Chapter 30 Post-Cambrian igneous rocks of older date than the great thrust-movements of the region: their petrography

By J. J. H. Teall

The post-Cambrian igneous rocks described in the last chapter have been shown to occur as plutonic masses and as sills or dykes, but without any lavas or effusive types.

i. Plutonic masses

The principal plutonic mass stretches from the neighbourhood of Ledbeg for about five miles in a south-easterly direction, with an average width of rather less than one mile. Cnoc-na-Sroine (1306 feet) forms the culminating point. This mass is by no means uniform in composition. It includes granite, quartz- syenite, melanite-syenite, nepheline-syenite, and borolanite; while the outlying patches which occur as satellites to the main mass supply additional varieties such as acmite-granite and pyroxenite.

The rock which forms the hill of Cnoc na Sroine is a red granite, remarkably poor in ferro-magnesian or any other dark-coloured constituents. The amount of quartz is variable. Sometimes this mineral is present in considerable quantity, and the rock is then a true granite; at other times it is rare or absent, and the rock becomes a syenite. A typical specimen from the burn behind the inn at Aultnacallagach (S3082) [NC 25 12] is a coarse-grained red granite or quartz-syenite, composed mostly of felspar, but containing also a few blebs of quartz and some insignificant dark specks representing a ferro-magnesian constituent. Under the microscope two felspars are recognisable. The plagioclase occurs in more or less idiomorphic crystals, which are often zoned and always twinned on the albite plan. The twin lamellae are numerous and very narrow. The second felspar occurs in large irregular plates, and shows moiré-structure under crossed nicols; it is often twinned on the Carlsbad plan, and frequently contains inclusions of idiomorphic plagioclase. Quartz occurs in irregular grains. The ferro-magnesian mineral is represented by minute scales of chlorite.

When the powder of the rock is placed in a diffusion column three well-marked bands are formed, one corresponding to quartz, which is present only in small quantity (2.65), another corresponds to albite (2.62), and a third to orthoclase. Although the specific gravity of the plagioclase practically agrees with that of albite, the extinctions on M-flakes are slightly less than those characteristic of this mineral — 15° to 17°, as against 19°. The optical characters of the second felspar agree with orthoclase. Of the two felspars albite is the more abundant.

Another specimen (S3090) [NC 25 12] from Cnoc na Sroine (about six miles south of Inchnadamff) is very similar in general appearance, but contains less quartz. In this rock the two felspars are intimately intergrown, and often take on the character of microperthite. Other red rocks from the same mass are true syenites, without quartz, and these sometimes contain pseudomorphs after nepheline as well as accessory melanite (S3083) [NC 25 12]. The felspars are either orthoclase or micro-perthite.

The greater portion of the area which is composed of plutonic rocks is occupied by varieties similar to those above described, but on the margins and to the south-east other varieties occur.

The most important of these varieties are grey or black in colour, and contain melanite as an essential constituent. On the one-inch map the south-eastern portion of the plutonic area is coloured as borolanite, but this area is by no means uniform in composition. Typical borolanite is best seen in the small burn named Allt a' Mhuilinn on the six-inch map, and in the area to the east of this burn. The burn has no name on the one-inch map, but it may be easily recognised as it crosses the road about one and a quarter mile east of the inn at Aultnacallagach. Between the eastern end of Loch Borrolan and Allt a' Mhuilinn the crags overlooking the road are formed of rocks which contain less melanite than the typical borolanite, and may be appropriately termed melanite-syenite. They are largely composed of grey orthoclase, with variable amounts of green biotite and melanite. Micaceous pseudomorphs, precisely similar to the so-called liebenerite, and presumably after nepheline, are sometimes present. The grains of melanite are sometimes surrounded by an

opaque border reminding one of that which commonly surrounds the hornblende in hornblende-andesites. In some cases only a trace of melanite substance remains, and in others none at all.

Melanite-syenites are not limited to the area in question. They occur also on the lower slopes of Cnoc na Sroine to the north, and in the Ledmore River between Loch Borrolan and the shepherd's house at Ledmore. Many interesting varieties may be collected from the last-mentioned locality. A specimen from a point 200 yards east of Ledmore Lodge, close to the Ledmore River (S9920) [NC 249 120], is a medium-grained mottled rock in which the light and dark coloured constituents are unequally mixed. The constituents are orthoclase, melanite, green biotite, alteration products after nepheline, sphene, epidote, and apatite. Another specimen from the Ledmore River not far from the above (S9923) [NC 250 121] is a dark grey. medium-grained melanite-biotite-syenite, verging on typical borolanite. The light-coloured constituents are orthoclase and micrographic intergrowths of orthoclase, and the alteration product after nepheline, such as occur in the psuedoleucites of the borolanite hereafter to be described.

Typical borolanite<ref>On Borolanite — an Igneous Rock intrusive in the Cambrian Limestone of Assynt. By J. Horne and J. J. H. Teall, *Trans. Roy. Soc. Edin.*' vol. xxxvii., Part I. (No. 11), pp. 163–178.</ref> is best seen in Allt a' Mhuilinn and in the area to the east. The crags overlooking the road immediately to the east of the burn furnish excellent exposures.

The rock is dark in colour and of medium-grain. It contains whitish patches, usually more or less spherical or ellipsoidal in form, but occasionally showing polyhedral boundaries. These patches vary considerably in size. The smallest are only just distinctly visible to the naked eye; the largest measure an inch or more across. Where the rock has been subjected to deformation during or subsequent to consolidation, the white patches take the form of lenticles or streaks.

The dominant constituents of the main mass of the rock are orthoclase and melanite; plagioclase, an alteration product after nepheline, and biotite come next in importance. Apatite, sphene, and iron-ores occur as accessory constituents.

Orthoclase is the principal felspar. Soda-felspar is comparatively rare. It occurs as small grains between large, irregular individuals of orthoclase, as grains in association with similar grains of orthoclase, and also as a constituent of micro-perthite.

Next to orthoclase, melanite is the most important constituent. It is black when viewed macroscopically, and possesses, when fractured, a somewhat resinous lustre. Good crystalline form is absent, as a rule, but perfect little crystals may occasionally be observed. The dominant form is the rhombic dodecahedron {110}. The edges of this form are sometimes truncated by those of the icosi-tetrahedron {211}, exactly as is the case with the well-known melanite from Frascati. In thin sections the colour of the melanite varies from a pale to a very deep brown. The central portions are sometimes more deeply coloured than the margins, and sometimes the reverse relation may be observed. The borders of the differently tinted portions may correspond to the crystallographic outlines of the individual, thus producing true zonal structure, or they may be irregular. The individuals vary in size from very small grains, only 0.05 mm in diameter, to large crystals or irregular masses measuring 1 or 2 mm across. Iron-ore, sphene, and biotite occur as inclusions, and the mineral is both idiomorphic and allotriomorphic with respect to felspar. The biotite is black when viewed macroscopically. Cleavage flakes, examined with the microscope, appear dull dark-green by transmitted light and are nearly uniaxial. Thin sections at right-angles to the principal cleavage, when tested for pleochroism, change from dark-green to yellowish-brown. The individuals vary considerably in size, and are generally irregular in form. The larger flakes are often corrugated. Pyroxene. iron-ores, garnet, and occasionally felspar occur as inclusions.

Of the accessory minerals, sphene is the only one that deserves special mention. It occurs in the form of minute (0.03 x 0.07 mm) spindle-shaped granules, which are found only in the melanite. These granules sometimes occur so abundantly as to leave scarcely any of the isotropic garnet-substance between them in the thin sections. At other times they are entirely absent. If these melanites were isolated and analysed they would in general be found to be highly titaniferous, but this would not prove that titanium was present in the melanitemolecule.

Pyroxene is rare in typical borolanite, but it occurs in the associated rocks, some of which are true augite-syenites. When present it is usually without any very definite crystalline form, but sometimes the individuals are elongated in the direction

of the vertical axis and more or less idiomorphic in the prismatic zone. The forms recognisable are {110}, {010}, and {100}. The orthopinacoid {100} is always conspicuous when any trace of form is present. The mineral is green in thin section, but the tint is not uniform, the marginal portions being often more deeply coloured than the central parts. The maximum extinction is about 40°. All the above characters agree with those of the gegirine-augite known to occur in nepheline-bearing rocks.

The white patches already referred to as occurring in the typical borolanite of Allt a' Mhuilinn undoubtedly correspond to the pseudo-leucites described by Derby, Hussak, and J. F. Williams from the phonolites of Brazil and the leucite-syenites of Magnet Cove, Arkansas. Under the microscope these patches are in all cases seen to be aggregates. They are principally composed of orthoclase and an alteration product probably after nepheline. Micrographic intergrowths of orthoclase and the alteration product are not unfrequent.

In the majority of cases the rocks are massive and granitic in structure, but in some instances a well-marked foliation may be observed. In the foliated varieties the white patches have been drawn out into lenticles and streaks, and the structure both of the lenticles and of the matrix is then granulitic.

The rock most nearly allied to borolanite is unquestionably the "leucite-syenite" from the igneous complex of Magnet Cove, Arkansas, described by the late J. F. Williams.<ref>The Igneous Rocks of Arkansas, *Annual Report of the Geological Survey of Arkansas for 1890,* vol.ii.</ref> This rock is described by Williams as "a hypidiomorphic granular combination of pseudo-leucite, eleolite, orthoclase, and basic silicates, which presents a more or less perfect granitic structure, and is genetically connected with the eleolite-syenite dike-rocks". The pseudo-leucites are composed mainly of orthoclase and nepheline, as were, in all probability, those of borolanite, but they are more perfect in form. The ground mass of the leucitesyenite consists principally of eleolite, melanite, and orthoclase. A green pyroxene, biotite, and sphene are also present.

Melanite, according to Williams, "is found in varying quantities in the different specimens. In some it is almost entirely wanting, while in others it is very abundant. It is of a rich brown or yellowish-brown colour, decidedly zonal in its structure and isotropic in its optical characters…. In some cases more than half the area enclosed within the boundaries of the section consist of melanite material". This description leaves no doubt that these portions of the " leucite-syenite of Magnet Cove, which, by the way, contains no leucite, are practically identical with the borolanite of Assynt.

Outside the plutonic area of Cnoc na Sroine and its immediate vicinity, the only district in the North-West of Scotland where rocks allied to borolanite are known is in the Coigach district of West Ross-shire, about five miles to the north-west of Achiltibuie and about seventeen miles slightly south of west of Cnoc na Sroine<ref>A remarkable foliated rock, essentially composed of alkali-felspar, melanite, legirine, and biotite, occurs as an integral portion of the eastern Highland schists at a point half a mile east-south-east of Derry Lodge, Aberdeen. An analysis by Dr. Pollard gave the following result:

SiO_2	61.79
TiO_2	0.90
Al_2O_3	16.90
Fe_2O_3	3.10
FeO	1.07
MnO	0.19
CaO	2.44
MgO	0.90
K_2O	6.96
Na_2O	5.26
P_2O_5	0.34
H_2O at 105°	0.14
H_2O above 105°	0.29
	100.28

This rock has been referred to (*Summary of Progress* for 1900, 160) as aegirine-granulite. It is allied in chemical and minerarogical clliposition to the melanite-syenites of Assynt, and if of the same age, which is of course doubtful, it would prove that the crystalline schists of the eastern Highland are in part at least of post-Cambrian date.</ref>.

Here the late W. Gunn found two vertical dykes of a peculiar rock intrusive in Torridon Sandstone. The rock is of medium grain, brownish-grey, and massive. Lath-shaped cleavage faces of felspar may be seen with the unaided eye, and numerous black specks (melanite) with the assistance of a lens.

Under the microscope the rock is seen to be composed of orthoclase, nepheline and its alteration products, melanite, egirine, and biotite. The main mass is an aggregate of orthoclase and nepheline or its alteration product. Melanite is scattered through the orthoclase-nepheline aggregate in small idiomorphic crystals, which usually consist of a deeply-coloured nucleus surrounded by a pale external zone. Aegirine occurs in long slender prisms, which are idiomorphic in the prismatic zone.

The rock of the dykes contains less melanite than the typical borolanite of Allt a' Mhuilinn, from which it differs also in containing unaltered nepheline and Eegirine. An analysis of this rock by Mr. J. Hort Player is given below side by side with an analysis of the " leucite-syenite ' of Magnet Cove:

	I.	II.
SiO_2	47.8	50.96
Al_2O_3	20.1	19.67
Fe_2O_3	6.7	7.76
FeO	0.8	—
MgO	1.1	0.36
CaO	5.4	4.38
Na_2O	5.5	7.96
K_2O	7.1	6.77
H_2O Ign.	2.4	1.38
TiO_2	0.7	0.52
SO_3	0.4	—
MnO	0.5	tr.
BaO	0.8	—
Cl	—	0.25
	99.3	100.01

I Borolanite dyke, Camas Eileen Ghlais.

II "Leucite-syenite", Magnet Cove. Analysis by Noyes.

The borolanite of the low crag close to the main road and immediately east of Allt a' Mhuilinn is traversed by a coarse-grained pegmatite composed of orthoclase and an alteration product, presumably after nepheline. The orthoclase is in thick tables with conspicuous development of the clino-pinacoid, and the individuals often measure an inch or more across. The alteration product is either white or pale-blue. It shows aggregate polarisation, and is decomposed by hydrochloric and sulphuric acids, with the separation of gelatinous silica and the evolution of bubbles. The white substance has been separated and analysed by Dr. Pollard with the following result:

SiO_2	43.35
Al_2O_3	31.93
Fe_2O_3	0.78
CaO	1.53
MgO	0.28
K_2O	8.16
Na_2O	8.03
Li_2O	0.15

CO_2	0.57
SO_3	1.67
H_2O (105)	0.38
H_2O (above 105°)	5.47
	100.30

The state of oxidation of the iron was not determined.

A trace of manganese is present. The principal result of the alteration of the nepheline has been the removal of a considerable amount of soda and the introduction of water. The presence of sulphuric acid is remarkable, and suggests the presence in the original rock of a mineral of the Hauyn group. Chlorine was looked for but not found.

The presence of this pegmatite in the borolanite is of considerable interest in connection with the discovery of a boulder of true nepheline-syenite-pegmatite by Mr. Hinman on the east slopes of Coul More, about five miles west of Cnoc na Sroine, and, therefore, in the direction of the movement of the ice of the glacial period. The boulder measured 9 x 5 x 4 inches. Its component minerals are orthoclase, nepheline, and aegirine. The individuals of orthoclase are of a dull, dark, purplish-grey colour, similar to the orthoclase of the pegmatite vein above referred to, but larger, as the cleavage faces sometimes measure three or four inches across. Nepheline occurs in large masses measuring one or two inches in diameter. Neither of these two minerals possesses any decided superiority over the other so far as idiomorphism is concerned. Aegirine is present in the form of long slender prisms, sometimes measuring two or three inches in length by a quarter of an inch in breadth. It is sharply idiomorphic in the prismatic zone with development of the orthopinacoids and prismatic faces, and it pierces alike the orthoclase and the nepheline. In view of what is now known, there can be no doubt that this boulder was derived from the plutonic complex of Cnoc na Sroine; otherwise it might well have been supposed to have travelled from the Christiania district. From the description already given of the rocks of the complex, it appears that, although an alteration product after nepheline is fairly common in the melanite-syenites and borolanites which form the eastern portion of the mass, fresh nepheline is generally absent<ref>Mr. Coomaraswamy found a specimen containing fresh nepheline near the waterfall in Allt-a-Mhullin.</ref>. Great interest, therefore, attaches to the occurrence of comparatively unaltered nepheline syenite on the north side of Cnoc na Sroine, at the base of the slopes, and on the south side of the Ledbeg River. There are no large continuous exposures of this rock. It occurs in bosses protruding through the peat half a mile south-east of Loyne shepherd's house.

The best specimens of nepheline-syenite may be obtained from coarse-grained bands measuring only one or two inches in width, and traversing in a more or less horizontal direction a finer grained nepheline-melanite-syenite or borolanite. The bands do not appear to be separate intrusions, but merely coarse-grained portions of constituents (melanite and biotite). Taking a specimen (S3095) [NC 2 2] as a type, the weathered surface is seen to be rough, owing to the more rapid weathering of the nepheline, which has a dull-green, waxy appearance. The alkali-felspar is present in flat tables with d weathering of the nepheline, which has a dull-green, e rapid waxy conspicuous development of the clino-pinacoid, and the crystals are often twinned on the Carlsbad plan. Under the microscope the rock is seen to be composed of nepheline and alkali-felspar, in approximately equal proportions, with a greenish biotite and melanite as accessories. Both felspar and nepheline are present as large individuals, measuring half an inch or more across.

The principal varieties of the main plutonic mass and its satellites have now been described, and it remains only to notice one or two exceptional types.

A coarse-grained pegmatitic variety of acmite-granite may be observed above the bridge over the Ledbeg River near Ledmore Lodge. The constituents are quartz, microcline, albite or oligoclase-albite, and acmite, with pyrite as an accessory. Acmite occurs in long slender prisms. The pleochroism is faint and of the following type: X, brown; Y, yellow; and Z, brownish-yellow. Close to the above is another striking rock composed of pink orthoclase and a dull green substance, which is probably a pseudomorph after nepheline. The individuals of orthoclase often measure an inch across. Under the microscope the pseudo-morphs are seen to be confused aggregates of minute mica-scales, closely resembling the so-called liebenerite from the well-known liebenerite-porphyry of the Fleimser Thal in the Tyrol.

About one-third of a mile S.S.W. of Ledmore, in a small burn which runs into the Ledmore River, there occurs a small exposure of melanite-pyroxenite. It is a coarse-grained dark rock, mainly composed of green pyrosene, biotite, melanite, black iron-ores, and pyrite. This is the most basic phase of the borolanite magma known (specific gravity, 3.45–3.56).

A brief summary of the results of the petrographical examination of the plutonic complex and its satellites will now be given. The principal constituents of the different varieties of rock may be classed as follows:

Colourless	***Coloured***
Quartz	Melanite
Orthoclase	Biotite
Microcline	Aegirine-augite
Albite or oligoclase-albite	Aegirine
Nepheline	

The red rocks of Cnoc na Sroine and the pegmatite with pseudomorphs after nepheline are almost entirely free from coloured constituents, whereas the pyroxenite is almost entirely composed of them. Between these two extremes there is a regular gradation when the whole area is taken into consideration, and the most striking differences are seen to be due to a variation in the relative proportions of the coloured and colourless constituents.

Special interest attaches to a comparison of the colourless constituents found in the different kinds of rock. In the quartzose rocks no trace of the existence of nepheline is ever found: nearly the whole of the soda is present in albite or oligoclase-albite. In the quartz-less rocks nepheline or its alteration product is often present, either with or without a soda-felspar. As the amount of nepheline or its alteration product increases, the amount of soda-felspar diminishes, and finally, in the borolanite and nepheline-syenite-pegmatite, orthoclase is the only felspar present. These facts of paragenesis are strictly in accordance with what might be anticipated from the composition of the minerals. In albite the ratio of Na_2O : $A1_2O_3$: SiO_2 is 1:1:6, in nepheline it is 1:1:2. When silica is in excess, albite or oligoclase-albite is formed to the exclusion of nepheline, When it is less than that required for the ratio 1:1:6, but greater than that required for the ratio 1:1:2, albite and nepheline may coexist; when it is not greater than that required for the ratio 1:1:2, nepheline alone is formed.

The facts observed are in complete agreement with the principles laid down by Professor Iddings in his paper on the Chemical and Mineral Relationships in Igneous Rocks .<ref>*Journal of Geology,* 1898, p. 219.</ref>

In view of the frequent occurrence of anorthoclase in rocks which are more or less allied to those under consideration, it has been looked for, but no evidence of its existence has been found. The potash-felspar appears to be in all cases orthoclase or microcline; at the same time, it should be noted that micro-perthite is not uncommon.

The orthoclase and nepheline of the boulder of nepheline syenite-pegmatite found on the slopes of Coul More have been isolated and analysed by Dr. Pollard:

	Orthoclase	**Nepheline**
SiO_2	63.84	44.37
Al_2O_3	18.87	32.00
Fe_2O_2	68	1.53
CaO	0.18	0.47
K_2O	14.76	6.72
Na_2O	1.23	14.00
H_2O 105°	0.30	0.11
H_2O above 105°		0.87
	99.86	100.57

Sp. Gr. 2.556–2.510 2.60–2.68

The one mineral which is present in all the rocks of the district is orthoclase. It is found in the most acid granites, and is not entirely absent from the most basic pyroxenite. Between the granite and the pyroxenite are many intermediate varieties, which may be conveniently designated by such terms as syenite, nepheline-syenite, melanite-syenite, melanite-biotite-syenite, augite-syenite, and borolanite. The basic rocks occur on the margins of the main mass and in the outlying satellites.

ii. Sills and dykes

The phase of minor intrusions is represented by innumerable sills and a few dykes. Their distribution is well shown in the one-inch Sheets 101 and 107, and Inchnadamff forms a good centre from which they may be examined. On the one-inch maps the sills and dykes are represented as felsite and diorite; but for purposes of description it is convenient to recognise three main groups — felsites, porphyrites, and vogesites or spessartites (diorites on the map).

Felsites

The most acid rocks are usually pink, more rarely green, in colour and felsitic in texture. Sometimes phenocrysts of alkali-felspar are present, sometimes absent. Quartz is not present in porphyritic crystals, although the analyses show a considerable excess of silica. Ferro-magnesian minerals form an insignificant portion of the mass, and when recognisable are usually represented by aegirine.

Aegirine-felsites are well represented by a sill or dyke traversing the quartzite of the north shoulder of Cnoc an Droighinn, about a mile north-east of Inchnadamff Hotel, in a north-east and south-west direction. The average breadth of the exposure is about 30 or 40 feet. The main mass of the intrusion is a normal pink felsite, but on the north-west side the rock assumes a green colour, and in this variety minute needles of grass-green mgirine may be recognised with a lens.In a paper on "Nepheline-syenite and its Associates in the North-West of Scotland" (*Geol. Mag.,* 1900; pp. 385–392), the locality of this green felsite is given as Poll an Droighinn. This is a mistake. It is not exposed in the burn but on the hill, Cnoc an Droighinn, to the west of the burn.

Under the microscope the green variety (S2324) [NC 273 230] is seen to be composed of polysynthetic aggregates, representing original porphyritic alkali-felspars, streaks of micro-crystalline quartz, and a crypto- or micro-crystalline felspathic matrix, crowded with oracular microlites of mgirine. Similar microliter occur in the polysynthetic aggregates, just as they do in Professor Brögger's typical Grorudite, but they are far less numerous than in the matrix, where they are often so thickly crowded together as to form a felt-like mass. The larger microlites are green, but the smaller ones are colourless; both show the characteristic This properties of mgirine when isolated from the matrix. This rock was analysed by Dr. Pollard with the following result:

SiO_2	75.20	1.2450
TiO_2	0.12	0.0015
Al_2O_3	12.65	0.1238
Fe_2O_3	1.53	0.0095
FeO	0.28	0.0039
MnO	0.10	0.0014
CaO	0.60	0.0107
MgO	0.26	0.0064
K_2O	4.14	0.0439
Na_2O	5.67	0.0913
H_2O (105°)/H_2O (above 105°)	0.12	0.0066
	100.67	

From these figures we get the following composition of the rock<ref>Leaving unaccounted for TiO_2 0.12, FeO 0.28, MnO 0.10, MgO 0.26, Na_2O 0.12, CaO 0.60, H_2O 0.12.</ref>:

$K_2\ Al_2\ Si_6\ O_{16}$	24.54

$Na_2 Al_2 Si_6 O_{16}$	42.08
$Na_2 Fe_2 Si_4 O_{12}$	4.41
SiO_2	28.04
	99.07

The ratio of ortholcase to albite is therefore 1 : 1.82.

Another specimen of acid felsite from a burn a quarter of a mile north of the top of Sgonnan More (S8370) [NC 307 144] consists of numerous phenocrysts of pink felspar, usually giving rectangular sections about a quarter of an inch across, embedded in a compact light-grey felsitic matrix. Under the microscope the phenocrysts are seen to consist of intergrowths of albite and orthoclase similar to those often present in the plutonic mass of Cnoc na Sroine. The ground mass is a micro- or crypto- crystalline aggregate of alkali-felspar and quartz, together with a few minute ragged prisms of aegirine.

The porphyritic felspars and matrix were separated and analysed by Dr. Pollard:

	Porphyritic Felspar	Matrix
SiO_2	66.73	74.44
Al_2O_3	19.05	14.72
Fe_2O_3	{0.86}	1.17
FeO		0.17
CaO	trace	trace
K_2O	6.69	3.99
Na_2O	6.59	5.82
H_2O (185°)	0.17	0.06
H_2O (above 105°)	0.20	0.26
	100.29	100.63
Orthoclase	37.63	23.64
Albite	56.41	49.36
Silica	—	25.15
	96.04	98.15

The ratio of orthoclase to albite is therefore:

Porphyritic felspars	1 : 1.51
Matrix	1 : 2.21

The felspars are thus seen to be intergrowths of albite and orthoclase having the composition of Professor Brögger's cryptoperthite.<ref>*Zeit. f. Kryst,* 1890, p. 529.</ref>

Porphyrites

The most striking rock belonging to this group is the so-called Canisp porphyry. This is a handsome rock composed of large tabular crystals of oligoclase-albite, measuring half an inch or more in their largest diameter, embedded in a red ground-mass. Brick-red crystals of orthoclase are sometimes present. Under the microscope egirine-augite and biotite may be recognised as minerals of primary consolidation. The ground-mass is a micro-crystalline aggregate of quartz and turbid felspar. The porphyritic felspars from this rock were analysed by Dr. Heddle, and his analyses show that the orthoclase contains but little soda (1.69 per cent.) and the plagioclase but little potash (1.13 per cent.). The plagioclase corresponds to $Ab_9 An_1$ and, like that of the more acid rocks belonging to the Cnoc na Sroine complex, is closely allied to albite.

The other members of the porphyrite group all contain hornblende, and in this respect are allied to the vogesites and spessartites of Professor Rosenbusch. They occur abundantly in the Assynt district, and typical examples may be obtained at Loch nan Cuaran, at the head of Allt Pol na Droighinn (three miles north-east of Inchnadamff). The most

usual type (S9934) [NC 290 237] consists of numerous small phenocrysts of oligoclase, rarely measuring more than a quarter of an inch across, and still smaller phenocrysts of hornblende, embedded in a dark-grey matrix. The phenocrysts of oligoclase may be either white or red, and they form about one-third of the entire mass of the rock; under the microscope they sometimes show zonal structure, but the successive zones do not differ markedly in optical characters, and the average composition, as proved by specific gravity, is that of oligoclase. The crystals of hornblende are sharply idiomorphic and green in colour. The secondary minerals arising from the alteration of hornblende are epidote and chlorite. The felspars not unfrequently contain numerous minute scales of secondary mica. The ground-mass is a micro-crystalline aggregate of quartz and felspar.

The following analysis of one of these oligoclase-hornblende porphyrites, which is intrusive in quartzite at the base of Beinn an Fhurain, has already been published<ref>Notes on some Hornblende-bearing Rocks from Inchnadampff. J. J. H. Teall, *Geol. Mag.,* 1886, p. 346.</ref>:

SiO_2	63.41
Al_2O_3	16.92
Fe_2O_3	2.67
FeO	2.96
CaO	4.32
MgO	2.08
Na_2O	5.18
K_2O	2.36
Ig.	0.64
	100.54

Special interest attaches to the above type of porphyrite from the fact that it occurs in intimate association with Moine-schists on the shore of Loch Broom, at Lech Melm Wood, near Ullapool. As many as a dozen bands of more or less foliated rock may here be seen alternating with dark-coloured platy mica-schist of typical Moine character. The bands vary from a foot to an inch in thickness. The phenocrysts of plagioclase stand out prominently on the weathered surfaces, and, in the markedly foliated varieties, give the rock somewhat the appearance of a fine-grained "augen gneiss". The phenocrysts of oligoclase are precisely similar to those of the normal porphyrite, but the matrix is different. It is a foliated aggregate of alkali-felspar, quartz, epidote, and biotite. The igneous and the sedimentary rocks have been simultaneously affected by powerful movements, and possess a common foliation.

Vogesites and spessartites

The dark basic sills which are so common in the dolomites of the Assynt district were originally termed diorites, and have been so mapped. They consist essentially of idiomorphic green hornblende and two felspars.

A pale-coloured pyroxene is often present, and is sometimes as abundant as the hornblende. Apatite and magnetite occur as accessories; carbonates, chlorite, and epidote as secondary constituents. Orthoclase and plagioclase are both present, but the condition of the rocks is such as to make it extremely difficult to determine which of the two predominates, and, therefore, to separate the vogesites from the spessartites in accordance with the classification proposed by Professor Rosenbusch for rocks of this type.

Since this description of borolanite and its associates was written, an important paper by Dr. J. Shand — Lieber Borolanit and die Gesteine des Cnoc na-Sroine Massivs in Nord-Schottland — has appeared. (*Neues Jahr. f. Min.., etc.,* Beilage Band xxii., 1906, p. 413) In this paper the author classifies the rocks as follows: Quartz-syenite, quartz-free syenite and pegmatite, nepheline-syenite, nepheline-augite-pegmatite, borolanite and leucite-borolanite, nepheline-borolanite, augite-sodalite-syenite, aegirinesyenite, aegirine-felsite and pyroxenite.

He describes the rocks in detail, and records the presence of sodalite in quartz-free syenite, nepheline-augite-pegmatite, borolanite and leucite-borolanite. He has carefully studied the peculiar intergrowths of orthoclase and a second mineral to which reference has been made, and has arrived at the conclusion that the second mineral was originally sodalite, not

nepheline, as suggested above.

There are many other points of interest in the paper, but these are the most important in which the author adds to or differs from the statements made in this chapter.