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## Chapter 17 Tertiary ring-dykes of Centre 2, Ardnamurchan (continued)

The intrusions to be described in this chapter are as follows (see Index Map, p. 201 (Plate 5)):

(c.) Quartz-gabbro of Garbh-dhail.

(c') Granophyre of Grigadale.

(c'') Older Quartz-gabbro of Beinn Bhuidhe.

(d.) Quartz-gabbro of Aodann.

The above intrusions are abundantly cut by the Inner Cone-sheets, excepting the Quartz-gabbro of Aodann which, as already mentioned, lies on the concave side of the belt of country traversed by these sheets (p. 207). Individually, the first three can hardly be said to conform to a ring-pattern, though, regarded collectively, they indicate an arrangement around Centre 2. The inner intrusive margins of the Quartz-gabbro (c) and the Granophyre (c') against the Old Gabbro (b) certainly conform to Centre 2. Also, the outer margin of the Quartz-gabbro, though in contact with a later ring-dyke, the Beinn nan Ord Eucrite (f), is a fine-grained marginal type of rock north-east and westwards of Beinn na Seilg, and runs parallel to its inner intrusive margin. The ring-fracture into which the Eucrite (f) was intruded would appear to have closely coincided with the outer edge of the Quartz-gabbro.

An interesting feature of the Quartz-gabbro (c) is the development of flinty crush-rock in its outer marginal portion, which was recognized by Mr. Bailey. This is, so far as is known, the first record of flinty crush-rock in British Tertiary igneous rocks.

### (c) Quartz-gabbro of Garbh-Dhail

Great variations in composition and texture occur throughout this mass. Generally, more basic and also finer-grained varieties are found in the exterior portion, while towards the inner margin more acid quartz-gabbro is prevalent. At several points within the mass quartz-gabbro may be seen to grade into quartz-dolerite with porphyritic felspar, which is found in other quartz-gabbro intrusions to occur as a marginal variety. A sharp, apparently intrusive, contact between different varieties of quartz-gabbro has been noted at one place, as described below. There seems good reason therefore to believe that we are dealing with a complex mass. Everywhere the mass is intruded by the Inner Cone-sheets, so that its components must, at any rate, all belong to approximately the same period.

The fine-grained marginal type along the outer margin is evidently baked. This is attributed mainly to the Eucrite of Beinn nan Ord, and, in the portion north-east of Beinn na Seilg, to the Quartz-gabbro (A) in addition (see pp. 265 and 285). The baked rock, where it forms a ridge along the summit of Beinn nan Ord, is in sharp contact on its inner eastern side with a more acid fine-grained quartz-gabbro. These two rocks were traced side by side along a north-west line for a few hundred yards, but their separation could not be carried farther. The marginal type can be traced eastwards around to the north-east side of Beinn na Seilg, where it comes next to the later Quartz-gabbro (A). In this vicinity, the fine-grained rock, when traced westwards, passes gradually into coarser-grained quartz-gabbro, and so appears here to be a definite marginal facies of a larger mass.

Flow-banding is sometimes seen, and is inclined inwards towards the Aodann Centre (2) at high angles.

Xenoliths are plentiful locally, and sometimes occur as bands of fine-grained basic rock — as in the Hypersthene-gabbro. Examples may be seen west of the N.–S. fault marked by a stream-hollow west of Beinn na Seilg, and 400 yds. south of a patch of marshy alluvium shown on the one-inch Geological Map (Sheet 51).

Acid veins traverse the xenolithic bands just mentioned, as well as the quartz-gabbro generally. They are perhaps most abundant north-west of Beinn na Seilg. That some of them, at least, were derived from the Garbh-dhail Quartz-gabbro

itself, during the later stages of its consolidation, is suggested by the fact that such veins are cut by the Inner Cone-sheets. North-east of Beinn na Seilg, where the Garbh-dhail Quartz-gabbro forms a roof to the younger Quartz-gabbro (A), an example of this relation was noted, and under the microscope the cone-sheet concerned ([S24445](#)) [NM 4617 6467] was found to be contact altered. The alteration is ascribed to the adjoining Quartz-gabbro (A). The pre-sheet acid veining cannot therefore be attributed to (A).

The effects of earth-stresses are frequently very evident. For example, in the area south-west of the Grigadale Granophyre, west of the Allt Grigadale, the Quartz-gabbro is cut to pieces with lines of shear, and is much broken up in appearance. Again, on the south-east shoulder of Beinn nan Ord and in the hollow immediately to the east, shear-lines and also bands of black flinty crush-rock are abundant. This linear shearing is of early date, preceding the intrusion of the Inner Cone-sheets. In no other mass in Ardnamurchan have such pronounced effects of earth-stresses been noted. They are even more marked than the shearing found along the course of the Loch Ba Fault in Central Mull<ref>W. B. Wright in Tertiary Mull Memoir, 1924, pp. 340, 341.</ref>

## Age relations

The intrusions that are both earlier and later than the Garbh-dhail Quartz-gabbro (c) are tabulated below, together with the kind of evidence on which their relative ages are based.

### Older intrusions

Hypersthene-gabbro (a)

Old Gabbro (b)

### Younger intrusions

Grigadale Granophyre (c')

Beinn nan Ord Eucrite (f)

Quartz-gabbro (A)

### Evidence of age

(c) marginal type against (a) non-marginal type

(c) chilled against (b)

### Evidence of age

(c') chilled against (c).

(f) marginal type against baked (c); (c) sheared and cut by minor intrusions (Inner Cone-sheets) next to (f) unshattered and uncut by minor intrusions

(c) cut by Inner Cone-sheets, both being baked next to (A) uncut by these cone-sheets

In the case of the above-mentioned younger intrusions, evidence of age will be dealt with in detail under the headings of these intrusions. Descriptions of contacts between the Garbh-dhail Quartz-gabbro and the older intrusions are given below.

Contact with the Hypersthene-gabbro (a) occurs eastward of Beinn na Seilg. In contrast to its condition on its outer margin, the Hypersthene-gabbro is on this, its inner side, a coarse grained rock. The Quartz-gabbro (c) alongside is, on the other hand, fine in grain, and is profusely cut by acid veins. The best locality for studying the contact is on the north-west side of the rocky summit of Stacan Dubha, north of the twin lochs and east-north-east of the higher, southern, peak of Beinn na Seilg. The evidence stated was considered, during the mapping of the junction, sufficient indication of the relative ages of the two masses, though further investigation might be profitable.

Contacts with the Old Gabbro (b) may be seen at several places. A good instance is situated west of the Allt Garbh-dhalach, northwest of a prominent wooded bluff formed of the Old Gabbro, and just south of a projecting tongue of the Quartz-gabbro shown on the Memoir-map. The Quartz-gabbro can be traced for some distance as a practically continuous outcrop up to its contact with the Old Gabbro, east of where a stream debouches from a small patch of bog. Here, grey-black quartz-gabbro with acid patches grades rapidly into a brown fine-grained quartz-dolerite, which is definitely chilled against the Old Gabbro, a black augite-rich rock. The marginal belt of quartz-dolerite is 3 or 4 yds. in width. It may be mentioned that along the west side of the wooded bluff referred to above, the marginal Quartz-gabbro is a fine-grained, brown-weathering dolerite, with gabbroid portions that appear to be acidified gabbro. The petrological characters of this type of rock will be described in detail in the case of the Aodann Quartz-gabbro (d) (p. 252). J.E.R.

## Petrology

The Quartz-gabbro (c) as exposed at Garbh-dhail ([S21816](#)) [NM 4512 6534] is a fairly fine-grained rock composed mainly of a moderately basic plagioclase feldspar and augite, with interstitial micrographic quartz and orthoclase, and accessory magnetite and apatite. The feldspar is much zoned and twinned. It is usually edged with a fairly wide zone of oligoclase-albite and a narrow border of orthoclase which is optically continuous with the orthoclase of the micrographic matter. The intergrowth of quartz and orthoclase occasionally forms an outer layer to the feldspars and presents definite crystal-boundaries towards the larger quartz-areas. The augite has a tendency towards idiomorphism, a feature which is encouraged by the relatively large quantity of fine-grained interstitial material. It has suffered alteration as the result of general reheating. It has evidently recrystallized with the separation of microscopic magnetite, and the occasional adoption of a micro-granular structure, without the destruction of the larger crystal-outlines. Biotite and hornblende are also developed as products of its alteration. The interstices between the larger crystals are filled mainly by a copious fine-textured intergrowth of alkali-feldspar and quartz, while an excess of the latter mineral has given rise to small patches of quartz without crystal-form. The abundance of accessory apatite is a feature common to most of the quartz-gabbros and quartz-dolerites, and stands out in contrast to the general paucity of this mineral in the quartz-free gabbros and eucrites.

Southwards towards Beinn na Seilg ([S21578](#)) [NM 4537 6454], ([S21560](#)) [NM 4634 6425] as well as northwards towards the Grigadale Granophyre ([S21574](#)) [NM 4419 6640], the rock is a fine-grained quartz-gabbro or quartz-dolerite with a somewhat variable texture and composition. The texture is controlled largely by the size of the constituent feldspars, and the composition by a variation in the amount of augite, iron-ore, and interstitial micrographic material. Towards its outer boundaries, in the direction of the Beinn nan Ord Eucrite, as has already been pointed out (p. 242), we encounter fine-grained and generally more basic types ([S21242](#)) [NM 4441 6531], ([S21484](#)) [NM 4417 6520], ([S24431](#)) [NM 4367 6611]. In these the feldspars appear to be richer in lime, and although albitized to some extent are less markedly zonal than those of the more acid varieties of the gabbro.

At the same time, the quantity of granophyric matter and free quartz is reduced to a minimum. The rocks thus exhibit more normal gabbroic and doleritic characters. Less frequently, as to the north of Beinn na Seilg ([S21515](#)) [NM 4575 6496], the rock passes into an olivine-gabbro of medium texture, which contains fresh olivine with subordinate hypersthene, a moderately basic labradorite feldspar and ophitic augite, with practically no accessories.

Included within the Quartz-gabbro of Garbh-dhail are masses of definitely earlier intrusions which have been entirely granulitized in the process of reheating to which they have been subjected. They are mainly fine-textured compact rocks that in some instances show traces of an original porphyritic structure ([S24433](#)) [NM 4347 6578].

These compact granulites ([S21579](#)) [NM 4534 6481], ([S22680](#)) [NM 4614 6471] consist of an aggregate of olivine, augite, plagioclase feldspar (labradorite to oligoclase), and, occasionally, a little quartz. Original olivine has frequently reacted with the feldspar and produced a reaction zone of augite between the minerals, and a separation of magnetite ([S24433](#)) [NM 4347 6578]. There is little doubt that these rocks were originally either dolerites or fine-grained gabbros.

An additional metamorphic change in these rocks, due presumably to intrusions later than the Garbh-dhail Quartz-gabbro, is noticeable in the production of secondary biotite ([S22680](#)) [NM 4614 6471] in the areas occupied by decomposed olivine and its associated magnetite-separations.

The Garbh-dhail gabbro-mass is remarkable for the intense shattering that has locally affected it, more particularly at and near its outer margin towards Beinn nan Ord. In all cases that have come under observation (p. 243), cases that are clearly indicated by special features in the field, the disruption that the rock has suffered is truly remarkable ([S24447](#)) [NM 4561 6476], ([S24405](#)) [NM 4374 6548]. This disruption is at any rate in part due to earth-movement, for bands of flinty-crush are encountered ([S24407](#)) [NM 4460 6463], ([S24408](#)) [NM 4460 6463], but explosive action also may have been operative. The feldspars of such rocks are mostly comminuted, and thus we meet with only a few quite small patches of fine-grained gabbro which have escaped destruction, and which are set in a thoroughly cataclastic matrix. These shattered rocks, as already stated, are mainly close to the Beinn nan Ord Eucrite. The latter mass has also been shattered throughout the greater part of its length, but in this case the shattering is attributed to explosion rather than to earth-movement, of later date than the disruption of the Garbh-dhail intrusion (p. 267). A similar metamorphosing and healing influence, however, has been at work in each case, for the shattered rocks both in the Garbh-dhail Quartz-gabbro

and Beinn nan Ord Eucrite have been more or less completely granulitized. In the case of the Quartz-gabbro, the Eucrite is, partly at least, the cause of the granulitization (p. 265). As pointed out in the case of the shattered granulites that occur in the Hypersthene-gabbro (a) (p. 231), the finer cataclastic material has yielded most readily to the metamorphosing influences, and the final structures and mineral assemblages are of a similar kind ([S24432](#) [NM 4367 6611], [S24448](#) [NM 4523 6451]). There is evidence that the Quartz-gabbro (c) was completely shattered before certain cone-sheets referable to Centre 2 were intruded, but that granulitization was effected in both ([S24404](#) [NM 4476 6460]).

A series of acid veins ([S24401](#) [NM 4335 6574]) and occasional dyke-like masses ([S24430](#) [NM 4365 6617]) cut the Garbh-dhail Quartz-gabbro but do not penetrate the Beinn nan Ord Eucrite (pp. 267, 281). They thus presumably belong, at least in part, to the gabbro itself, which, as already discussed, may be of multiple nature (p. 242). These acid veins are fine-grained, dark, white-weathering rocks that consist of a mass of quartzo-felspathic devitrified material containing a few small phenocrysts of andesine-oligoclase feldspar. H.H.T.

### **(c') Granophyre of Grigadale**

This mass occupies a peaty hollow traversed by the Allt Garbhdhalach east of Loch Grigadale (Figure 37). In composition, it is very uniformly a rather fine-grained granophyre of basic type. A well-exposed junction against the Old Gabbro (b) may be seen along a scarp bounding to the east the flat peat-covered area underlain by the granophyre, 250 yds. south of the track-road leading from Achosnich to Grigadale farm. The Granophyre is chilled to a felsite at the contact.

A contact with the Quartz-gabbro (c) is seen just east of the Allt Grigadale. Under the microscope, the Granophyre is found to be chilled against the Quartz-gabbro, which is shattered ([S24429](#) [NM 4376 6622]).

Another junction with (c) occurs at the south-east corner of the Granophyre outcrop, 130 yds. south-west of the Allt Garbh-dhalach. Only about 2 feet of the junction are on view on a flat rock-surface. The Quartz-gabbro grades rapidly into a marginal facies, a fine-grained rock with porphyritic feldspar, from which veins are intruded into a band of fine-grained basic rock. This band is in contact on its other side, along a clean-cut line, with the Granophyre, which is vertically jointed at right angles to the junction. This contact does not supply any good evidence of the age-relationship of (c) and (c'), though microscopic examination of the rocks concerned might be profitable.

A second, smaller mass of granophyre surrounded by the Garbhdhail Quartz-gabbro (c) has been mapped on the north-east side of Beinn nan Ord, south of the Grigadale mass (see (Figure 37)). Owing to poorness of exposure, no contacts with the Quartz-gabbro could be located.

The Inner Cone-sheets that so plentifully cut the Granophyre may be briefly referred to. They are more especially well seen in the western half of the intrusion. All contain abundant porphyritic feldspars, have well-chilled margins, and are steeply inclined at about 70 degrees. One individual noted contains numerous basic xenoliths probably of cognate origin, and was traced for some distance on either side of the Allt Garbh-dhalach, about 300 yds. eastward of where this stream enters Loch Grigadale. J.E.R.

### **Petrology**

(Anal. III; (Table 3), p. 84). — The Grigadale Granophyre as represented by the analysed specimen ([S22820](#)) [NM 437 664], which is typical of the mass, is a fine-grained, medium-grey rock speckled with a black ferromagnesian constituent. A few feldspars with bright cleavage faces of a millimetre or so in cross section are noticeable on freshly fractured surfaces, but otherwise the rock is very uniform in grain. A comparison of the analysis with those of the Tertiary granophyres of Mull and Skye shows that in general it is slightly less siliceous and richer in the albite end of the plagioclases than is usual, but the departure from the average type is, in reality, slight.

Microscopically (Figure 33)A, the rock consists of crystals of a medium plagioclase, zoned to albite and edged with orthoclase, which are packed fairly closely together in a fine-textured micrographic matrix of quartz and alkali-feldspar. The feldspar crystals range up to a millimetre in greatest dimension, and their alkali-feldspar edges, owing to their turbidity,

stand in contrast to the soda-lime felspar of their interiors.

Augite occurs sparingly, and with a somewhat sporadic distribution. It exists as partially resorbed crystals, turbid with magnetite, and it never appears to be in harmony with its surroundings. It would seem that the whole granophyre is basified to some extent, some parts much more so than others, by contamination with gabbro material. The analysed rock represents the least contaminated portion of the mass, but the resorption of basic material would quite well account for the slight departure of the composition from that of an average uncontaminated Tertiary granophyre. In other parts of the mass, evidence for basification is much more pronounced and conclusive. Here, the plagioclase crystals increase in size, and the proportion of magnetite-charged pyroxenic patches becomes much greater ([S21575](#)) [NM 4414 6640]. Although not much darker in general tint, the rock in this form has a more blotchy aspect. In extreme cases, the rock contains so much basic matter that it may almost be described as an acidified gabbro ([S21582](#)) [NM 4388 6638]. The basic clots consist of magnetite-charged pyroxenes which have suffered some resorption, granulitization, and recrystallization the last tending to produce an acicular habit. As a whole, the rock presents a more gabbroic than granophyric appearance; it has a relatively coarsely crystalline texture due to the size and frequency of the pyroxene crystals, but on a weathered surface the granophyric matter shows as a pure-white network that involves the darker constituents.

The Grigadale Granophyre, as stated above, is in contact with, and is chilled against, the Old Gabbro (b) (p. 246). The microscope demonstrates the fact that the gabbro is shattered at the junction and that there has been some absorption of gabbro-material by the acid rock ([S22282](#)) [NM 4429 6672].

The junction of the granophyre with the quartz-gabbro to the west (p. 246) exhibits a similar state of affairs. The gabbro has been shattered and locally acidified, while the granophyre at the contact exhibits an accompanying basification ([S24429](#)) [NM 4376 6622].

That the granophyre mass has been thermally affected by subsequent intrusions is suggested by the local development of secondary biotite, slight granulitization, and other metamorphic changes ([S24395](#)) [NM 4364 6660]. H.H.T.

### **(C'') Older Quartz-gabbro of Beinn Bhuidhe**

This rock-mass forms the rugged, southern side of Beinn Bhuidhe. In being earlier than the Inner Cone-sheets it differs from the Younger Quartz-gabbro (h) in contact, of which the remainder of Beinn Bhuidhe is composed. In rock-type it differs from the still older Quartz-gabbro (c), being everywhere a grey-black medium-grained rock with light-coloured streaks and patches of more acid character. The latter represent a granophyric mesostasis that is particularly well defined from the gabbroid portions. It bears a strong resemblance to certain varieties of the Old Gabbro (b) which is locally spotted with acid material, and it was indeed at one time taken to be an outlying portion of the Old Gabbro. <ref>Summary of Progress for 1922, *Mem. Geol. Surv.*, 1923, fig. 6; p. 99.</ref> But, since it presents a very fine-textured marginal facies against the Grigadale Granophyre (c'), and since this Granophyre clearly cuts the Old Gabbro, an age-difference seems apparent.

The locality where the marginal facies against the Granophyre is seen lies south of the Achosnich–Grigadale track-road, 600 yds. south-east of Grigadale farm, and just east of a stone wall, shown on (Figure 37). The black Quartz-gabbro (c''), as it is traced towards the Granophyre, becomes increasingly finer grained and lighter in tint, though still retaining its characteristic dull black hue. Actual contact with the Granophyre could not be established, and the possibility of the one rock grading into the other was at first considered, but closer scrutiny, aided by microscopic examination has made a break apparent between the marginal type, a fine-grained acid quartz-gabbro ([S24394](#)) [NM 4361 6668], and the adjacent granophyre ([S24395](#)) [NM 4364 6660].

Alongside the track-road leading to Grigadale farm, in the west half of the Quartz-gabbro, the latter is traversed by numerous Inner Cone-sheets inclined at angles of 65 to 70 degrees. J.E.R.

### **Petrology**

Petrographically speaking, this intrusion, which is of somewhat fine texture and dark grey in colour, is a gabbro in all stages of acidification. An acid magma, or partial magma, permeates microscopically the whole mass, but it is also collected into definite areas and strings visible to the unaided eye.

In its more basic varieties ([S22374](#)) [NM 4406 6692], the gabbro is a moderately coarse rock with constituents that range up to several millimetres. It is composed of zoned labradorite feldspar, schillered and somewhat corroded subophitic augite, rather copious iron-ore, and a coarse interstitial matrix of alkali-feldspar and quartz in micrographic intergrowth. Where in contact with the matrix, the plagioclase is edged with alkali-feldspar that is continuous with the orthoclase of the micrographic intergrowth, and in the case of the augite there are evident signs of resorption. South-east of the summit of Beinn Bhuidhe ([S21555](#)) [NM 4403 6707], near to where the mass ends against the Later Quartz-gabbro of Beinn Bhuidhe, the rock shows an increased amount of interstitial felsitic matter and a more marked albitization of the basic feldspars. These feldspars also exhibit corroded and regrown boundaries against the matrix and are turbid with schiller inclusions. Augite has practically disappeared except where protected from the acid mesostasis by a shield of basic plagioclase. In some cases reaction between the migrating acid matter and the basic constituents of the gabbro has resulted in the formation of biotite in moderately large flakes in a quartzo-feldspathic matrix ([S21279](#)) [NM 4386 6703]. In such rocks there is some indication of an early shattering of the mass, and albitization of the original feldspars is a prominent feature.

Towards the Grigadale Granophyre (c') there is a marginal change in the gabbro (p. 249). A number of specimens taken along a north and south line across the junction, to the east of Loch Grigadale, and representing a horizontal distance of about 150 yds., present the following features. About 100 yds. from the presumed junction the rock ([S24412](#)) [NM 4357 6674] has a moderately coarse doleritic texture and medium to dark-grey colour. It consists of elongated crystals of zoned labradorite-andesine feldspar, which are schillerized and bordered by a turbid fringe of alkali-feldspar. Enmeshed by these are abundant patches of partially resorbed augite with magnetite, and a copious matrix of alkali-feldspar and quartz in fine micrographic intergrowth. Sometimes the micropegmatite assumes the crystal boundaries of orthoclase.

Nearer to the granophyre the rock ([S24413](#)) [NM 4358 6671] keeps the same texture, but is somewhat lighter in tint and more blotchy in appearance, while there seems to be a tendency towards an acicular crystallization of some of its constituents. The microscope shows that the feldspars have taken on an idiomorphic habit, chiefly by regrowth and the addition of wide alkaline borders. This idiomorphic growth has to a great extent been permitted by reason of a greatly increased amount of acid mesostasis. The acid matrix is more definitely and more coarsely granophyric, and the proportion of obvious quartz is considerably greater. Remnants of partially resorbed augite are still abundant and sufficient to account for the relatively dark colour of the rock as a whole.

Still closer ([S24394](#)) [NM 4361 6668], the general tint is even paler than before, but continues considerably darker than the pale-grey speckled granophyre ([S24395](#)) [NM 4364 6660] of the Grigadale mass. There is very little change, here, in the microscopic structure except perhaps the more scattered character of the partially resorbed augite, and the segregation of free quartz into well-defined areas, in addition to its dissemination as an intergrowth with alkali-feldspar.

Passing to within the Grigadale mass itself ([S24395](#)) [NM 4364 6660], we find a granophyre that is intensely basified with gabbro material. The type of crystallization and the order of contamination are certainly similar in both rock-masses, and on these considerations alone it is impossible to decide which is the earlier intrusion. It does not follow, of course, because the granophyre is basified (p. 247), that it absorbed its basic material from the particular gabbro now in contact with it, and the converse argument applies to the acidified gabbro. The field evidence, however, as set out above, seems conclusively in favour of the gabbro being the later injection. H.H.T.

#### **(d) Quartz-gabbro of Aodann**

The position of this mass almost entirely within the belt of Inner Cone-sheets has already been referred to (p. 242). Only one porphyritic cone-sheet has been recorded as cutting it, at a point close to its boundary with the basalt lavas and agglomerates, 350 yds. south-west of Lochan an Aodainn. No contact between the intrusion and the Later Quartz-gabbro of Beinn Bhuidhe (h), which is later than the Inner Cone-sheets, has been located. Where the two masses probably join, in the vicinity of Achosnich, rock-exposure is poor across grass-covered fields.

The Quartz-gabbro (d) varies from place to place in texture, and also in the amount of the acid mesostasis. A fine-grained type, usually with porphyritic feldspar, forms a capping to a hill between Aodann and Lochan an Aodainn. It weathers with smooth pinkish-hued surfaces, and has the appearance of being slightly baked. Downhill, a normal-textured and less durable quartz-gabbro is found, and on the north and south slopes the change in type is abrupt, though to the west there appears to be a gradual passage. On the other hand, at an apparent contact on the north side between the two varieties, the fine-grained rock shows distinct signs of baking ([S24428](#)). Further, the two varieties differ in their marginal behaviour against the Old Gabbro (b), on the south side of the hill, north of Lochan an Aodainn. The upper, fine-grained, rock makes sharply-defined chilled contacts with the Old Gabbro, which is much veined by granophyre in the vicinity; while the lower, coarser, quartz-gabbro becomes hybridized near to contacts with the Old Gabbro, taking on a black hue on account of contained cloudy feldspars that are probably derived from the Old Gabbro ([S24427](#)) [NM 4574 6611], ([S21561](#)) [NM 4574 6611]. It is likely that there have been here two injections of magma, the first more quickly cooled and now forming a capping to the succeeding main injection. Farther north, the rock around Aodann, and by the roadside leading towards Achosnich, is a medium-grained quartz-gabbro with abundant grains of iron-ore, and with little acid mesostasis. It locally bears feldspar phenocrysts.

Perhaps the chief interest of the mass lies in its relation to the Old Gabbro, which has been referred to above. Some of the contacts may be briefly described. At the north end of the Old Gabbro, along the track leading from Achosnich towards Grigadale, quartz-gabbro grades rapidly into quartz-dolerite with porphyritic feldspar, which is in sharp contact with the Old Gabbro. The latter is coarse-grained and black in colour, and can be easily distinguished from the dolerite which is brown on weathered surfaces. Farther south, about two thirds of a mile west-south-west of Aodann, non-porphyritic brown-weathering quartz-dolerite, charged with coarse white-weathering acidified-looking gabbro, forms a broad zone extending for a hundred yards or more from the Old Gabbro, which is contact altered ([S22283](#)) [NM 4436 6649]. Sometimes the quartz-dolerite makes sharp contact against the coarse acidified gabbro, which thus appears to be xenolithic. More usually, the relation between the two is a merging one. The acidified gabbro will be described in more detail later (*see below*).

South-east of Aodann and south of Lily Loch (Lochan an Aodainn), the Quartz-gabbro close to contacts with the Old Gabbro becomes dull-black in colour, as has been already remarked of it at another point in the vicinity (p. 251). South of Lily Loch, it is especially clear that the Old Gabbro is intruded by the quartz-gabbro magma, which has penetrated along cracks and into angular spaces in the former, and which in these positions has crystallized as a brown-weathering quartz-dolerite. J.E.R.

## Petrology

The normal gabbro ([S21563](#)) [NM 4561 6432], if normal can be applied to so variable a rock, is a moderately fine-grained, dark-grey, speckled quartz-dolerite. It is composed of augite, rhombic pyroxene, zoned labradorite feldspar, and magnetite, with a little interstitial alkali-feldspar and quartz. The pyroxene occurs in patches and grains comparable in size to that of the feldspars, and has a distinct leaning towards idiomorphism. The augite is frequently schillerized and of a pale-greenish tint in thin section. The rhombic variety occurs in somewhat irregularly bounded crystals that have the well-marked pleochroism of hypersthene. Where of somewhat coarser texture ([S22339](#)) [NM 4553 6593], the rock might be described as a diallagic moderately coarse gabbro. The coarse areas occur in a xenolithic manner and often present quite sharp boundaries against the finer-grained material. In a section across such a junction ([S22339](#)) [NM 4553 6593], the coarser, xenolithic rock has been swamped by apatite-rich acid magma that has deschillerized the augite with which it comes in contact, albitized the basic plagioclase, and finally crystallized as a copious interstitial micrographic growth of quartz and orthoclase. The fine-grained rock with which it is in contact is of doleritic composition, but has a pronounced granulitic structure. It consists of augite in small rounded grains, moderately abundant magnetite, and a base of fairly acid plagioclase. The feldspar, which has a composition approximating to andesine, forms small elongated crystals for the most part, but is also segregated into larger areas without definite form. In this granulitic base occur large crystals of altered plagioclase, as well as of augite, which are of xenocrystal nature and are presumably derived from the coarser gabbroid rock. Occasionally the rock is definitely porphyritic ([S22335](#)) [NM 4513 6621], the porphyritic crystals being labradorite that has been schillerized, albitized, and regrown.

A strip of dark-grey porphyritic rock ([S21562](#)) [NM 4595 6619] separates the Quartz-gabbro (d) from the Old Gabbro (b) north-east of Lochan an Aodainn, and is evidently a portion of some older mass. It is an interesting rock, because in addition to porphyritic labradorite it contains moderately large phenocrysts of augite and olivine. It has been modified to some extent by the metamorphic action of the intrusions with which it is in contact. Felspars have been schillerized, albitized, and regrown; olivine, which is partly fresh, is surrounded by a reaction zone of rhombic pyroxene and biotite, while the matrix now consists of a subgranulitic mass of augite, hypersthene, and magnetite with irregularly formed laths of plagioclase (labradorite to oligoclase).

In nearly all these gabbro masses the chief interest lies in the nature of their contacts with adjacent rock-bodies, and much material has been collected and studied with the object of determining their mutual relations and their marginal characteristics. In the case of the gabbro under discussion, specimens have been chiefly collected adjacent to the Great Eucrite (E), and at its contact with the Felsite (j) south of Aodann.

At and near the junction with the Great Eucrite, to the east and north-east of Aodann, the gabbro (d) is fine textured and is perhaps more basic in composition than elsewhere, although quartz is present as an ultimate product of consolidation. Hypersthene and augite, the latter frequently ophitic and diallagic, are the dominant ferromagnesian constituents ([S22334](#)) [NM 4572 6635], ([S22327](#)) [NM 4574 6638], but olivine is occasionally encountered ([S22323](#)) [NM 4539 6653]. A still finer-textured rock from this neighbourhood, close to the Old Gabbro (b), is of similar composition. It contains moderately abundant rhombic pyroxene ([S24428](#)) [NM 4571 6618]. Most of these rocks show effects of contact metamorphism that must be attributed to the intrusion of the Great Eucrite of Centre 3. Such effects are variously the schillerization of the older felspars, albitization, deschillerization of diallagic augite, and granulitization of the matrix.

At its junction with the Felsite (j), situated some 500 yds. to the south of Aodann, the rock is fine grained and somewhat porphyritic, containing small porphyritic felspars, some half a centimetre in length. It is a dark-grey quartz-dolerite that approaches the Talaidh type in general characters ([S22338](#)) [NM 4515 6586], and shows occasionally a tendency towards a variolitic microstructure. Quite close to the felsite, the rock has been completely granulitized ([S22337](#)) [NM 4519 6590]. It consists of a plexus of lath-shaped labradorite-oligoclase felspars with ragged regrown edges, between which lie strings and small granules of greenish augite and strongly pleochroic hypersthene associated with magnetite. The porphyritic labradorite felspars are schillerized and albitized, and include abundant granules of pyroxene. Also, large areas are occupied by a secondary brown hornblende that exhibits a poecilitic structure. The intensely metamorphosed condition of the rock in this instance is probably due to the combined action of the Felsite and subsequent later neighbouring intrusions. Farther to the east, against the Old Gabbro (b) and the screen of basalt lava and agglomerate, the rock is of the coarser-grained type ([S24410](#)) [NM 4571 6586], ([S22312](#)) [NM 4568 6553], similar to that which bounds the Great Eucrite to the north, but is variable in the amount of acid mesostasis it contains.

A specimen ([S21567](#)) [NM 4496 6583] collected close to the Old Gabbro is a granophyre-gabbro hybrid, showing gabbro material undergoing resorption by acid magma that has solidified as a graphic inter-growth of alkali-felspar and quartz.

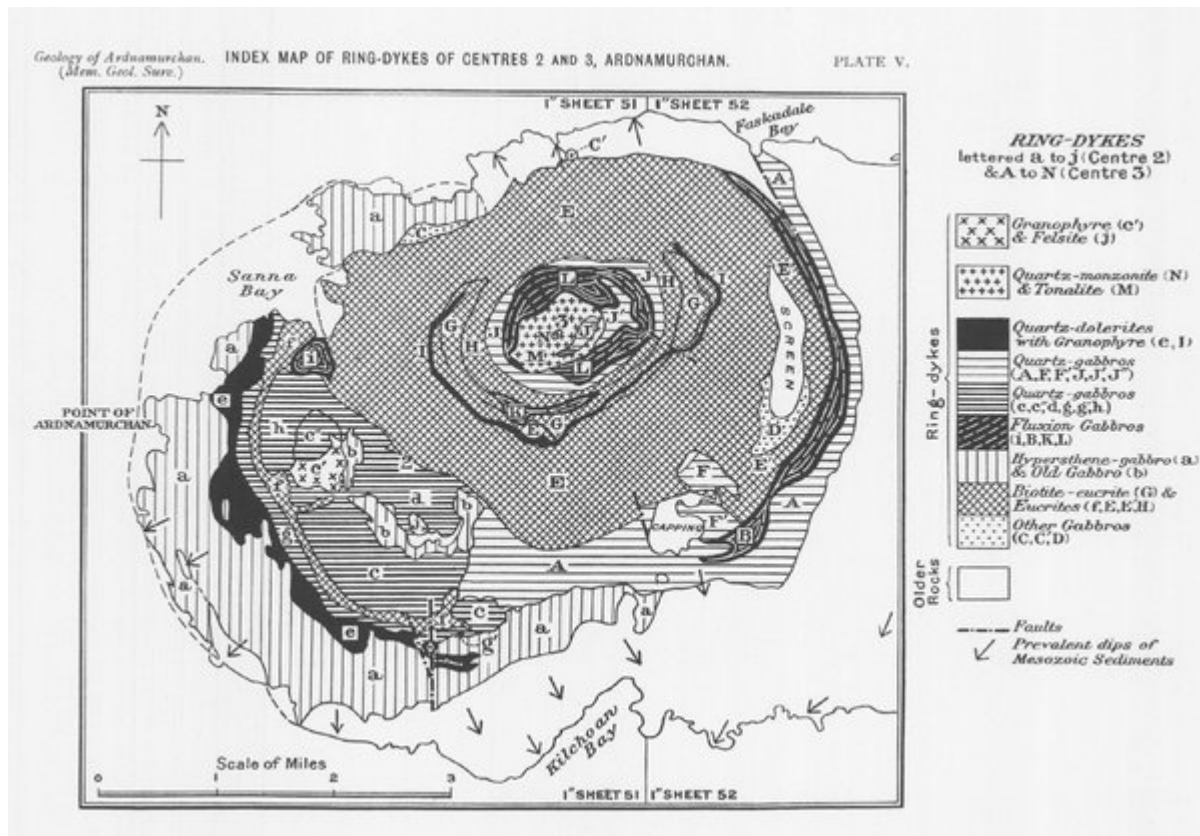
The gabbro east of Aodann encloses certain strips and patches of fine-textured dark rock that are xenolithic in character and certainly represent remnants of some older mass of quartz-dolerite composition. They are usually completely granulitized, with granulitic augite and subordinate rhombic pyroxene ([S22328](#)) [NM 4554 6643]. Their structure is similar to that of certain cone-sheets of which it is quite possible they are representative.

From what has been set out above it is clear that this mass, although behaving as a unit, is very variable in texture and composition, and it is more than probable both on field and petrographical evidence that it is of a multiple nature. In places the mass is clearly divisible, there being sharp contacts between coarse and fine-grained types (p. 251).

A somewhat remarkable rock ([S22329](#)) [NM 4550 6646] occurs at one of these contacts about 250 yds. east of Aodann. It is a finely crystalline dark-grey rock banded with coarser and lighter-coloured material. The fine portion may be described as an olivine-granulite consisting of small granules of fresh olivine which poecilitically enclose little rounded crystals of basic plagioclase, an occasional poecilomorphous augite, scattered well-formed magnetites, and a mosaic matrix of labradorite. The coarse bands contain abundant fresh olivine, ophitic schillerized augite, large plates of hypersthene, and bytownite to labradorite felspar, the whole with a gabbroid texture. The origin of this rock is obscure, as



it is much more basic than any parts of the gabbro. It is possible that it represents a modified mass of a still earlier and more basic rock. H.H.T.



(Plate 5) Geology of Ardnamurchan. Index Map of ring-dykes of Centres 2 and 3, Ardnamurchan. (Mem. Geol. Surv.)

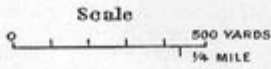
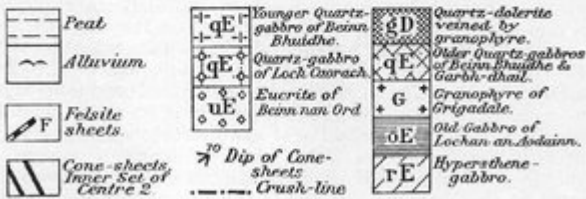
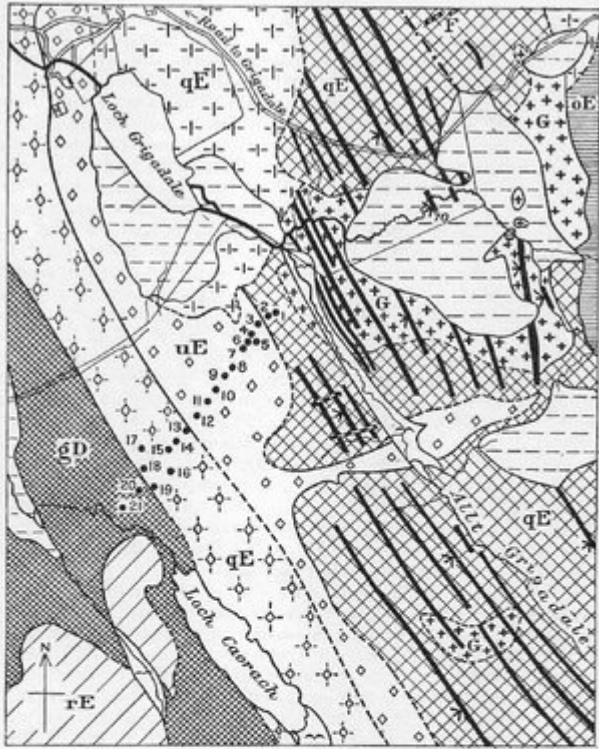


FIG. 37.—Map of portion of Ring-dyke Complex of Centre 2, north of Beinn nan Ord.

NOTE.—Localities of a serial collection of rock-specimens are indicated by black dots numbered 1–21 (see pp. 268–270, 274, 275).

(Figure 37) Map of portion of Ring-dyke Complex of Centre 2, north of Beinn nan Ord. Note. Localities of a serial collection of rock-specimens are indicated by black dots numbered 1–21 (see pp. 268–270, 274, 275).

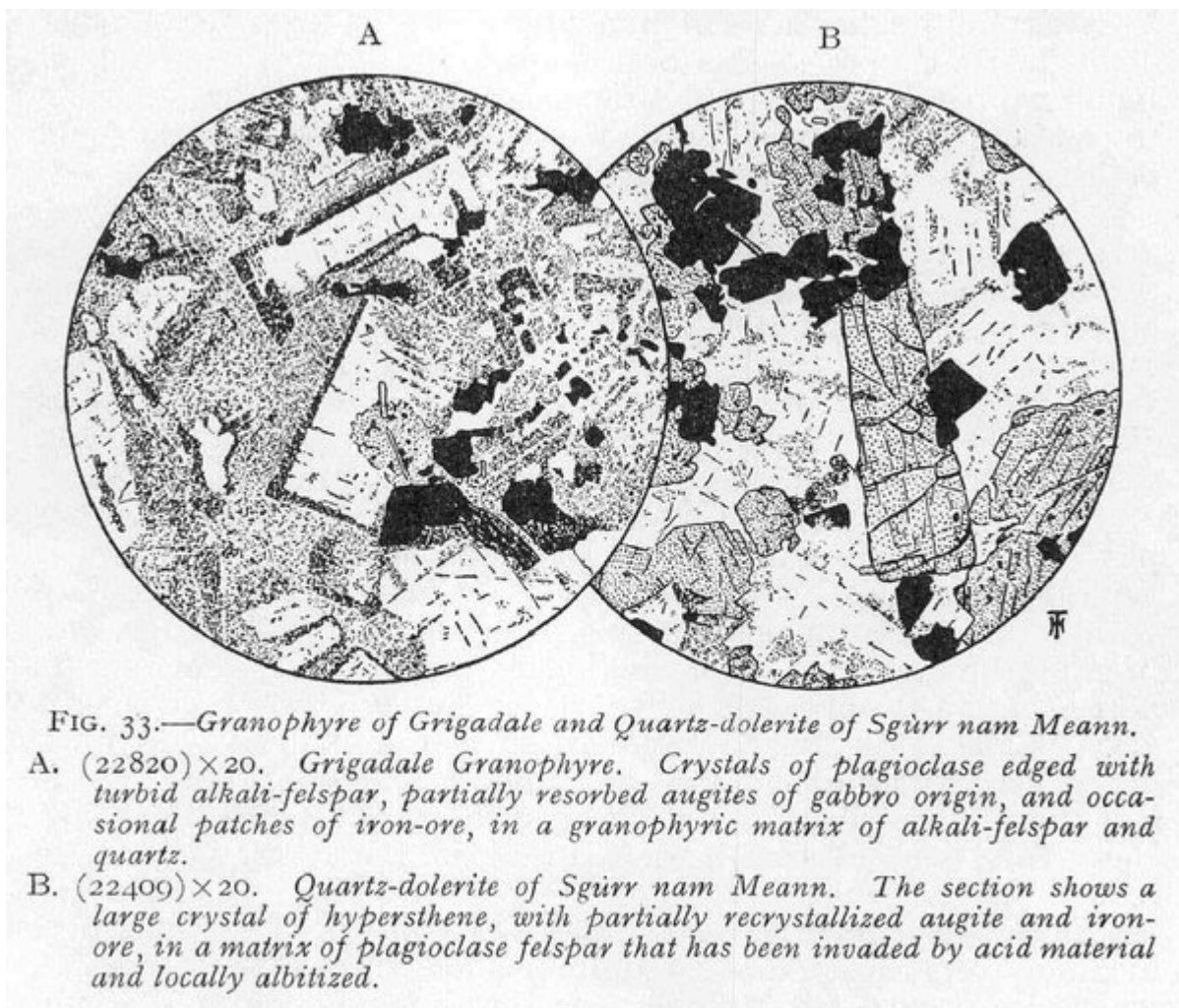
TABLE III  
SUB-ACID AND ACID MAGMA-TYPES (see Fig. 6)

	INNINMORITE.			GRANITE AND GRANOPHYRE.			
	A.	I.	II.	III.	B.	C.	
SiO <sub>2</sub> .. ..	64.13	64.30	66.06	68.42	71.60	74.87	SiO <sub>2</sub>
Al <sub>2</sub> O <sub>3</sub> .. ..	13.15	14.18	13.14	13.54	13.60	11.24	Al <sub>2</sub> O <sub>3</sub>
Fe <sub>2</sub> O <sub>3</sub> .. ..	1.08	1.09	2.27	2.53	2.40	0.34	Fe <sub>2</sub> O <sub>3</sub>
FeO .. .. .	6.31	4.44	2.84	2.02			1.22
MgO .. .. .	1.08	1.47	0.77	0.22	0.21	0.22	MgO
CaO .. .. .	3.62	2.87	2.75	2.13	2.30	1.30	CaO
Na <sub>2</sub> O .. .. .	3.64	4.30	4.28	5.12	5.55	3.31	Na <sub>2</sub> O
K <sub>2</sub> O .. .. .	2.32	2.83	1.54	4.08	3.53	5.68	K <sub>2</sub> O
H <sub>2</sub> O > 105° ..	2.71	3.02	3.38	0.15	0.70	0.49	H <sub>2</sub> O > 105°
H <sub>2</sub> O < 105° ..	0.36						0.74
TiO <sub>2</sub> .. .. .	1.19	0.75	1.08	0.81	—	0.26	TiO <sub>2</sub>
P <sub>2</sub> O <sub>5</sub> .. .. .	0.31	0.17	0.09	0.38	—	0.09	P <sub>2</sub> O <sub>5</sub>
MnO .. .. .	0.27	0.26	0.31	0.10	—	0.05	MnO
CO <sub>2</sub> .. .. .	—	0.00	0.37	0.06	—	0.49	CO <sub>2</sub>
FeS <sub>2</sub> .. .. .	0.00	—	trace	0.05	—	0.33	FeS <sub>2</sub>
SO <sub>2</sub> .. .. .	—	0.00	0.16	trace	—	—	SO <sub>2</sub>
Cr <sub>2</sub> O <sub>3</sub> .. .. .	—	0.00	trace	trace	—	0.02	Cr <sub>2</sub> O <sub>3</sub>
(Co, Ni)O .. ..	0.00	—	0.00	—	—	—	(Co, Ni)O
BaO .. .. .	0.09	0.16	trace	0.03	—	0.04	BaO
Li <sub>2</sub> O .. .. .	0.00	—	trace	trace	—	0.00	Li <sub>2</sub> O
F .. .. .	—	—	—	—	—	0.00	F
C .. .. .	—	traces	—	—	—	—	C
Organic matter..	—	—	0.02	—	—	—	Organic matter
	100.26	99.84	99.80	99.89	99.89	100.24	

- A. (15990; Lab. No. 387.) Fairly glassy Inninmorite or Inninmorite-Pitchstone. Sheet.  $\frac{1}{16}$  mile S.W. of Trigonometrical Station on Beinn an Lochain, Mull. Quoted from E. M. Anderson and E. G. Radley, *Quart. Journ. Geol. Soc.*, vol. lxxi., 1915, p. 212. *Anal.* E. G. Radley.
- I. Inninmorite-Pitchstone. Lava. E. slope of Ben Hiant, Ardnamurchan. *Anal.* Harcourt Phillips.<sup>1</sup>
- II. (21255; Lab. No. 739.) Inninmorite-Pitchstone. Lava. In stream bank  $\frac{1}{2}$  mile S. 12° E. of Trigonometrical Station at 1729 ft., Ben Hiant, and  $\frac{1}{2}$  mile W. 3° S. of Bourblaige, Ardnamurchan. *Anal.* B.E. Dixon.
- III. (22820; Lab. No. 789.) Augite-granophyre. Major intrusion, Centre 2, Ardnamurchan. 800 yds. S. 30° E. of Grigadale. *Anal.* B. E. Dixon.
- B. Augite-granophyre. 100 yds. E. of summit, Carrock Fell, Cumberland. Quoted from A. Harker, *Quart. Journ. Geol. Soc.*, vol. li., 1895, p. 129. *Anal.* G. Barrow.
- C. (24380; Lab. No. 820.) Biotite-granite. Northern granite mass, Arran. Glen Rosa,  $\frac{1}{2}$  mile above confluence with Garbh Allt. Quoted from G. W. Tyrrell, 'The Geology of Arran,' *Mem. Geol. Surv.*, 1928, pp. 155-156. *Anal.* B. E. Dixon.

<sup>1</sup> Supplied by Dr. A. Harker.

(Table 3) Sub-acid and Acid Magma-Types (see (Figure 6)).



(Figure 33) Granophyre of Grigadale and Quartz-dolerite of SgUrr nam Meann. A. [\(S22820\)](#) [NM 437 664] × 20. Grigadale Granophyre. Crystals of plagioclase edged with turbid alkali felspar, partially resorbed augites of gabbro origin, and occasional patches of iron-ore, in a granophyric matrix of alkali felspar and quartz. B. [\(S22409\)](#) [NM 432 662] × 20. Quartz-dolerite of Sgùrr nam Meann. The section shows a large crystal of hypersthene, with partially recrystallized augite and iron-ore, in a matrix of plagioclase felspar that has been invaded by acid material and locally albitized.