O_3	1·36	1·98	1·38	0·17	0·21	0·87	2·27	0·03	3·73	2·37	1·11	Fe_2O_3
FeO	1·92	2·17	2·90	0·16	0·63	0·82	1·92	3·84	2·42	3·20	nt. fd.	FeO
MgO	1·88	1·76	2·11	0·02	0·55	6·48	3·63	3·32	2·69	2·47	15·52	MgO
CaO	4·28	3·55	4·20	0·64	0·00	6·78	5·97	5·06	3·84	5·32	31·44	CaO
Na_2O	4·18	3·88	3·64	0·11	0·66	0·49	3·92	2·86	1·82	5·00	0·05	Na_2O
K_2O	1·42	2·99	2·18	7·11	7·68	0·66	1·06	1·68	1·59	2·82	0·78	K_2O
$H_2O+105°$ C.	0·47	0·77	0·63	0·21	0·54	0·46	0·44	0·84	0·89	1·27	4·01	$H_2O+105°$ C.
$H_2O-105°$ C.	0·03	—	0·04	0·03	0·03	0·08		0·05	0·17	0·15	0·51	$H_2O-105°$ C.
TiO_2	0·38	0·51	0·54	0·06	0·00	0·12	—	0·67	0·82	0·59	0·09	TiO_2
P_2O_5	0·13	0·13	0·13	0·07	0·00	0·45	—	0·13	0·06	0·24	0·22	P_2O_5
MnO	0·38	0·07	0·37	0·26	0·00	0·30	—	0·42	0·10	0·09	0·42	MnO
CO_2	0·13	—	0·39	0·28	0·64	0·95	—	0·10	1·28	trace	24·84	CO_2
FeS_2	nt. fd.	—	nt. fd.	nt. fd.	—	nt. fd.	—	0·88	—	—	nt. fd.	FeS_2
S	—	—	—	—	—	—	—	—	0·05	0·00	—	S
Cr_2O_3	—	—	—	—	—	—	—	trace	0·00	—	—	Cr_2O_3
(Co, Ni)O	nt. fd.	—	nt. fd.	nt. fd.	—	0·03	—	nt. fd.	—	—	nt. fd.	(Co, Ni)O
BaO	nt. fd.	—	nt. fd.	0·03	—	nt. fd.	—	0·04	—	—	nt. fd.	BaO
Li_2O	nt. fd.	—	nt. fd.	trace	—	trace	—	trace	—	—	trace	Li_2O
Cl	—	—	—	—	—	0·03	—	—	—	—	—	Cl
	100·19	100·00	100·28	100·14	100·01	100·22	99·96	100·02	100·27	100·00	100·05	

nt. fd.=not found.

(Table 1) Analyses.