Chapter 9 Metamorphic rocks Ardgour district

The metamorphic rocks of the Ardgour district, north-west of Loch Linnhe in Sheet 53 (Geol.), were mapped by Grant Wilson, except those within a considerable triangle south-west of Sgùrr nan Cnamh [NM 886 644] and Amhainn Coir ' an Iubhair [NM 920 623], which were allotted to Maufe and the writer — both inexperienced recruits. The field-work was carried out under Peach as District Geologist; but before the memoir was written Grant Wilson had died, Clough had succeeded Peach, and Maufe had gone to Southern Rhodesia. Clough took the writer for a brief investigation tour of the Glen Scaddle district, and then entrusted to him the preparation of the short account published in the 1916 memoir, largely based on preliminary notes by Wilson to successive *Summaries of Progress.* The district has since been made the subject of important papers by Drever (1936, 1939, 1940) and Harry (1954), and its borders have been touched by the Geological Survey working in the adjoining Geological one-inch Sheets 52, 61, 62, so that considerable additional knowledge has been obtained. At the same time there has been no Geological Survey revision, beyond a two-day re-examination of critical points, which was undertaken by the writer in conjunction with G. S. Johnstone in 1956. Johnstone and J. E. Wright had lately mapped Glen Loy [NN 130 830], the next big glen north of Loch Eil [NN 000 780] in Sheet 62, where there is a basic pluton comparable with that of Glen Scaddle, Sheet 53; and they had reached interim conclusions regarding its intrusive and metamorphic relations, which are in some respects similar to those developed in the sequel.

In the absence of detailed local knowledge it has been thought wise to retain most of the old description, including its quotations from *Summaries of Progress,* in this new edition, printing it in small type, and to append comments to establish contact with up to date research. It has been a great encouragement to realise how valuable Wilson's pioneer work has proved. It must be remembered that it was accomplished rapidly, much of it before the close of the last century and that the geology is of quite exceptional difficulty. It has proved impossible in a short chapter to do full justice to the more modern work, and readers must consult the originals, more particularly for petrological descriptions and discussions.

Altered sediments and structural. relations

In the main the metamorphic rocks are altered sediments, but they also inlude the Glen Scaddle complex of epidiorite and other igneous rocks, the Sgùrr Dhomhnuill [NM 890 679] mass of augen-gneiss farther to the west, and numerous small lenticles of hornblende-schist. (1916 edition)

The West Highland Unit of the Geological Survey has reported that an injection area starts at about twelve miles west of Sheet 53 and increases in intensity eastwards (Sum. Prog. 1931, p. 63; Kennedy 1946, see our (Figure 40); Phemister 1948, p. 31). It has also stated specifically that the Sgùrr Dhomhnuill augen-gneiss is an injection product rather than an igneous rock (Sum. Prog. 1932, p. 58; 1934, p. 68). It is now realised that much of the western part of Sheet 53 north-west of Loch Linnhe lies within the injection area entered in Sheet 52. On the map as published certain zones of "felspathised sedimentary gneiss" have been shown around the Glen Scaddle Pluton and along the Great Glen Fault. These will be discussed separately (pp. 124, 127). What is meant by the western injection-complex may be gathered from the description given in 1931: injection "is especially obvious in a pelitic or semipelitic host. There is every variation between schists with pegmatitic or granitic strings and lenticles, lit-par-lit injection-gneisses and permeation-gneisses". It has been found by A. G. MacGregor and W. Q. Kennedy that the main injection episode antedated the emplacement of the Strontian granodioritic pluton, the edge of which crosses Gleann Feith 'n Amean [NM 870 623] on the west margin of Sheet 53 (Sum. Prog. 1932, pp. 106–9).

Drever as often as not speaks of the Glen Scaddle "epidiorite" as diorite-gneiss (1940, p. 152). Most of it, however, is free from metamorphic foliation. Perhaps diorite or gabbro-diorite would be a better term for the rock since according to Drever it often retains unaltered pyroxenes. In the present description, to keep contact with the published map, the term "epidiorite" will be retained, but always between inverted commas. Moreover Teall has said that a specimen submitted to him (S8233) [NM 9922 6837] is epidiorite in "structure and composition" (Sum. Prog. 1899, p. 40). By this he meant a basic non-schistose igneous rock with secondary hornblende.

The metamorphic sediments of this district are of the following main types:

1. Siliceous gneisses of 'Moine' type, with a considerable proportion of felspar and mica accompanying the quartz; these represent banded, impure, arenaceous sediments.
2. Highly micaceous gneisses; these represent argillaceous sediments.
3. Quartz-granulites; these represent exceptionally pure sandstones.
4. Marble; this is of restricted occurrence and represents a thick, pure limestone or dolomite.

The structural and stratigraphical relations of these various types are very imperfectly known. Their variations of dip and strike are sufficiently indicated on the map. (1916 edition)

At the northern boundary of Sheet 53, dips in the main outcrop of the siliceous gneisses (a) are often as low as 20° or 15°, though they become steep towards the micaceous gneisses on the north-west and Loch Linnhe on the south-east. The belt of low dips is about six miles broad, and reaches south-westwards for two to six miles until Cona Glen [NM 955 720] is approached, beyond which lies the Glen Scaddle "epidiorite". So much is clear from Wilson's mapping. North-eastwards, as G. P. Leedal has pointed out (1952, pp. 37–8), the same "flat belt" can be followed for an additional twenty-five miles without coming to an end. The Cona strip, which interrupts the "flat belt" to the south-west. is about a mile wide and characterised by very steep dips and a west-north-western strike that parallels the outcrop of the Glen Scaddle complex. This and further related complications to the south-west will be discussed under heading (d).

Beyond the western boundary of the map MacGregor and Kennedy have found that, "where the country rocks have a regional strike nearly normal to the margin" of the Strontian Pluton west of its crossing of Gleann Feith 'n Amean [NM 870 623] in Sheet 53, "they have been swung round into conformity and now strike parallel to the outer margin of the complex — e.g. north of Strontian" (Sum. Prog. 1932, p. 115). The continuation of this approximate conformity is very marked in the course of the quartz-granulite outcrop (c), which mostly lies in Sheet 53. The swing is presumably due to magmatic pressure exerted by the pluton.

(a) The siliceous gneisses form the bulk of the country. As far south as Glen Gour [NM 950 640] "the chief type is a grey flaggy rock, with bands of varying thickness, and lighter and darker in tint, according to the presence of more or less black mica. Felspar and white mica are always present" (Wilson *in* Sum. Prog. 1898, p. 65). South of Glen Gour the flaggy character of what appears to be the continuation of these siliceous gneisses is lost, owing to an intricate puckering of thebedding planes. In this southern district the crystallisation of the gneisses is exceedingly coarse". (1916 edition)

Drever (1940, p. 151) correlated the main outcrop of siliceous gneisses (including the part mapped by Grant Wilson as "felspathised sedimentary gneiss" bordering the Glen Scaddle "epidiorite") with the Upper Psammitic Group of Moines established by Richey and Kennedy in the Morar district further north (1939). Rightly or wrongly, this view has also been advanced by Leedal further north-east (1952, pp. 36, 38), and by Harry in Ardgour itself (1954, pp. 287, 308). The last-named bases his correlation on certain talc-silicate ribs (quartz, basic plagioclase, epidote, garnet) which he has found in a marginal position relative to the outcrop of highly micaceous gneisses (b) (1954, p. 288, pl. xiv). By analogy these talc-silicate ribs lead him to correlate the sedimentary background of the micaceous gneisses (which are much granitised) with the Pelitic Group of Morar, which has been shown by current-bedding in its home region to be older than the Upper Psammitic Group. He then proceeds to interpret these micaceous gneisses as rising in an anticline from under their psammitic associates (1954, p.291). He tacitly assumes, it would appear, that there has been no great inversion and that an anticline must be an antiform.

Structural relations will be further discussed under headings (c) and (d). Meanwhile it may be noted that Drever has indicated four localities for calcsilicate ribs (quartz, basic plagioclase, pyroxene or hornblende, garnet) outside Grant Wilson's "felspathised" zone, but far from marginal to the micaceous gneisses (b) (1940, fig. 3, pp. 144, 146).

(b) The highly micaceous, or pelitic, gneisses occur near the western border of the map, and their outcrop, so far as it is included in the present district, terminates in a tongue extending southwards from Glen Gour [NM 950 640] across Glen Tarbert [NM 910 600]. A common type is muscovite-biotite-gneiss "a coarsely crystalline rock with muscovite and biotite in large flakes, and with quartz and felspar, which may be scattered either more or less regularly throughout, or may be

arranged in layers, knots, and lenticles of varying size. The rock in places is flaggy, and alternates with layers of granulitic quartz-schist of Moine type, while in other places it becomes massive and coarse, and assumes the appearance of a foliated igneous rock. In certain parts of the present area it is much traversed with knots, strings and veins of quartzo-felspathic material, sometimes carrying muscovite or biotite, or even both micas, and the crystalline texture is often coarse" (Wilson *in* Sum. Prog. 1904, p. 66). In places muscovite is quite inconspicuous, and the rock is then a biotitegneiss. The material of the tongue which reaches south from Glen Gour affords a good example of this biotite-gneiss. (1916 edition)

The above description, if translated into modern terms, means that much of the band shown from the northern margin of Sheet 53 to beyond Glen Tarbert [NM 910 600] as pelitic Moine gneiss has suffered greatly from injection. Harry has modified its boundaries, more especially west of Lochan Dubh [NM 896 710] where he has transferred a considerable portion to the psammitic category. He has then interpreted the remainder (by far the greater part) as "composite granitic gneiss with a foundation of pelitic Moine Schist" (1954, p. 285, pl. xiv). In his mapping, what he decides to call composite granitic gneiss is about three times as abundant as what he leaves as injected pelitic schist, otherwise termed "oligoclase-biotite-quartz-gneiss"; and it shows a distinct tendency to occupy a central position in the combined outcrop. He further points out that his composite granitic "gneiss develops a subordinate amount of augen-gneiss". Thus in some slight measure his composite gneiss agrees with what Wilson mapped as "augen-gneiss (Sgùrr Dhomhnuill [NM 890 679])"; but Harry states that the summit of Sgùrr Dhomhnuill [NM 890 679] is composed of composite granitic gneiss devoid of augen (1954, p. 286) — in fact in his map he stops his augen ornament a mile to the south-west. E. B. B.

(c) The quartz-granulites are only shown separately on the map in a belt reaching south across Glen Tarbert [NM 910 600] to Cilmalieu [NM 898 557], and in small isolated patches, apparently outliers, on Meall a' Chuilinn [NM 893 614] and Maol Odhar [NM 885 577] further east. The main outcrop is flanked on both sides by banded, impure, siliceous gneisses of type (a), while the detached outcrops are completely surrounded by rocks of this character. At the head of Glen Galmadale the main outcrop swings round to the east and thus comes across the line of the minor outcrops already mentioned. This renders it probable that the tongue of micaceous gneisses (b), which terminates on the southern slopes of Glen Tarbert [NM 910 600], marks the core of a fold, since it occupies a symmetrical position midway between the main and minor outcrops of quartz-granulite (c).

It is quite uncertain whether the siliceous gneisses of type (a) lying on the west and south of the main outcrop of quartz-granulite are on the same horizon as those on the east and north. which come into contact with the micaceous gneiss (b). A good example of the interfolding of the western siliceous gneisses and the quartz-granulite is afforded on the mountain west of Maol Odhar [NM 885 577]. The crystallisation of the quartz-granulite is often exceedingly coarse, reminding one of the structure of glacier ice. H. B. M., E. B. B. (1916 edition)

The quartz-granulite (c) is relatively untouched by injection. The fact that its patches on Meall a' Chuilinn [NM 893 614] and Maol Odhar [NM 885 577] look like outliers has always made it probable that the belt of psammitic gneiss (a) and composite pelitic gneiss (b), separating them from the main outcrop, is antiformal — the same conclusion as has been later reached by Harry, but on rather more satisfactory grounds.

A problem is presented by the three-sided nature of the main outcrop of siliceous gneisses (a) as presented in Sheet 53. On one side we have the micaceous gneisses (b); on another the quartz-granulites (c); and on still another the marble-bearing group (d). No firm answer to this problem can be given. It is possible, for instance, that the quartz-granulites (c) outcrop in the surrounds of the Glen Scaddle "epidiorite", but not with sufficiently marked character to be separated by Grant Wilson from associated siliceous gneisses. At first sight this view seems supported by Dreyer, who has used the name quartzite for everything he saw of Grant Wilson's siliceous gneisses in the Glen Scaddle country; but he has explained that he calls quartzo-felspathic rocks quartzite so long as "the amount of quartz present is distinctly greater than that of felspar" (1940, pp. 147, 161). Other alternatives suggest themselves, for instance that the marble-bearing group (d) may be introduced by a sedimentary or tectonic discordance. Quartzite will presently be mentioned in group (d), but its associates seem to negative correlation with that of group (c).

(d) The Ardgour Marble was discovered by Mr. Wilson in 1902. It consists of a thick bed or beds of crystalline marble weathering pale grey [one bed measures 23 ft (Drever 1939, p. 502)]. The outcrops lie between Glen Gour [NM 950 640]

and Glen Scaddle [NM 950 680]. Specimens examined by Dr. Flett (S11176) [NM 9700 6376]; (S11177) [NM 9599 6620]; (S11178) [NM 962 661]; (S11179) [NM 9700 6376]; (S11181) [NM 958 657] have been found to contain calcite, forsterite, colourless pyroxene, felspar, garnet, sphene and graphite in very variable proportions. [Drever adds wollastonite, scapolite, phlogopite, etc., but seems to suggest that forsterite is confined to baked carbonated serpentine.]

The marble is everywhere closely associated with portions of the Glen Scaddle igneous complex. It is accompanied in some of its outcrops by a thinly bedded series of slightly calcareous grey pelitic sediments, containing quartzose bands. These sediments have quartz veins developed along their bedding planes, but their degree of regional metamorphism is certainly not very high. Dr. Peach (*in* Sum. Prog. 1904, p. 66) has accordingly suggested that they have been protected through having been contact-altered by the Glen Scaddle intrusions prior to the period of movement. (Compare the protection of hornfels round the augen-gneiss of Inchbae, Ross-shire, first interpreted by Peach. Clough, Crampton, Flett 1910; 1912, chaps. v, vi.) As will appear immediately it is certain that the introduction of the Glen Scaddle Complex antedated a large part of the schist-making movement; it is doubtful, however, whether it is older than the whole of the movement. In one locality the dioritic rock is crowded with inclusions of quartzite, gneiss, etc., including some of pelitic character containing much kyanite [corrected to sillimanite, Drever 1940, p. 145; *cf.* (S41717) [NM 960 654]]. Here the foliation of the containing rock is indistinct, and it seems as if some of the inclusions may have been foliated before their immersion in the igneous magma. (1916 edition)

This last observation was due to Clough and the writer. It was based upon an exposure within a fork of the Bealach Choire nam Muc [NM 960 660] stream-system. The stream junction, resulting in this fork, can scarcely be distinguished as such on the geological Sheet 53; but it occurs at Nat. Grid [NM 962 659] at the head of a half-mile strip of alluvium, which last is easy to identify both on Sheet 53 and in the field. Drever has illustrated the locality with a large-scale map extending 700 yd north-west of the stream junction (1940, p. 148). His map covers the type area, including the best exposures of the sedimentary associates of the Ardgour marbles found anywhere in the Glen Scaddle district.

A specially good marble outcrop runs for 300 yd along the more north-easterly of the two streams of the fork, and there are several others; but, most of the sediment seen is non-calcareous pelite and quartzite, and it usually occurs as enclosures in what is spoken of above as dioritic rock. The exposure to which Clough and the writer directed attention is near the more south-westerly stream, 200 yd upstream from the fork, and there are many like it.

One of the two days the writer spent with Johnstone in 1956 was devoted to this critical area. We took the precaution in advance to ornament the outcrops on Drever's map, which otherwise are very difficult to read. Anyone, however, without this map will find in Sheet 53 a rough and ready guide sufficient for intelligent sampling of the field evidence. Exposures are numerous and easily accessible, and clearly lie just about the margin of the Coire nam Muc [NM 960 660] outcrop of Glen Scaddle "epidiorite".

Above we have referred to Peach's suggestion that the Ardgour marble and associated sediments had been "contact-altered by the Glen Scaddle intrusion prior to the period of movement". It so happens that Peach, in conversation with Crampton over hand-specimens, had been the first to suggest the pre-movement date of hornfelsing round the Inchbae — Càrn Chuinneag augen-gneiss of Ross-shire, an idea since brilliantly vindicated. It was natural therefore that he should hazard a similar interpretation in connexion with the hornfelses that Grant Wilson found adjoining the Glen Scaddle "epidiorite". Now however, it is thought that this interpretation requires important adjustment, and that the regional metamorphism later than the Glen Scaddle "epidiorite" is of the nature of a minor recurrence.

This change of outlook started when Clough and the writer, as recorded above, suggested that some regional metamorphism antedated the intrusion of the "epidiorite", although we considered the degree of this pre-hornfels metamorphism to be "certainly not very high". Dreyer, with incomparably fuller knowledge of the district, has also been satisfied "that in Ardgour the rocks have been subjected to regional metamorphism on two occasions separated by a period when a large mass of basic magma invaded and thermally altered the limestone-pelite group" (1940, p. 164). To the evidence already cited he added the observation" that relics of pelitic hornfels and limestone entirely enclosed in diorite-gneiss [his usual term for the Glen Scaddle "epidiorite"] are often flat-folded or highly contorted" (1940, p. 164). This, he pointed out, is "a feature of the Ardgour hornfelses which has no parallel in the Càrn-Chuinneag area" (1940, p. 168).

In regard to the intensity of the pre-hornfels regional metamorphism, Drever was cautiously prepared to admit that it might have been considerably higher than Clough and the writer had envisaged. "The presence of basic plagioclase in the calc-silicate rocks not associated with the diorite-gneiss, and the development of sillimanite in the thin rare bands of pelitic schist at some distance from the diorite-gneiss, and the relative coarseness of grain exhibited by the quartzites are features", he says, "which might conceivably be ascribed to the effect of a more general regional metamorphism of a high (sillimanite) grade", (1940, pp. 163–4) — and of pre-hornfels date. The calc-silicate rocks here mentioned are the ribs referred to above under heading (a). The sillimanite is fibrolitic sillimanite, not the stout prisms common in the hornfelses, and it is associated "with injection or segregation veins principally composed of potash felspar". Drever gives the locality as Glen Gour [NM 950 640], one third of a mile from the margin of the "epidiorite" (1940, p. 147). He also points out that hornfelsing may have obliterated evidence of previous metamorphism, and argues that the final post-hornfels folding of the district was conducted at a moderate temperature since it has not developed garnet in the metamorphism of any rock that he regards as part of the Glen Scaddle "epidiorite" (1940, p. 164). After returning to Bealach Choire nam Muc [NM 960 660] with Johnstone in 1956, the writer is prepared to accept the suggestions quoted above from Drever's account, with the supporting comment that some of the hornfelses do look under the microscope as well as in the field as if hornfelsing had been imposed on previously foliated rocks (S41714) [NM 960 660]; (S41715) [NM 960 658].

Drever has dealt rather fully with the petrology of both the calcareous and pelitic hornfelses. The more characteristic minerals of the former have been mentioned already. Those of the latter include garnet, sillimanite, spinel, cordierite, oligoclase, biotite, corundum (1940, p. 159). The reader is referred to the original accounts. Let us here concentrate on a matter upon which, so far as ultimate interpretation is concerned, agreement has not yet been reached. It concerns the "dioritic rock", recorded by Clough and the writer as "crowded with inclusions of quartzite, gneiss, etc". This problematical rock constitutes most of the exposures in the type area within the designated stream-fork of Coire nam Muc [NM 960 660]. It also, with varying composition, is stated by Drever, more generally, to be "one of the most characteristic rocks" that occur "in association with limestone" on the border of "the large epidiorite masses" (1940, p. 146).

For Clough and the writer, and again for Johnstone and the writer, this "dioritic rock" appears to be a marginal extension of the Glen Scaddle "epidiorite", enclosing and baking adjacent sediments through which in places it manifestly breaks. At the same time specimens sliced in 1956 from the Clough-Bailey exposure show that it is far from being normal Glen Scaddle "epidiorite" with pyroxenes and amphiboles. Instead it is an abnormal garnetiferous biotitediorite rich in oligoclase accompanied by subordinate quartz and orthoclase (S41716a) [NM 960 656]; (S41718) [NM 960 652]. The garnet is sometimes associated with groups of minute grains of green spinel. Similar garnet and spinel are common in many of the abundant rock enclosures. Also some of the biotite of the diorite is micropoecilitic. There seems no doubt to the writer that the diorite here is an igneous rock, derived from the Glen Scaddle "epidiorite" magma much contaminated through reaction with its numerous enclosures.

This dioritic rock is apparently Drever's "oligoclase-quartz-garnet-chlorite rock" (the chlorite secondary after biotite), which he treats as a local variety of what he calls in his text and on his map "sillimanite-gneiss". Of the latter he says (1940, p. 165), apart from the general coarser grain of the composite gneiss the main difference between it and the relics of pelitic hornfels lies in the absence in the former of cordierite and the development of relatively large sillimanites which may form clusters". He thinks of this "sillimanite-gneiss" as essentially a sedimentary rock, affected by "a certain amount of permeation" from adjoining "epidiorite"; and he gives two analyses, which certainly recall sediment rather than "epidiorite" ((Table 1), ii, iii). Still he notes that "contact with the epidiorite is a gradual one and there is no hard and fast line between coarse sillimanite-biotite-gneiss, coarse biotite-gneiss, and biotite-rich epidiorite quot; (1940, p. 146).

From what we saw of the variety at Coire nam Muc [NM 960 660], Johnstone and the writer feel that the term sillimanite-gneiss is unfortunate, for the matrix-rock does not have a gneissic appearance, but looks like a variable plutonic igneous product, sometimes a bit sheared. Apart from this the two views come very close in conveying an idea of chemical composition, for the one sees the rock as igneous with sedimentary contamination, while the other claims it as sediment with igneous contamination. It is only when we come to interpret its mode of emplacement that opinions differ strongly. Drever holds that, "in spite of the 'xenolithic' character of the composite pelitic gneiss there is no justification in concluding that it behaved like a contaminated magma" and it is important to remember that he has studied the subject intensively, whereas the writer has only seen the Coire nam Muc [NM 960 660] area. The main explanation that he offers of the difference between matrix and apparent xenoliths runs as follows:-During the sedimentation period, the bedded

pelite was, he thinks, affected by slumping, so that it passed into a mush with enclosures of unbroken mud, etc. Then in ensuing ages the "epidiorite" magma arrived and furnished hot solutions which permeated the mush matrix, but "did not so effectively penetrate the enclosed relics" (1940, p. 165). Drever also thinks that there may have been a certain amount of tectonic breakage, before the magma arrived on the scene, which is a possibility that probably all would admit.

(Table 1) Glen Scaddle Epidiorite and Sillimanite-Gneiss

	I	A	II	III
SiO_2	51.79	51.75	54.02	60.28
Al_2O_3	11.88	13.7	22.15	18.72
Fe_2O_3	0.67	{9.5}	0.77	0.30
FeO	10.66		6.64	6.03
MgO	8.51	9.2	2.22	2.68
CaO	7.92	8.5	1.54	2.44
Na_2O	2.37	2.0	214	3.43
K_2O	1.22	1.0	5.93	2.60
H_2O+	0.70		2.68	1.45
$H_2O–$	0.30		0.75	0.65
TiO_2	2.92	c.1.2	1.06	1.07
P_2O_5	0.64		tr.	tr.
MnO	0.19		0.16	0.15
CO_2	—	—	—	—
Total	99.77		100.6	99.80
Sp. Gr.	3.00		2.78	2.73

Analyses I, II, III by W. H. Herdsman, quoted from Drever (1940, pp. 153, 157).

I. "Epidiorite", Glen Scaddle.

A. Corresponding "average rock" of Devonian igneous series deduced from graphs, (Figure 38), p. 205.

II Sillimanite-gneiss "marginal" to "epidiorite", Coire nam Muc [NM 960 660].

III Sillimanite-gneiss", mixed from Coire nam Muc [NM 960 660] and Coire Dubh [NM 985 653].

Let us pass on. Drever has made an important point in claiming that the limestone-pelite group, with its associated "epidiorite" which in its main outcrops he interprets as a mighty sill, structurally overlies all other rocks of the district (1940, pp. 149, 151). He bases largely on dips south-west of Bealach Choire nam Muc [NM 960 660] and again south-west of Coire Dubh [NM 985 653]. In both cases the dips are towards the north-east and bring on limestone, pelite and "epidiorite". Admittedly the evidence of dips alone would place the limestone-pelite outcrop of Bealach Choire nam Muc [NM 960 660] on a lower structural horizon than that occupied at Coire Dubh [NM 985 653]; but Dreyer, probably correctly, duplicates the structural succession by inserting a curving fault as north-eastern boundary of the Bealach outcrop of limestone, pelite and "epidiorite". Such a fault suits Grant Wilson's mapping tolerably well, except that it is drawn across a digitate protrusion of "epidiorite" shown on Sheet 53 as extending towards Meall Dearg Choire nam Muc [NM 974 655]. Drever deals with this supposed protrusion (1940, fig. 3, p. 144) by treating it as "numerous epidiorite sills", companions of the main mass, intruded well below the level of the limestone-pelite group. It is unfortunate that Drever gives no direct evidence in his text to support his fault; but in the figure just quoted he writes "fault and shatter belt" along part of its course, while Johnstone and the writer further north-west noted an appropriate feature at the foot of Meall an Tairbh [NM 967 662].

Having made a good case for interpreting the main "epidiorite" outcrops in Coire nam Muc [NM 960 660] and Coire Dubh [NM 985 653] as parts of a single great sill intruded into the limestone-pelite group, Drever expands this hypothesis to include the extension of the Coire Dubh [NM 985 653] "epidiorite" outcrop right across Glen Scaddle to Druim Leathad nam Fias. As will appear presently (p. 124), Clough, the writer and Dreyer, all think that most of what has been mapped

on Sheet 53 as Felspathised Sedimentary Gneiss corresponds roughly with a stratigraphical unit, distinct from the surrounding siliceous gneisses (a). If this be accepted, then Dreyer's conception of a single great sill can scarcely be doubted. Otherwise we have to rely mostly upon continued association of the "epidiorite" with the limestone pelite group. Admittedly evidence for such association is meagre in the main Glen Scaddle "epidiorite" outcrop, except along 21 miles of south-western margin through Coire Dubh [NM 985 653]; but Drever has succeeded in finding "sillimanite-gneiss" on the eastern margin at Nat. Grid [NN 009 679] (1940, fig. 2, and N.E. corner, fig. 5, pp. 143, 147), and pure limestone a little in from the same margin at [NN 009 662] (1940, fig. 2).

In the Bealach Choire nam Muc [NM 960 660] belt, where the association of "epidiorite" with the limestone-pelite group is universal, the combined outcrop terminates north-westwards as soon as the external north-easterly dip, already noted along its south-west margin, swings round to become south-easterly (Drever 1940, fig. 3). This affords strong confirmation of Drever's view that here the "epidiorite", etc., in their whole breadth, overlie the "felspathized sedimentary gneisses" and the more external siliceous gneisses (a).

A similar termination of the main "epidiorite" outcrop is found north of Glen Scaddle, but marginal association with limestone or pelite has not been noted at this locality (1940, fig. 2). Beyond to the west, Sheet 53 shows a detached major outcrop of "epidiorite" crossing the end of Druim Leathad nam Fias. While this has not been reinvestigated, its position on the map suggests a reappearance of the Bealach Choire nam Muc [NM 960 660] band. If such be its true nature it would likely mean that Drever's curving fault bounding the latter is a low-angled thrust.

Returning to the main Glen Scaddle outcrop of "epidiorite", we get a further strong suggestion of synformal disposition on comparing the southwestern and north-eastern margins, along both of which limestone-pelite association has been established. The external schists dip inwards on the south-west side whereas they stand almost vertical on the north-east. Altogether Drever's conception of a Glen Scaddle Synform striking north-west, and furnished with a core of the limestone-pelite group intruded by "epidiorite", seems well grounded on the local evidence. It receives further strong support from the probability, already indicated, that the siliceous gneisses (a) to the north-west structurally overlie the micaceous gneisses (b) of Meall nan Damh [NM 920 745] and Meall Mòr.

If we accept the Glen Scaddle Synform as a reality, then we must regard the siliceous gneisses (a), outcropping to the north in the "steep belt" of Cona Glen [NM 955 720] (p. 117), as rising from under the "felspathic sedimentary gneisses"and"epidiorite" of the Glen Scaddle complex. We must also expect these steep siliceous gneisses to connect antiformally with their continuation mapped by Wilson with north-easterly dip in the comparatively "flat belt" north of Cona Glen [NM 955 720] in Sgùrr an Iubhair. Johnstone and the writer hunted for direct evidence on this latter point, but found nothing conclusive. Well up the north-east face of Cona Glen [NM 955 720], for a mile west of Allt a' Chnaip, the north-easterly dip recorded west of Sgùrr an Iubhair summit swings round to a little north or south of east with an inclination of about 50°. Also in the lower reaches of Allt a' Chnaip, 200 yd upstream from a farm-road bridge, there is a good exposure of an antiform pitching south-east. Both these observations favour the expected antiformal connexion; but too little is seen in the critical valley bottom to inspire confidence. For instance, the observed antiform might near at hand be neutralised by an unobserved synform.

Drever considers that he has recognised a minor stratigraphical break at the base of the limestone-pelite group, but it is safer to regard the whole question of relationship as unsettled. He has further suggested that while the rocks below should be considered as Moines, the limestone-pelite group may be Dalradian (1940, p. 151). If comparison be restricted to the north-west side of the Great Glen Fault, it is tempting to look for the allies of the Ardgour limestone-pelite group in the varied assemblage of Shetland.

The rocks entering into the Glen Scaddle Complex have been classified by Mr. Wilson (1901, p. 45) as follows:

1. Epidiorite.

2. Granulitic gneiss [feispathised sedimentary gneiss of Sheet 53].

3. Diorite dykes, cutting granulitic gneiss and the surrounding gneissose flagstones [group (a) of this chapter].

4. Grey basic dykes, now represented by hornblende-biotite-schists; these cut (1), (2), (3) and the gneissose flagstones.

5. Granulitic gneiss and Aplite (Porphyrite) dykes; these cut (1), (2), (3), (4) and the gneissose flagstones. (1916 edition)

The granulitic gneiss (2) of the above list may be taken first, as it is considered to be largely sedimentary — in the index of Sheet 53 it is shown as "felspathized sedimentary gneiss". The joint visit by Cough and the writer was undertaken largely to form an opinion as to its nature, and as to the propriety of separating it on the forthcoming one-inch map. Clough approached the difficult problem with intimate experience of what are mapped at Glenelg (Sheet 71) as Moines "permeated by pegmatites" — usually classed as injection products. His conclusion was that Wilson's mapping supplied a valuable approximation, that the rock should be separately shown on Sheet 53 with the title quoted above, and that the writer should insert the following paragraph in the 1916 memoir.

The more important epidiorite outcrops are surrounded by a felspathised zone of granulitic gneiss (S8235) [NN 0084 6893] from 150 to 300 yds. in breadth (Wilson *in* Sum, Prog. 1899, p. 40). A typical exposure of this felspathised zone is afforded by the River Scaddle [NM 960 682] near a small waterfall, half a mile above the junction of the river with the Cona. It is a fine-grained, banded rock in which close examination reveals a most unusual proportion of fairly idiomorphic felspar. The felspathic material appears to have been superimposed upon a thinly bedded, fairly pelitic sediment, considerably more pelitic, for instance, than that which gives rise to the siliceous gneisses occurring farther downstream. The felspathised rock has suffered very extensive shearing after the consolidation of the introduced felspathic material; in fact, it is quite possible that all the movement chronicled in the rocks of the district followed the epoch of intrusion, but this has not been proved for certain. (1916 edition)

Drever apparently considers the so-called felpathised sedimentary gneisses as mere sedimentary variants of the more siliceous gneisses, without significant late introduction of felspathic substance. The felspars, he finds, are orthoclase and oligoclase in any proportion (1940, p. 162). Interbanding of more or less felspathic types he attributes to interbedding. Contact with his "sillimanite-gneiss" (p. 121) he describes as gradual. On the whole, he says, the felspathic granulite becomes coarser on approach to the main "epidiorite", but its most interesting feature in this position is that it contains, fragments, which though distinguishable, are still closely similar to itself. This reminds him of how the "sillimanite-gneiss" commonly includes fragments of sillimanite-hornfels (1940, pp. 147, 149).

Drever finds complex folding in the felspathic zone away from immediate proximity of the "epidiorite". "Much, if not all, of this folding"he regards as"clearly due to slumping" (1940, p. 149). He has also noted that the part of the felspathic granulite adjacent to, or interbanded with, the "sillimanite-gneiss" holds fragments of banded heavy-mineral sediment, rich in sphene and iron ore. These, he says, "were formed almost undoubtedly by original slumping" (1940, p. 163); but it may be well to suspend judgement. Drever further realises that quartzo-felspathic veins traverse some of the fragments in a manner suggesting that mobile granitic material existed in the granulite during its crystallisation.

On comparing Clough's and Drever's interpretations of the felspathic gneiss or granulite, it will be noted that they agree in holding that the felspathic zone roughly corresponds with a group that originally differed from the underlying more siliceous Moines. Clough was prepared to believe that there had been considerable chemical modification by introduced felspar constituents — he probably was quite doubtful as to how much. Drever seems to have thought that there was little or no reinforcement from outside.

The difference may be less than appears at first sight, for Clough was one who thought auto-injection an important possibility. Thus, speaking of the Moines "permeated by pegmatites" at Glenelg, he notes that they occur in regions of high metamorphism, and continues: "As the pegmatite patches are usually edged with a sheath of rock which is much richer in biotite than the rock further away, it is suggested that they represent segregations derived from the immediately adjoining rock, rather than injections of foreign materials. This suggestion is, perhaps, somewhat strengthened by the frequent occurrence of small pegmatitic spots or augen, varying in size from a hazel nut to a duck's egg, which appear to be quite isolated in the rock" (1910, p. 83). Most authors, however, think that the injection complexes of Glenelg, etc., have received a large proportion of their quartzo-felspathic material from a distance. On the other hand, the Glen Scaddle felspathic granulites are not normal injected products. Their felspar is distributed, rather than concentrated. "It is a point of importance", Drever says (1940, p. 149), "that pegmatite veins are not a prominent feature though occurring in certain

places"; and he categorically states that the felspathic granulite "is not confined to the belt which surrounds the epidiorite masses, but occurs again in thick and extensive beds farther up Glen Gour".

The writer agrees with Clough and Drever that the rocks of the felspathic zone have not been developed through alteration of siliceous gneisses of group (a); and he is also inclined to favour Drever's view that their peculiar chemical composition is an original sedimentary feature.

Let us now turn back to the "epidiorite", item (1) in the table on p. 124:

1. The main epidiorite mass [of Glen Scaddle] is of somewhat irregular shape. It stretches north-westwards from Loch Linnhe, with one important interruption, for about half a dozen miles, and it has a maximum breadth of rather less than three miles. In texture the epidiorite varies from coarse to medium, and is generally of a dark grey colour, which, at several points not far from the margin, gives place to red. It appears to have been originally a diorite and, to a large extent, it has escaped conspicuous alteration. It is often massive or imperfectly foliated (S8233) [NM 9922 6837], but in many instances it is in a thoroughly gneissose condition. Mr. Wilson (Sum. Prog. 1899, pp. 40–2) found that the foliation commonly strikes between 15° and 25° west of north, and that it is parallel to the foliation of the surrounding sedimentary gneisses.

There are many isolated masses of epidiorite in connection with the Glen Scaddle Complex, and perhaps the numberless lenticles of hornblende-schist found intruded among the sedimentary gneisses of the Glen Tarbert [NM 910 600] district belong to the same suite. The small mass of epidiorite by the roadside at Gearradh [NM 959 608], between Glen Gour [NM 950 640] and Glen Tarbert [NM 910 600], consists of dark foliated rock resembling that of which the lenticles are composed. The Inversanda [NM 940 595] outcrop at the mouth of Glen Tarbert [NM 910 600] is a grey dioritic rock, much shattered owing to the proximity of the Loch Linnhe fault, but with very little foliation. The detached outcrops between Glen Gour [NM 950 640] and Glen Scaddle [NM 950 680] are in every way similar to the main mass of Glen Scaddle.(1916 edition)

The structural significance of the association of the Glen Scaddle "epidiorite" with limestone and pelite, especially well seen at Bealach Choire nam Muc [NM 960 660] and Coire Dubh [NM 985 653], has already been discussed somewhat fully, under heading (d). Here we may add that the minor "epidiorite" outcrop, which north of Inversanda Bay [NM 940 595] forms a hill called Creag nam Bà [NM 948 600] on the six-inch map, has yielded Drever calc-silicate-hornfels of a type represented at both the localities just mentioned. It would therefore appear possible that the major Glen Scaddle "epidiorite" sill has been folded down to ground-level at Inversanda [NM 940 595].

Drever has supplied an analysis from Glen Scaddle, quoted on p. 122. Except that it has quite unusually high TiO_2, it agrees wonderfully closely with Analysis A placed alongside for comparison. This latter gives the composition expected of an "average rock" of like silica percentage in the Devonian suite of chapter 17. One notices especially the low alumina, high magnesia and rather high potash. Drever says: "The essential minerals are the two pyroxenes (which are present in about equal amount) and plagioclase. The amount of hornblende and biotite is variable. Ilmenite, apatite and interstitial quartz are prominent minor constituents, and microperthite found irregularly replacing plagioclase or forming antiperthitic structure is very often present but in variable amount. Myrmekite may be found associated with microperthite. A specimen from Coire nam Muc [NM 960 660] has fresh pyroxenes with considerable biotite and microperthite" (1940, p. 152). Such descriptions suggest the augite-diorites and monzonites of the Devonian suite, and one is not surprised to hear of minor outcrops of appinite and paid otite.

The question naturally arises as to whether the Glen Scaddle "epidiorite" may not belong to this Devonian suite — which, it is thought, may have started to intrude in pre-Devonian times. Perhaps an answer will eventually come based on physical rather than geological research. Meanwhile it must be remembered that a monzonitic diorite in Colonsay (60 miles to the south-west) has been shown by Wright (1908; Wright and Bailey 1911, chaps. v, vii) to be intermediate in date between two cleavage-making movements that have folded the local Torridonian. This Colonsay augite-diorite.is associated with kentallenite and appinitic hornblendite, so that its place in the Devonian suite is admitted by all.

The following comments concern Items (3) to (5) of the table on p. 124:

"(3) In Cona Glen [NM 955 720] the river-section for a distance of half a mile, below the keeper's house, exposes numerous foliated diorite dykes from 2 to 30 ft broad which traverse the flagstones. Some of these in turn are cut by small dykes of granulitic gneiss and veins of aplite. To the south-east of Glen Scaddle several broad diorite dykes cut both the acid gneiss [Item 2, p. 124] and the flagstones" [Group a, p. 117]."

"(4) Eleven foliated grey basic dykes, now represented by hornblende-biotite-schists, were mapped last year on the southern slopes of Glen Scaddle (S8236) [NM 9831 6819]<ref>Teall says this rock differs from ordinary hornblende-schist in that the felspar tends to be lathy and zoned. He is "inclined to regard it as igneous" (Sum. Prog. 1899, p. 141).</ref>. They intersect both the epidiorite and the granulitic gneiss [Item 2], while two in Cona Glen [NM 955 720] traverse the flagstones [Group a]."

"(5) On the south side of Glen Scaddle [NM 950 680] the epidiorite is cut by a large number of dykes and veins of foliated granulitic gneiss (S8234) [NM 9922 6837].<ref>T. R. M. Lawrie says this rock is identical with certain fine-grained felsparphyric sheets recently reported by the West Highland Unit from near Loch Shiel [NM 900 800] and Loch Arkaig [NN 100 910], west and north of Sheet 53. These are described as "possibly of trondhjemitic affinities" and occasionally foliated but younger than the regional pegmatites (Sum. Prog. 1953, p. 36).</ref>. Similar dykes have also been mapped to the southeast of Corrlarach [NM 960 722] in Cona Glen [NM 955 720], intersecting the flagstones" [Group a] (Wilson *in* Sum. Prog. 1901, p. 46). These aplite veins are often more foliated than the surrounding epidiorite (Wilson *in* Sum. Prog. 1899, p. 41). Like the Scourie dykes of the North-West Highlands these veins have been specially picked out by shearing movement. More than this, the epidiorite was evidently foliated, in some cases, at least, before the introduction of the aplite veins. The latter are frequently sheared more or less parallel with their length in marked discordance with the general direction of the older and frequently much ruder foliation developed in the surrounding epidiorite. The shearing of individual veins has extended for a short distance into the epidiorite, and the older foliation of the latter has sometimes been dragged sharply round into parallelism with the newer structure of the adjacent vein. These phenomena of intermittent intrusion and foliation recall the sequence which has been worked out in the Lizard Complex in Cornwall (Flett 1912, pp. 22–25).

Just as there are abundant lenticles and sills of hornblende-schist, the connection of which with the Glen Scaddle Complex is uncertain, so too, there are abundant pegmatite veins cutting the surrounding sedimentary gneisses, which can only be assigned to this complex with a certain amount of hesitation. These veins are, some of them, massive, some foliated, and the same vein may be massive in one part of its course and foliated in another. One pegmatite may often be seen cutting another. Small sills of hornblende-schist intruded into quartz-granulite [Group a] and cut by pegmatite may be seen in the crags north of Loch nan Gabhar [NM 970 632]. In this case the igneous rocks may be referred with high probability to the Glen Scaddle Complex which is represented in force a little farther north-east. (1916 edition)"

Drever points out that sheets of "epidiorite" and hornblende-schist of variable dimensions occur both in the "felspathised sedimentary gneisses" of Sheet 53 and in Wilson's flagstones (Group a) alongside; and that they are sometimes so numerous as to constitute a basic injection complex (1940, p. 149). He also gives details of appinite occurring as sheet-like masses in the former (1940, p. 145).

The 1916 edition includes a short account of the Sgùrr Dhomnuill augen-gneiss, which it says has a very irregular margin against adjacent schists, in part due to injection. Later work ascribes the gneiss to injection phenomena (p. 116). The statement by Peach and Wilson that "it is seen to cut some small masses of epidiorite and hornblende-schist, but in turn is pierced by later dykes of that material" (Sum. Prog. 1904, p. 68) presumably still holds.

Small portions of the Strontian Granodiorite Complex projecting into Sheet 53 from the west, and certain red granite outcrops along Loch Linnhe will be dealt with shortly in chapter 15. The latter are accompanied by felspathised border rocks, which are locally responsible for outcrops included on Sheet 53 under the title "felspathised sedimentary gneisses". E. B. B.

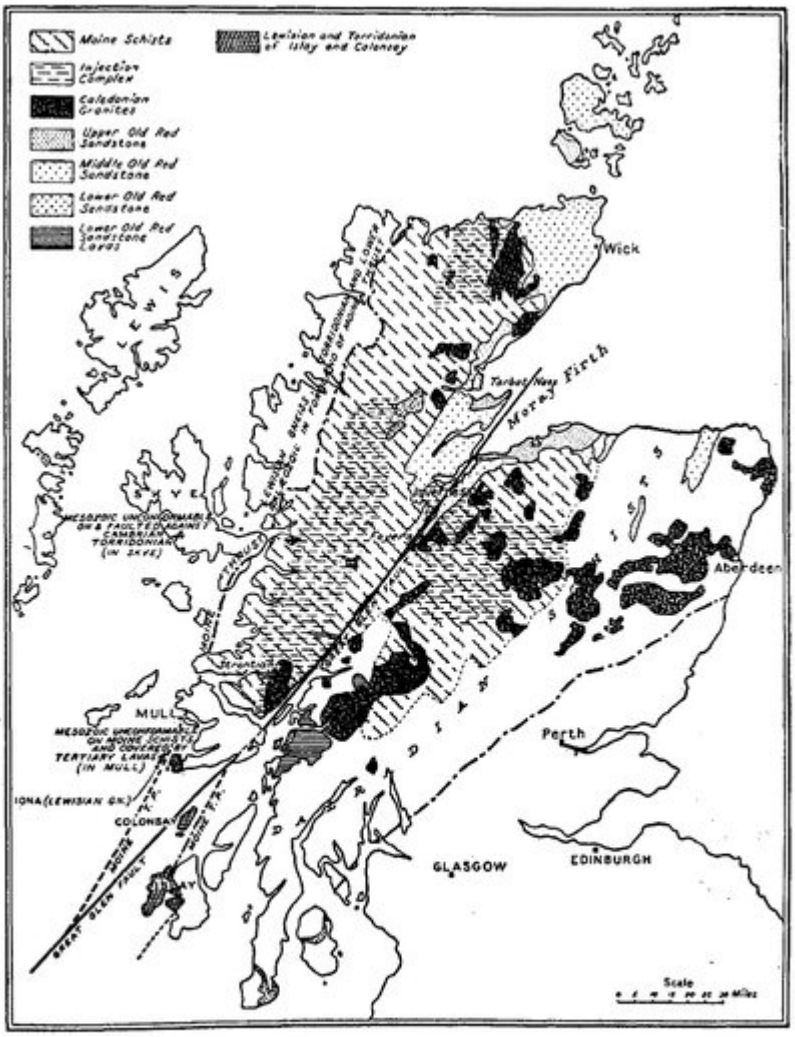

FIG. 40. Geological map of the Scottish Highlands to show the present position of the Moine injection complexes, the Strontian and Foyers granites, and the Moine Thrust-plane, after W. Q. Kennedy

(Reproduced, by permission, from *Quart. Journ. Geol. Soc.*, vol. cii, pt.i, 1946, fig. 2)

(Figure 40) Geological map of the Scottish Highlands to show the present position of the Moine injection complexes, the Strontian and Foyers granites, and the Moine Thrust-plane, after W. Q. Kennedy (Reproduced, by permission, from Quart. Joum. Geol. Sot., vol. cii, pt.i, 1946, fig. 2).

TABLE 1

Glen Scaddle "Epidiorite" and "Sillimanite-Gneiss"

	I	A	II	III
SiO_2	51·79	51·75	54·02	60·28
Al_2O_3	11·88	13·7	22·15	18·72
Fe_2O_3	0·67	9·5	0·77	0·30
FeO	10·66		6·64	6·03
MgO	8·51	9·2	2·22	2·68
CaO	7·92	8·5	1·54	2·44
Na_2O	2·37	2·0	2·14	3·43
K_2O	1·22	1·0	5·93	2·60
H_2O+	0·70		2·68	1·45
H_2O-	0·30		0·75	0·65
TiO_2	2·92	c.1·2	1·06	1·07
P_2O_5	0·64		tr.	tr.
MnO	0·19		0·16	0·15
CO_2	—		—	—
Total	99·77		100·06	99·80
Sp. Gr.	3·00		2·78	2·73

Analyses I, II, III by W. H. Herdsman, quoted from Drever (1940, pp. 153, 157).

I. "Epidiorite," Glen Scaddle.

A. Corresponding "average rock" of Devonian igneous series deduced from graphs, Fig. 38, p. 205.

II. "Sillimanite-gneiss" marginal to "epidiorite," Coire nam Muc.

III. "Sillimanite-gneiss," mixed from Coire nam Muc and Coire Dubh.

(Table 1) Glen Scaddle "Epidiorite" and "Sillimanite-gneiss".

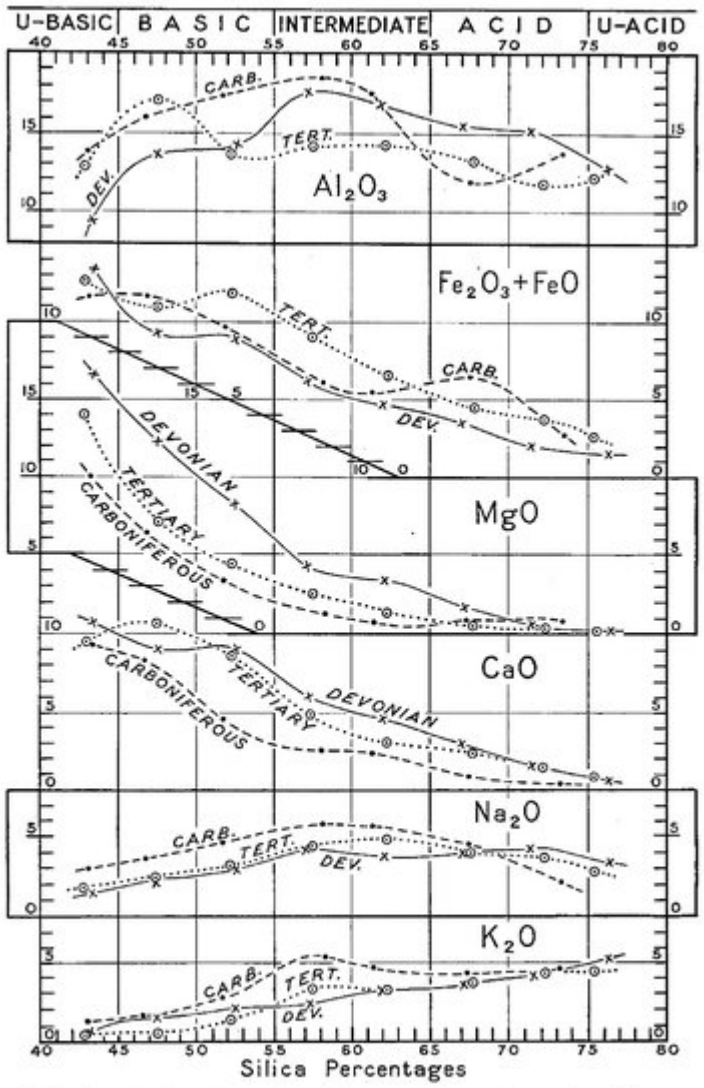

FIG. 38. Graphs comparing average analyses of igneous rocks spaced according to SiO_2 percentages. Tertiary and Carboniferous for all Scotland, Devonian for South-West Highlands

(Figure 38) Graphs comparing average analyses of Scottish Tertiary, Carboniferous and Devonian igneous rocks, the last-named restricted to S.W. Highlands.