Chapter 6. b. Rocks of presumably sedimentary origin in the Lewisian Gneiss

Mica-schists, graphitic schists, quartz-schists, calcareous rocks

By J. J. H. Teall

The rocks of the Fundamental Complex, above described, have in most cases marked affinities with igneous products. Such rocks make up the greater portion of the area mapped as Lewisian Gneiss. Nevertheless we find included within that area, in certain districts, and especially in the neighbourhood of Gairloch and Loch Maree, some rocks of a very different character, which have equally decided affinities with sediments. These include mica-schists, graphitic schists, quartz-schists, siliceous granulites, limestones, dolomites, and cipolins.

I Mica-schists

Three distinct types of rock, as well as certain varieties more or less intermediate between these three types, are included under the general term of mica-schist. The three types may be defined as follows:

1. Fine-grained, dark-brownish, often platy schists.
2. Silvery mica-schists, often containing large, idiomorphic garnets.
3. Fine-grained, dark-gray granulitic biotite-schists, or biotitegranulites.

(a) A specimen from the road-side, ½ mile west of Loch Bad na-Sgalaig, between Loch Maree and Loch Gairloch (S3751) [NG 840 720], may be taken as an example of the first type. It is a dark brown, fine-grained, platy mica-schist. The flat surfaces of schistosity possess a silky lustre and show a fine parallel striping. The rock is essentially composed of brown mica, white mica, and quartz, with small grains of zircon, iron-ore, and garnet as somewhat rare accessories. The micas occur in thin plates uniformly scattered through the mass of the rock, not aggregated in planes. The individuals of quartz are irregular in outline and variable in size, the largest measuring about 0.3 or 0.4 mm in diameter. Although often of fairly uniform dimensions in the different directions, a slight tendency to flattening in the direction of schistosity and elongation in the direction of striping may be observed. Undulose extinction, due to strain, is common.

In microscopic structure there is a marked contrast between the section at right angles to the schistosity and parallel to the striping, and that at right angles to the schistosity, and also at right angles to the striping. The former shows a perfect parallel structure, due to the arrangement of the mica-flakes; the latter shows the mica-flakes lying at all angles, and gives unmistakable evidence of minute puckering.

This rock has been analysed by Mr. Wilson with the following results:

SiO_2	75.31
Al_2O_3	8.45
Fe_2O_3	2.84
FeO	4.68
MnO	0.13
CaO	1.27
MgO	1.53
K_2O	4.71
Na_2O	0.01
Ignition	1.19
	100.12
Sp. Gr.	2.73

The other rocks grouped under this head may all be described as dark brown biotite-schists. They vary a little in the sizes of the essential constituents, in the tint of the biotite, which is sometimes pale-brown and sometimes deep reddish-brown,

and in the presence of accessory constituents. Felspar is often and may be always present. It is usually untwinned, water-clear, and may be easily mistaken for quartz.

One specimen of this type from Loch Maree (S4273) deserves special mention as furnishing indisputable evidence that the rocks have been subjected to deformation since the period of crystallisation. This rock shows, under the microscope, the structure of a mylonite. Lenticles of felspar, and perhaps in some cases of quartz, lie in a matrix of mylonised quartz and biotite. The lines of biotite, composed of flakes which have been frayed and torn to shreds, wind round the lenticles of felspar, thus producing a most perfect type of fluxion-structure.

(*b*) As an illustration of the second type of mica-schist, a specimen (S4322) [NH 022 673] from Meall Each, near Ben Slioch, Loch Maree, may be selected. This is a somewhat platy schist, with bright, silvery lustre on the surfaces of schistosity which are roughened by the projection of idiomorphic garnets. On a cross-fracture the planes of foliation are seen to be partly truncated by the garnets, and partly to wind round them. The matrix of the rock is composed almost entirely of a colourless or pale-green mica, a reddish-brown biotite, and epidote. Quartz and iron-ores are also present. The white mica occurs in thin plates often measuring more than 1 mm in breadth. The plates lie, as a rule, with their flat surfaces in the plane of schistosity; but occasionally a plate may be seen to lie transversely without having suffered any distortion.

The reddish brown mica is irregular in outline and does not show any very definite orientation. The epidote exhibits a marked tendency to assume a prismatic form with ragged terminations. The individuals often measure over 1 mm in length. The large garnets lie as porphyritic constituents in the matrix. They are bounded by sharp, well-defined, crystalline faces, and often contain iron-ore as inclusions.

A bulk analysis of this rock by Mr. J. Grant Wilson gave:

SiO_2	46.11
Al_2O_3	28.25
Fe_2O_3	4.78
FeO	6.51
MnO	0.53
CaO	3·47
MgO	3·09
K_2O	6.01
Na_2O	0.26
Loss on Ignition	1.18
Total	100·19
Sp. Gr.	3.11

The other rocks referred to in this group differ as regards the relative proportions of the different minerals. Felspar is sometimes present in considerable quantity, and quartz is often more abundant than in the rock selected as a type.

(c) The third type of mica-schist is well represented by a specimen from a point about one mile W.N.W. of Lochan Fada Inlet, three miles north-east of Loch Maree (S4414) [NG 986 737]. The greater portion of this specimen shows the structure of a granulite rather than that of a schist. It possesses, however, schistose partings extremely rich in biotite. The principal constituents are a deeply-coloured biotite, quartz, alkali-felspar, and epidote. The biotite occurs as thick plates without any very strongly marked idiomorphism or definite orientation, the quartz and felspar as irregular grains and the epidote as ragged patches, the continuity of which is much interfered with by the other constituents. White mica and sphene are present as accessories.

Another specimen from the same locality (S4413) [NG 986 737] is dark-brown in colour and fine-grained, with scattered plates of white mica. The constituents are granulitic quartz and alkali-felspar with biotite. The white mica occurs in thin plates which often lie acros$_s$ the planes of schistosity, and do not show any trace of deformation.

II Graphitic schists

The graphitic schists are characterised by the presence of a variable amount of black carbonaceous matter which is disseminated through the rock, and occurs as inclusions in minerals such as biotite and hornblende. When the powder of the rock is treated with hydrochloric and hydrofluoric acids, the carbonaceous matter is obtained in a tolerably pure state, and is then seen to possess the properties of black lead. The examination of thin sections shows that the substance occurs as minute particles which may be either arranged in lines or aggregated together in opaque patches. Definite crystalline plates of graphite have not been observed.

The microscopic examination of the rock is attended with considerable difficulty in consequence of the opacity of the slides. Felspar is frequently recognisable as a constituent of a fine, micro-crystalline mosaic, and the larger individuals sometimes show albite-twinning. It is apparently andesine or some allied species. The carbonaceous matter is scattered through the rock in such a way as to show that the development of the mosaic has had little or no influence on its distribution. Colourless and brown micas occur in different specimens. They also contain inclusions of carbon, and the arrangement of these inclusions is similar to that occurring in the matrix of the rock, thus proving that the micas must have grown in situ after that arrangement had been brought about.

A specimen from Allt-na-Leth-Chreige (1■ mile east of Letterewe, Loch Maree) (S4427) [NG 975 717], is a black, platy schist with radiating masses of actinolite. A cross-section of this specimen is seen to be traversed by wavy streaks of carbonaceous material separated by lighter streaks or folia of quartz and felspar. These folia sometimes wind round fragments which appear, under ordinary light, to be similar to the main mass of the rock, but which, under crossed nicols, polarise as individuals, and can be definitely identified as hornblende. It is clear that the actinolite was developed in an impure carbonaceous shale, in the same way as the tremolite described by Mr. Allport in a contact-rock from Botallack,<ref>Metamorphic Rocks surrounding the Land's End Granite". *Quart Jour. Geol. Soc., xxxii.,* p. 410.</ref> and that, when the deformation of the mass took place, those portions which were cemented by hornblende-substance offered greater resistance to the deforming stresses than those which were not so cemented. This actinolite-schist furnishes. therefore, indisputable evidence of the development of hornblende in a solid rock, and of the subsequent deformation of this rock by mechanical means.

A specimen from Allt Airidh na Eilein, one mile north-west of Letterewe, Loch Maree (S4793) [NG 940 733], deserves special mention in this connection. It is almost entirely composed of hornblende and carbon. The substratum, so to speak, is a coarse-grained aggregate of allotriomorphic individuals of hornblende, and the black streaks pass through this aggregate without any reference to the optical orientation of the grains. In this rock there is no evidence of deformation since the hornblende was developed. The composition, apart from the carbonaceous matter, must have agreed very closely with that of hornblende; not exactly, however, for a few scattered idiomorphic garnets, a little quartz and felspar, and some biotite also occur.

The specimens, regarded as a whole, vary in colour according to the amount of carbon present; some are black, others lead coloured. The majority show a parallel structure which probably represents stratification more or less modified by subsequent mechanical movements.

Mr. J. Hort Player kindly made partial analysis of a specimen from Mill na Claise, one mile west of Loch Bad an Sgalaig. (S4188) [NG 830 718].

Moisture	0.8
Loss by ignition in reducing atmosphere	3.4
Further loss, probably all carbon	19.6
	23.8

Quartz-Schists

Highly siliceous rocks, which are usually granulitic in texture, and which probably represent the more arenaceous types of of sediment, are found in the same areas as the mica-schists and graphitic schists. Apart from one or two specimens, which consist almost entirely of quartz or of quartz and felspar, these rocks may be grouped under two heads — (a) quartz-hornblende rocks and (b) quartz-magnetite-rocks.

(a) The typical quartz-hornblende-rocks consist of a granulitic aggregate of quartz with which more or less green actinolitic hornblende is associated. They vary considerably as regards the relative amounts of the two chief minerals, some specimens consisting almost entirely of quartz, others containing the two minerals in nearly equal proportions. Variations from the type depend on the introduction of other minerals, such as chlorite and epidote, and on the extent to which the rocks have been modified by dynamic action. Some specimens are dark, others nearly white; but the dark varieties do not contain as much hornblende as might at first sight be supposed. The quartz, which is the Principal constituent, is perfectly transparent, so that a small proportion of the dark hornblende, scattered through the colourless quartz, affects, in a marked manner, the general aspect of the rock. The dark varieties of quartz-hornblende rocks always show a peculiar resinous lustre which distinguishes them from the ordinary hornblende-schists of the district. As regards the origin of these peculiar rocks it is, perhaps, not desirable to speak with any great degree of confidence. It may, however, be pointed out that the association of quartz and hornblende, without felspar, is unknown in igneous products.

A compact, dark, platy rock with resinous lustre (S4340) [NG 837 721] from the road ¾ of a mile S.S.W. of Meall Aundrary was analysed by Mr. Wilson. It is essentially composed of quartz, hornblende and epidote. The quartz gives undulose extinction, and has been partly mylonised.

SiO_2	71.55
Al_2O_3	5.73
Fe_2O_3	7·27
FeO	3.68
MnO	0.19
CaO	6.36
MgO	1.88
K_2O	0.95
Na_2O	0.79
Ignition	1.54
Sp. Gr.	2.84

(b) The quartz-magnetite rocks are usually granulitic or hälleffinta-like in texture. A specimen from Torr an Fhithich, near Smiorasair, 1i mile from head of Loch Maree (S4664) [NG 999 674], may be taken as a type. It is a compact, banded rock. The bands appear dark and light on a weathered surface owing to a variation in the amount of magnetite present. They vary in width, and, in one part of the specimen, have been bent into s-shaped folds. A cut surface of the rock appears brown, owing to the partial oxidation of the magnetite. The constituents are quartz, magnetite, ferric oxide, and a mineral which forms slender prisms — probably sillimanite. The quartz breaks up under crossed nicols into an aggregate of a peculiar type. It is not composed of sharply defined grains which are independently orientated, as is the case with typical granulites; but of somewhat ill-defined grains which show a tendency to uniform orientation. As the nicols are rotated through 360° the quartz-aggregate shows four positions of maximum and four positions of minimum illumination. The orientation is by no means exact; nevertheless it is quite unmistakable, and differentiates the rock from a typical granulite. The magnetite forms compact streaks or lenticles, and rarely occurs as detached idiomorphic crystals. The compact masses occasionally show projecting portions bounded by crystalline faces. The rock, as a whole, exerts a marked influence on the magnetic needle. A partial analysis of this rock yielded the following result:

Silica	90.3
Ferric oxide and alumina	8.5
Loss on ignition	0.02
	98.82

No lime could be found, and only a trace of magnesia. No importance must be attached to the relative proportions of silica and iron. It would be possible to select for analysis specimens of this group of rocks which would consist of almost pure quartz or pure magnetite.

Other specimens differ somewhat in the character of the quartz aggregate. In some (S4320) [NH 022 673] this is typically granulitic, in others (S3754) [NG 810 767] it contains large and extremely irregular individuals which sometimes abut

against each other along sutural junctions, but are more frequently separated by a variable amount of micro-crystalline material. That the rocks have been subjected to dynamic action is proved not only by the folding seen in the type specimen, but also by the structure of many microscopic sections. Flaser of micro-crystalline quartz wind round phacoids of magnetite in the most striking manner, and thus produce the structure characteristic of differential flow.

It is interesting to compare the rocks of this and the preceding group with certain rocks found in the Penokee iron-bearing series described by Irving and Van Hise.<ref>*Monographs of U.S. Geological Survey,* vol. xix. (1892).</ref> The rocks of this series include (1) cherty carbonates; (2) ferruginous slates and cherts; and (3) actinolitic and magnetitic slates. The quartz-hornblende rocks and the quartz-magnetite rocks from the Loch Maree area have decided affinities with the actinolitic and magnetitic slates of Van Hise. Both groups of rocks contain the same minerals and possess to a certain extent the same structures.

IV Calcareous rocks

Calcareous rocks are represented by limestones, dolomites, and cipolins, that is, rocks mainly composed of carbonates but containing also various silicates. The specimens include compact white or cream-coloured dolomites, often veined with calcite, grey compact limestone, and white crystalline marble. Under the microscope the rocks are sometimes seen to consist of an aggregate of crystalline grains of approximately uniform size; more frequently, however, the individuals vary considerably in size, so that the rocks have a brecciated aspect. There is no doubt that they have, in many cases, been subjected to deformation since the development of crystallisation, and under conditions which admitted of the fracture of the individual crystalline grains.

In addition to the carbonates, the rocks of this group often contain one or more of the following minerals: Quartz, mica, tremolite, green hornblende, garnet, felspar, and epidote.

Quartz, when present, is usually in the form of a very fine micro- or crypto-crystalline aggregate which is either intimately mixed with the carbonate or present as thin folia. When grains of considerable size are present they are usually separated from each other by a little micro-crystalline material, due apparently to the peripheral granulation of the larger individuals. In a few rare cases very large individuals may be seen, forming thin plates in the plane of foliation.

Mica is frequently present in well-developed plates which have often been puckered and distorted by interstitial movement. It may be colourless, brown, or greenish brown. The darker-coloured varieties occur in bands. They possess a very small optic axial angle, whereas in the white mica the axial angle is considerable. Both green and colourless hornblendes are found, the latter sometimes occurring as conspicuous radiating masses of tremolite. Felspar has been observed only in one specimen (S5478) [NG 902 770]. It is a basic oligoclase or andesine, and occurs as irregular, twinned grains in association with quartz, a ferriferous carbonate, and rutile. Garnet, also, has been observed in one specimen (S4795) [NG 995 708]. It is brown in the hand-specimen, but practically colourless in thin section, and does not show the anomalous double refraction so frequently seen in the garnets found in limestones.

The rocks vary considerably in colour and structure. They may be white, grey, greenish-grey, or cream-coloured; compact or coarsely crystalline; schistose, banded or massive. The banding in a rock from Allt Airidh a' Char, one mile N.N.E. of Ardlair, Loch Maree (S5480) [NG 905 766], is strongly suggestive of stratification. It is due to the concentration of silicates along certain definite layers.

The calcareous portion of a banded specimen from Allt Airidh a' Char (S5480) [NG 905 766] was analysed by Mr. Wilson

Insoluable	9.57
SiO_2	0.13
AL_2O_3	0.16
Fe_2O_3	1.44
FeO	1.42
MnO	0.36
CaO	34·25

MgO	11.75
CO_2	40.65
Total	99.73
Sp. Gr.	2.78

The insoluble portion consisted mainly of silica, which is recognisable in the microscopic section as microcrystalline quartz. The original rock was probably a cherty carbonate. It effervesces freely with cold, dilute hydrochloric acid, and the analysis shows that it has only been partially dolomitised.

Another specimen (S5475) [NG 903 770] from a point east of Allt Coire nan Dearcag, one mile north of Ardlair, on the north side of Loch Maree, gave the following result. The rock is a white, saccharoid dolomite containing a few Rakes of a nearly colourless mica:

Insoluable	1.35
SiO_2	0.06
AL_2O_3	0.09
Fe_2O_3	0.97
FeO	0.45
MnO	0.35
CaO	32.8
MgO	21.01
CO_2	42.55
Total	99.63

The foregoing descriptions show that the rocks of the Loch Maree and Gairloch area differ markedly in composition and structure from those which form the main mass of the Lewisian Gneiss. This difference is best explained by the assumption that they represent metamorphosed sediments, the mica-schists corresponding to argillaceous, the siliceous granulites to arenaceous, and the marbles and cipolins to calcareous deposits. It must not, however, be forgotten that some of the siliceous rocks may represent cherts.

In addition to the rocks above described, we find also chloriteschists, cyanite-gneiss, and a peculiar rock which may be termed cummingtonite-garnet schist; but these are present only in small quantity. The chlorite-schists possess no feature of special interest, and, as they are unimportant so far as distribution is concerned, need not be further referred to.

Cyanite-gneisses occur near Carnmore Old House, four miles N.N.E. of Letterewe, Loch Maree (S5115) [NG 986 771], (S5116) [NG 986 771], and (S5117) [NG 975 772]. They are coarse-grained, quartzose biotite-gneisses. The cyanite is sometimes very conspicuous, forming crystals measuring an inch or more in length. The other constituents are quartz, felspar (oligoclase and orthoclase) and biotite. Two of the specimens above referred to are almost entirely free from felspar.

The cummingtonite-garnet schist is a remarkable rock occurring at a point about 5/12ths of a mile south-west of the outlet of Loch Bad-na-Sgalaig, between Loch Maree and Gairloch (S5125) [NG 839 705]. The cummingtonite was at first mistaken for sillimanite, and the rock is referred to in the Annual Report of the Geological Survey for 1895 (p. 18) as a sillimanite-garnet-schist. It consists of numerous brown garnets about the size of small shot scattered through a light coloured, silky, fibrous matrix. A bulk analysis partly made in duplicate by Mr. J. Grant Wilson gave the following result, and at once disposed of the idea that the silky, fibrous mineral was sillimanite:

SiO_2	52.01	51.78
Al_2O_3	7.22	7.2
Cr_2O_3	0.54	0.54
Fe_2O_3	2'2	2'52
FeO	18.68	18.68
MnO	6.72	7.45
CaO	0.88	0.99

MgO	9.38	8.98
K_2O	0.81	0.81
Na_2O	0.31	0.31
Loss on Ignition	1.33	1.33
Total	100.08	100.59
Sp. Gr.		3.38

Tinder the microscope the rock is seen to be essentially composed of garnet and cummingtonite. The garnet is pale reddish brown, and varies in size from 1 to 3 mm The cummingtonite forms a fibrous aggregate in which the garnet is embedded. The fibres sometimes abut against the garnets and sometimes wind round their edges. More rarely they occur as inclusions in the garnet. They are colourless, and show cross jointing. The isolated fibres give extinctions varying from 0° to 20°. Quartz and iron-ores occur as unimportant accessories.

The two principal minerals were isolated by Dr. Pollard and analysed by Mr. Grant Wilson with the following results:

	I	II
SiO_2	37.45	54.56
TiO_2	0.25	—
AL_2O_3	20.08	5.02
Cr_2O_3	0.34	—
Fe_2O_3	4.35	0.82
FeO	15.05	16.12
MnO	19.61	4.89
CaO	1.86	0.38
MgO	0.30	14.99
K_2O	0.57	0.76
Na_2O	0.26	0.21
Loss on Ignition	0.22	1.67
CO_2	—	0.63
Total	100.32	100.05
Sp. Gr.	4.1	3.21

I. — Spessartite. II — Cummingtonite

From a consideration of specific gravities Mr. Wilson concludes that the rock consists of about one part of garnet to four of cummingtonite.