Chapter 19 Tertiary Ring-Dykes of Centre 3, Ardnamurchan

The plutonic intrusions of Centre 3, the latest centre of igneous activity in Ardnamurchan, constitute an excellent example of a ring-dyke complex. This complex is itself completely preserved, but has replaced large portions of those of earlier date.

The main features of the complex have been already described in Chaps. 5 and 15, but we may briefly reiterate certain differences between it and its predecessors. Explosive action that is manifested around Centre 2 by the formation of vent-agglomerates, and in the case of Centre 2 chiefly by the brecciation of ring-dykes, is here almost unknown. The only good example is afforded by the narrow Quartz-dolerite (I) of the Interior Complex, which is brecciated and injected with granophyre throughout its length. Fine-grained igneous xenoliths, for the most part cognate to the intrusion in which they occur, are abundant in the majority of the Ring-dykes of Centre 2, and are locally plentiful in the Quartz-gabbro of Faskadale (A), the outermost and probably the earliest ring-dyke of Centre 3. In the Great Eucrite (E) they are very sparse, and occur chiefly as elongate strip-like masses. It is likely that these fine-grained xenoliths denote comparatively superficial conditions of consolidation. The complex of Centre 2 certainly appears to occupy an intermediate position between the largely superficial complex of Centre r and the more deep-seated and mainly plutonic complex of Centre 3.

The eucrites and quartz-gabbros typical of the ring-dykes about Centre 2 are well represented in the complex of Centre 3. But in the Interior Complex of Centre 3, enclosed by the Great Eucrite, biotite becomes an almost invariable constituent mineral. In this, the last phase in the plutonic history of Ardnamurchan, a rock-series of unusual character was produced, the origin of which has been already discussed (pp. 98 and 211).

The Great Eucrite (E) and Outer Eucrite (E′) conveniently subdivide the complex for descriptive purposes, and the ring-dykes outside and partly surrounding these two Eucrites form the subject of the present chapter. They consist of the following intrusions (*see* Index Map, p. 201 (Plate 5)):-

A. Quartz-gabbro of Faskadale

B. Fluxion Gabbro of Faskadale

C. Gabbro of Plocaig

c′ Gabbro, south-east of Rudha Groulin

Of the above intrusions, the two first-mentioned, (A) and (B), are typical arc-shaped ring-dykes, and are obviously related to Centre 3. The other two are small masses, and are included here chiefly for convenience.

(A) Quartz-gabbro of Faskadale

This ring-dyke has been traced around almost half the circumference of the Later Complex. At its north-eastern end, it is separated from the Fluxion Gabbro, that usually accompanies it on its inner side, by a screen-like mass of agglomerate. The Quartz-gabbro and screen are in faulted contact along a gorge cut by the Allt Faskadale. On the west side of the fault, west of Faskadale Bay, the Quartz-gabbro is not seen again. At its visible termination to the south-west, east and north of Beinn na Seilg, the Quartz-gabbro disappears beneath a roof formed of rocks belonging to the Earlier Complex. Possibly it again reaches the present surface, south of Sanna Bay, as the mass called the Younger Quartz-gabbro of Beinn Bhuidhe (h), which there emerges from below an inclined roof of older rocks (p. 255).

The intrusion varies considerably in composition along this great length of outcrop. In the eastern portion, the prevalent variety is a coarse-grained gabbro, with white-weathering felspar, which differs markedly from the adjoining dark-weathering Fluxion Gabbro (B). Iron-ore is often plentiful and olivine is usually present. An acid mesostasis is sparsely developed. The rock is in fact a somewhat basic quartz-gabbro. Sometimes olivine becomes conspicuous in amount and the rock passes into eucrite, as, for example, north and south of Lochan Clach a' Chorrach south-east of

Meall an Tarmachain. The change in type is here only local, and near by, south-east of the loch, typical quartz-gabbro containing drusy cavities lined with quartz is met with. Westwards of this locality the rock is a more acid type, though olivine is usually present. The pale rough-weathered surfaces characteristic of quartz-gabbro, due to a well-developed acid mesostasis, are here often seen. A variety already described from the Earlier Complex (p. 252) consisting of a mixture of two types, quartz-gabbro and brown-weathering quartz-dolerite, is found south-west of Meall an Tarmachain and north-west of the Amhainn Chrò Bheinn stream, at a point 600 yds. east-north-east of the Kilchoan–Achnaha road. Sharp contacts between these two very different rocks often occur, as though the quartz-gabbro were xenolithic, but more usually there is a gradual passage of one type into the other.

North-west of the last locality, along a ridge flanked to the west by a marked north-west hollow, a porphyritic fine-grained type is met with. A sharp intrusive junction of this rock with normal-grained quartz-gabbro occurring to the north is to be seen 250 yds. north-west of the Amhainn Chrò Bheinn. The following description of the contact in microscopic section (S21586) [NM 4826 6536], supplied by Dr. Thomas, may be given here. The fine-grained rock consists of granular augite and little prisms of plagioclase enveloping phenocrysts of augite and labradorite. It becomes much more highly charged with iron-ore towards its margin. The coarser rock is a quartz-gabbro brecciated and invaded by the finer material. There appears to be some granulitization of the felspars, but the degree of metamorphism is not high. The line of separation between these two types was mapped westwards for a short distance obliquely down into the hollow, but could be traced no farther.

On either side of the Kilchoan–Achnaha road, typical quartz-gabbro with blade-shaped crystals of augite is well exposed. Towards the outer margin, next the Hypersthene-gabbro, it grades into a finer-grained type, sometimes containing porphyritic felspar.

This finer-grained facies is present also over a wide area farther west, beyond the Kilchoan–Achosnich road and towards Beinn na Seilg. There, it may also be marginal, developed in relation to a roof, since the intrusion is extending under roof immediately to the west.

Net-veining is especially abundant east of the Allt Faskadale gorge. The rock of the veins seems in the field to be an acid quartz-dolerite, rather than a granophyre. Granophyre containing biotite and veining the Outer Cone-sheet Complex just outside the gabbro is, however, to be found on the east side of Glas Bheinn (*see* pp. 288–9).

Crumbling banks of quartz-gabbro alongside the Amhainn Chra Bheinn stream, north of Glas Bheinn, contain much fine-grained quartz-dolerite, often sheet-like, which is apparently intrusive in the quartz-gabbro. Xenoliths are present in abundance right across the intrusion west of the Kilchoan–Achnaha road, and occur both as bands and as angular blocks of fine-grained basic material (S22249) [NM 4752 6495] and (S22250) [NM 4752 6501]. They are infrequent elsewhere.

Marginal relations

Along its outer margin, the Faskadale Quartz-gabbro is bounded by the Outer Cone-sheet Complex of Centre 2, except to the west where it comes into contact with the Earlier Ring-dykes. J.E.R.

At its north end, on the east side of Faskadale Bay, a contact with cone-sheet rock is well seen. Quartz-gabbro of basic type is there exposed along the rocky foreshore west of Faskadale House, and is in a soft, much weathered condition, and apparently unbaked. In contrast, the adjoining cone-sheet rock that extends for several hundred yards along the coast to the north is hard and highly baked. Just north of a sandy inlet to the north of Faskadale House, contact of these two rocks is seen. The Quartz-gabbro terminates rather vaguely with fine-grained crystallization against quartz-dolerite cone-sheet rock, which it veins. A microscopic section of the junction shows that the cone-sheet is highly granulitized, while the fine-grained gabbro in contact is quite unaltered (S23456) [NM 5001 7079]. South of Faskadale Bay, east of the Allt Faskadale, the Cone-sheet Complex forms a highly baked wall that stands up as a conspicuous scarp above lower ground to the west occupied by the Quartz-gabbro. E.B.B.

Perhaps the most striking demonstration of the relative ages of the Quartz-gabbro and the Outer Cone-sheets is afforded by the ridge of Glas Bheinn, where the Quartz-gabbro margin turns westwards to cut almost at right angles across the

cone-sheet belt for a distance of a mile. No actual contacts of gabbro and cone-sheets have been there observed, but both rocks are often exposed within a few feet of one another. The contrast between the highly baked cone-sheets and the soft unbaked gabbro is a sufficiently striking indication of their relative ages. For example, a massive cone-sheet extends as a conspicuous rocky feature up the southern side of Glas Bheinn at Tom a' Chrochaidh, and becomes highly baked at the summit of the ridge next to the unbaked quartz-gabbro that forms the opposite, northern slope.

West of Glas Bheinn, the Quartz-gabbro is in contact with the Hypersthene-gabbro (a) for a distance of if miles. Owing, in part at least, to discontinuity of exposure no actual junction of the two gabbros has been located. In the valley between Glas Bheinn and the Glebe Hill, the two intrusions are separated for a short distance by a narrow screen-like strip of compact amygdaloidal basalt and brown-weathering dolerite, interpreted as basalt lava cut by basic sheets. The Quartz-gabbro on the north side of the screen is chilled to brown-weathering quartz-dolerite near the contact. The Hypersthene-gabbro to the south, unlike its normal marginal facies, is coarse-textured. Just beyond the eastern end of the screen, where the two gabbros come together, their actual junction is not seen, but adjacent specimens of the gabbros were collected for microscopic examination. Of these, the Quartz-gabbro is a normal rock, while the Hypersthene-gabbro is shattered and invaded by acid material (S22371) [NM 4841 6470]. Farther west, on the west side of the Kilchoan–Achnaha road, exposures are fairly good, but here again the junction could not be located. Possibly shattering of the Hypersthene-gabbro at its contact with the Quartz-gabbro may be the reason for the difficulty. On either side of the belt of obscure rock, a yard or two wide, each type is definitely recognizable, the hypersthene-gabbro coarse in grain, the quartz-gabbro much finer and weathering brown.

The Quartz-gabbro is overlain by a capping of basalt lava and agglomerate on the south-west side of Meall an Tarmachain ((Figure 39), p. 286); and on the east side of Beinn na Seilg, as already stated, disappears beneath a roof. This roof is formed largely of the Quartz-gabbro (c) cut by the Inner Cone-sheets of Centre 2, and its edge is marked by a highly baked scarp that extends along the hillside. The top of the intrusion, immediately below the roof, is composed of granophyre. When traced downhill the granophyre becomes more basic and grades into an acid type of quartz-gabbro, about one third of which it., made up of acid mesostasis. Farther downhill, normal quartz-gabbro is found. This gradation downward from the acid into the basic rock is best seen along crags on the west side of a stream that flows northwards across the edge of the roof, where rock-exposure is continuous. In this section there are no xenoliths or sharp contacts between rocks of different type such as would suggest separate magmatic injections. Gravitational separation of the more acid from the more basic portion of the quartz-gabbro magma would seem to have taken place (*see* p. 210). The distance along the roof for which the acid top is seen is half a mile.

A good contact of the upper, acid portion of the intrusion against roof occurs at the base of the northern spur of Beinn na Seilg which is formed of the Eucrite (f). Hybridy-looking granophyre also makes contact with roof composed of the Quartz-gabbro (c), adjacent to the Old Gabbro (b), 550 yds. south of Lochan an Aodainn. North of this point, the margin of the Quartz-gabbro (A) has not been definitely located. Quartz-dolerite is seen in intrusive contact with the Old Gabbro, but whether it belongs to the Quartz-gabbro (A) or the older Quartz-gabbro (c) is not known.

Along its inner margin, the Faskadale Quartz-gabbro is bounded by the Fluxion Gabbro of Faskadale (B) for a long distance. Evidence supplied by a contact suggests that the Quartz-gabbro is the earlier (p. 289).

Beyond the western termination of the Fluxion Gabbro, on the south side of Meall an Tarmachain, the Quartz-gabbro extends beneath the capping of basalt lava and agglomerate referred to above. The base of this capping is slightly inclined south-westwards. It is separated by the valley of the Amhainn Chre Bheinn from smaller cappings to the south which form a link between it and the outer wall of the intrusion. On the west side of the main capping the slightly inclined edge of the Quartz-gabbro is marked by an escarpment which is conspicuously jointed, and presents a columnar appearance when viewed from a distance. The joint planes are inclined northwards and are evidently approximately at right angles to the inclined base of the capping. They are to be ascribed to the heating up of the country rocks of the capping by the underlying intrusion and their subsequent contraction on cooling.

West of the Meall an Tarmachain capping, the inner margin of the Quartz-gabbro (A) comes into contact with the Great Eucrite (E), which there is good reason to believe is of later date. J.E.R.

Petrology

(Anal. VI; (Table 4); p. 85). — As pointed out in the foregoing field descriptions, this gabbro mass exhibits considerable petrological variation when followed along its somewhat narrow outcrop. Portions are more than usually basic and assume an almost eucritic character, while at other localities more acid varieties are encountered. This variation in type, however, is merely of local significance and the bulk of the mass may be regarded as a quartz-gabbro with more or less normal characters. It is quite conceivable that the mass is multiple in origin, for, in addition to somewhat rapid changes in type, chilled junctions between coarse and fine-grained rocks are occasionally met with within the mass itself.

The gabbro, as represented by the analysed specimen (S22827) [NM 4825 6514], is a moderately fine-grained grey rock of speckled aspect, containing a variable amount of free silica. It is composed of a greenish-brown subophitic augite, somewhat platy zoned crystals of labradorite, fairly abundant magnetite, and a little interstitial quartz and alkali-felspar. Generally speaking, the interstitial matter carries abundant apatite and has reacted to some extent upon the adjoining felspars. It will be seen from the analysis that its composition is typical of the quartz-gabbros, while its relatively low percentages of alumina and lime as well as of magnesia are features correlatable respectively with a non-porphyritic habit and a general paucity of olivine.

Many parts of the gabbro mass are of this type (S21585) [NM 4824 6517], but occasionally a rhombic pyroxene (hypersthene) makes its appearance (S21588) [NM 4749 6509], and the augite may adopt a diallagic structure. Sub-granulitic varieties of gabbro are also represented (S21494) [NM 4640 6449]. A good deal of the mass shows evidence of the migration of an acid magma, or magmatic residuum, which has modified the original structure. Augite crystals exhibit ragged outlines (S22826) [NM 4825 6514] and a patchiness accompanied by the separation of minute scales of biotite due to attack. Albitization of the basic felspars is more pronounced, and the interstitial quartz and alkali-felspar residue more prolific (S24402) [NM 4612 6493]. The acidification of the mass is well marked beneath the roof that covers the gabbro to the north-east of Beinn na Seilg, and there appears to have been a concentration of acid partial magma in the upper and marginal portions. Here, the rocks are of paler tint than usual and contain a copious matrix of apatite-charged micrographic alkali-felspar and quartz. The original augite shows corrosion, and the crystals of basic plagioclase exhibit resorption followed by regrowth with a more soda-rich variety (S24443) [NM 4613 6479], (S24444) [NM 4613 6486]. Where the acid material has segregated immediately below the roof it is best described as augite-granophyre (S24441) [NM 4587 6478]. Except for a few kernels, these rocks contain little felspar more basic than oligoclase, but alkali-felspar in micrographic intergrowth with quartz is prevalent throughout. The augite where completely recrystallized is a greenish variety that builds granules and elongated slender prisms. Hornblende is occasionally developed at the expense of the incompletely resorbed augite of gabbro origin (S24442) [NM 4587 6478].

Mention of contiguous rock-types that exhibit chilled margins within the mass has already been made (p. 283). Frequently, the older of the two gabbros has been crushed before the later doleritic rock has chilled against it. Such features are exhibited by the gabbro and quartz-dolerite on the south-west of Meall an Tarmachain. The older rock has been reduced to a crush-mosaic and shows slight thermal metamorphism due, presumably, to the later intrusion with which it is in contact. The dolerite at its edge is a microporphyritic rock with small porphyritic crystals of labradorite and augite in a fine-textured matrix of plagioclase laths, granular augite, and abundant magnetite (S21586) [NM 4826 6536]. Similar sharp contacts, some of a welded character, are encountered elsewhere in the main mass, close to or at its inner margin, next to the Great Eucrite, to the west of Meall an Tarmachain (S24414) [NM 4752 6550], (S24415) [NM 4752 6550], (S24416) [NM 4752 6550], (S24451) [NM 4752 6550]. Sometimes a marked fluxion structure has developed in the doleritic rock there met with, and hypersthene has formed as a reaction product against the older gabbroic portion of the mass (S24411) [NM 4802 6574].

The Faskadale Gabbro shows minor variations; some parts are doleritic (S24397) [NM 4784 6556], (S22366) [NM 4790 6569], other parts are of fine-textured quartz-dolerites (S22367) [NM 4797 6513] that are occasionally reminiscent of the Talaidh and Ben Hiant types.

Some of the fine-grained granulitic masses enclosed in the normal gabbro may be described as granulitic gabbros. They are often veined by granophyre and have developed a rhombic pyroxene at their junction with the acid strings (S22249) [NM 4752 6495]. Such granulitic masses are obviously of an older basic rock that has undergone some modification and

recrystallization (S22250) [NM 4752 6501]. A small mass of pyroxene-granulite, however, at the eastern end of the gabbro, three quarters of a mile north-north-west of Kilchoan, is a completely granulitized, originally porphyritic, rock that recalls some of the granulitized basic lavas frequently encountered within or against many of the intrusive masses (S21244) [NM 4825 6496], (S21245) [NM 4825 6496].

The capping of agglomerates and basalt lavas which occurs to the south-west of Meall an Tarmachain has been considerably metamorphosed both by the Faskadale gabbro and later intrusive masses.

The olivine-basalts show recrystallization and granulitization (S21852) [NM 4902 6394] which are more pronounced in those rocks with the finer texture. In extreme cases, the whole of the original augite has recrystallized as granulitic aggregates or as minute granules dispersed throughout the rock (S21853) [NM 4902 6594]. Coarse and more felspathic types of lava show the effects of metamorphism chiefly in the ground-mass, although the felspar phenocrysts show alteration in the development of a uniform turbidity that is akin to schillerization (S21854) [NM 4857 6608].

The country rock just outside the gabbro on its eastern side, consisting mainly of agglomerate and lavas cut by cone-sheets, is often in an intensely altered condition. Vesicular fine-grained basalts have been transformed into minutely granular masses of augite, biotite, and partly recrystallized felspar (S26102) [NM 4895 6480]. Further, these granulitized rocks are strung by granophyre that has reacted with and absorbed basic material, whereby its original composition and mineral content have been modified. The granophyre where least contaminated, east of Glas Bheinn (S26673) [NM 4995 6480], consists of alkali-felspar, often perthitic, albite-oligoclase, and interstitial granophyric matter. In addition, there are present large plates of biotite which, it is inferred, result from the absorption of basic material. Patches of granulitized basic rocks, probably cone-sheets, may be detected in all stages of dissolution.

Where the interaction of granophyre and basic rock can best be studied it is seen that the most important change in both participants is the copious development of biotite (S26672) [NM 4995 6480]. This change is often accompanied in the granulitized rocks by the separation of rhombic pyroxene.

Definite hybrids of moderately coarse texture, in which biotite and dark-green hornblende play prominent parts, are frequently produced as extreme cases of basification of the invading acid magma (S26095) [NM 5030 6495], (S26674) [NM 4984 6480]. The likeness of such rocks to some of those of monzonitic affinities met with elsewhere in Ardnamurchan (p. 340) strengthens the conviction that these latter are not normal differentiates, but owe their distinctive characters to the basification of an acid magma.

The basalt and agglomerate screen to the west of Faskadale will be dealt with later (p. 317). The rocks are much altered, and the basic porphyritic lavas have been completely recrystallized to a fine granular mass of pyroxene, biotite, plagioclase, and iron-ore, while felspar phenocrysts have recrystallized as a mosaic. Deformation during metamorphism has developed in some instances what may almost be described as a schistose structure, there being a definitely parallel orientation of the recrystallized minerals and a pulling out of the felspar mosaics that represent the original porphyritic crystals (S21850) [NM 4994 7030].

(B) Fluxion gabbro of Faskadale

Fluxion gabbro as a rock-type is often met with in Ardnamurchan. In the present instance, as in all others, biotite is a usual constituent, and in microscopic slices Dr. Thomas has frequently found hypersthene (p. 278).

The inclination of the fluxion planes is often towards Centre 3, at rather low angles (20 to 40 degrees). There is no direct evidence of the shape of the intrusion, for it and the Quartz-gabbro on its outer side occupy a low-lying belt of country between a baked rim of country rock and the more durable Eucrites (E) and (E′).

On account of its distinctive rock-type, the Fluxion Gabbro (B) proved relatively easy to separate in the field from the adjacent ring-dykes just mentioned. Actual junctions between these intrusions are, however, difficult to locate, chiefly because exposures are discontinuous. The evidence afforded by contacts noted, coupled with the fact that all three intrusions are different in rock-type, justifies our regarding them as separate injections.

The only contact observed with the Quartz-gabbro of Faskadale occurs in the bank of a tributary stream east of the Allt Faskadale, 800 yds. W. 25° N. of the summit of Beinn an Leathaid.

The Quartz-gabbro is a coarse-grained rock, white on weathered surfaces, solid at the contact but soft and weathered a few inches away. The Fluxion Gabbro is weathered down into a kind of sand and contains biotite flakes: the inclination of its fluxion-planes is here at a high angle. Under the microscope the apparently contact-hardened quartz-gabbro is found to be unaltered mineralogically, except that it is strongly albitized (S22663) [NM 5108 6791].

Contact with the Outer Eucrite can best be seen in the north bank of the Allt Rath a' Bheulain (not named on Memoir-map), east of Meall nan Con. Along this stream a good section across the whole breadth of the Fluxion Gabbro is exposed. Its more central portion is coarsely crystallized, but fluxion structure and darker colour everywhere distinguish it from the white-weathering Quartz-gabbro outside it. Exposures fail, however, where these two masses come into contact. Upstream towards the Outer Eucrite, fluxion structure becomes more obvious and the rock is finer grained. At the actual junction, the fineness of grain is very marked, but the Eucrite in contact also has marginal characters, and so no deduction as to relative ages is possible. The marginal type of the Eucrite is that commonly found, in which iron-ore is developed to the partial or complete exclusion of olivine, and the rock takes on the appearance of a quartz-gabbro with a slight development of acid mesostasis. Farther upstream, between the inner side of the Eucrite and the granulitized rocks of the Meall nan Con screen, a small mass of fluxion gabbro is found, and resembles the mass downstream in being intruded by similar fine-textured sheets. Again, 1100 yds. south-south-west of this point, another small mass of fluxion gabbro occurs in a similar position at the inner margin of the Outer Eucrite.

At its northern extremity the Fluxion Gabbro could not be separated satisfactorily from the Great Eucrite (E), since the Eucrite also has a fluxioned margin, and rock is discontinuously exposed. Again, at its southern extremity, the Fluxion Gabbro is exceedingly difficult to separate in badly exposed ground from the Quartz-gabbro (A), and the mapping is largely arbitrary.

Fine-grained sheets are found traversing the Fluxion Gabbro, but do not bear marked chilled edges. They have been noted chiefly in the Allt Rath a' Bheulain, south-west of Beinn an Leathaid, and are restricted to the outcrop of the Fluxion Gabbro. In microscopic section, according to Dr. Thomas, they are midway in composition between quartz-dolerite and tonalite (S22654) [NM 5100 6740]. They are probably consanguinous with the Fluxion Gabbro, both being characterized by containing biotite. J.E.R.

Petrology

The Fluxion Gabbro of Faskadale, from microscopic evidence, appears to be an abnormal mass composed in the main of hybrid rocks produced by the action of a granophyre-magma upon a eucrite. All stages of acidification can be studied. As already pointed out (p. 289), the main features that distinguish this mass from those in which it is in contact are its fluxion structure and the general presence of biotite. Amongst the specimens collected are eucrites that show but little acidification, and these consist of olivine, ophitic brownish augite, and basic labradorite or bytownite felspars in moderately large much-twinned crystals (S22648) [NM 4981 7026].

Acidification, possibly in conjunction with reheating, has produced, in the initial stages, hypersthene at the expense of olivine; and biotite, sometimes in large flakes, at the expense of augite and iron-ore; while there is a marked disturbance of equilibrium in the felspar crystals (S22653) [NM 5107 6739]. In addition, there are rocks rich in iron-ore (S22697) [NM 5030 6656], and others which are almost entirely felspathic (S22698) [NM 5030 6656], or composed of felspar and olivine (S22701) [NM 4964 6553]. The structure of the majority of the specimens suggests that we are dealing with a moderately coarse gabbroid rock that has been broken up and invaded by acid magma. Evidence of hybridization is furnished by large old basic felspars that are much fissured (S22699) [NM 4977 6576], albitized, and resorbed; and by schillered augites that have been resorbed and locally deschillerized. These xenocrysts lie scattered or closely packed in an acid finer-textured matrix that consists of smallish crystals of acid plagioclase, alkali-felspar, and quartz, the last two minerals often in graphic intergrowth (S22664) [NM 5101 6827]. The matrix also contains large crystals of apatite (S22650) [NM 5021 6976]. The resorption of the gabbro xenocrystal material has modified the invading acid magma and has allowed the separation of a pale, almost colourless augite that fringes the original pyroxene and also occurs as isolated

hypidiomorphic crystals. Biotite has also been developed in varying amounts (S22649) [NM 5016 6994], more particularly in those areas which were rich in original iron-ore. In the extreme cases of assimilation by the acid magma and its consequent basification, as observed in acid veins and minor intrusive masses fine-textured rocks have resulted which must be referred to as hybrids. These masses are holocrystalline and only betray their hybrid nature by the presence of relatively few incompletely digested crystals of diallagic augite and basic plagioclase of gabbro-origin. The bulk of such rocks, apart from xenocrysts, consists of small crystals of oligoclase-andesine felspar, quartz, perthite, biotite, and abundant recrystallized pale-green to colourless augite with a little iron-ore. The acid plagioclase occurs as stumpy crystals, while the perthitic orthoclase, which is usually turbid, occurs either as separate crystals or is intergrown with quartz (S22654) [NM 5100 6740].

There is little doubt that this fluxion gabbro has been injected in a semi-fluid condition. Such a condition is not only indicated by the fluxion banding but by the microscopic evidence of abundant xenocrystal material carried by an acid and fluid base. Such intimate commingling of eucritic and granophyric types, and the attendant far-reaching absorptive processes that have operated within the mass, suggest that the original eucrite was either not completely solidified or was still at an elevated temperature when it was invaded by acid magma, and that it was carried forward as a somewhat heterogeneous gabbro-mass into its present position.

The resorption phenomena are interesting from a petrogenetic standpoint as indicating the tonalitic and monzonitic facies assumed by hybrids of this nature. H.H.T.

(C) Gabbro of Plocaig

This small, elongate mass extends for a short distance in ill-exposed ground between the outer, northern margin of the Great Eucrite (E) and the Hypersthene-gabbro (a), and appears to be a distinct intrusion from both its neighbours. In the hand-specimen, it is finer grained and darker looking than the Eucrite, but is not very different in composition. It contains olivine and sometimes porphyritic felspar.

No contact with the Hypersthene-gabbro has been found, but 300 yds. east of Plocaig, west of a stone dyke where exposures are fairly good, the outer part of the Gabbro (C) contains xenoliths that exactly resemble the Hypersthene-gabbro. The xenolith sliced (S24425) [NM 4551 6979] shows, however, but little sign of contact alteration. South and east of this point, next to the Great Eucrite, the rocks are granulitized. If these outcrops are rightly mapped as part of the Plocaig Gabbro, they indicate that this mass is separate from and earlier than the Great Eucrite. J.E.R.

Petrology

As developed at Plocaig (S21502) [NM 4534 6973], the rock is a moderately coarse olivine-gabbro that contains abundant fresh olivine, an ophitic brownish augite, and a twinned and zoned basic labradorite-felspar with practically no accessory minerals. It involves some interesting granulitic masses rich in hypersthene, and also includes xenolithic masses of the Hypersthene-gabbro of Centre 2 (S24425) [NM 4551 6979]. The xenoliths of gabbro, except for the development of a little uralitic hornblende, appear to have suffered slight alteration. The hypersthene-bearing granulite (S24424) [NM 4550 6975] contains some remarkable intergrowths of magnetite and rhombic pyroxene, the magnetite assuming a dendroid form. Such intergrowths appear to result from the reaction of olivine with an aluminous melt, for they are frequently noticed in the Hypersthene-gabbro and Great Eucrite ((Figure 42), p. 305) to occur as a zone separating olivine from augite and basic plagioclase. H.H.T.

(c′) Gabbro South-east of Rudha Groulin

This small mass (lettered eD on Memoir-map) is designated quartz-gabbro on field-determination. The only specimen sliced is, however, an olivine-hypersthene-gabbro (S22635) [NM 4738 7082]. In form, it appears to be a sheet. Along a scarp around its northern end a base to the intrusion is seen which is inclined gently to the south and cuts the Outer Cone-sheet Complex of Centre 2.

Along its inner, southern side next to the Great Eucrite, the gabbro (c′) is evidently baked, and xenoliths, apparently of it, were noted in the margin of the Great Eucrite (E). Presumably, therefore, it is a portion of some larger mass that has been in part replaced by the Great Eucrite. Since it is later than the Outer Cone-sheets of Centre 2, it is included with the ring-dykes of Centre 3 in the present chapter.

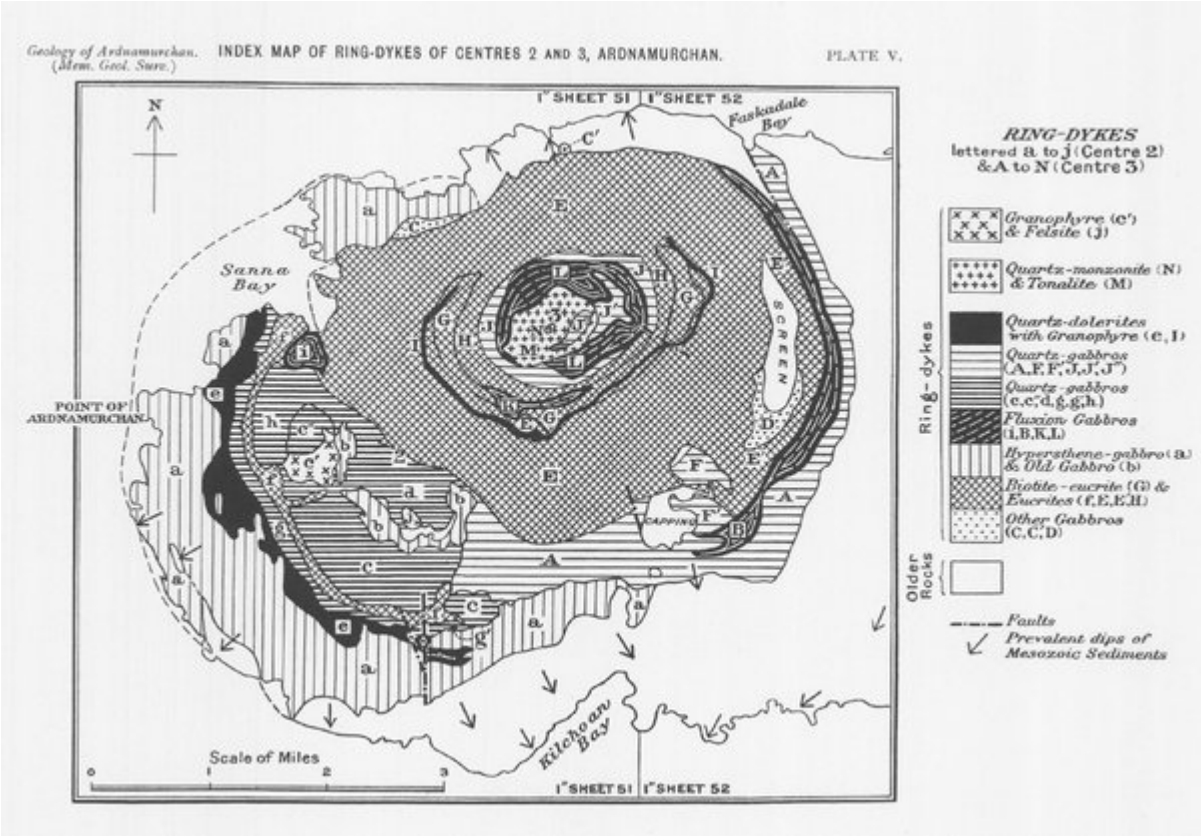
A special interest attaches to this mass. Along its north-east side, coarse pegmatitic veins proceed from its base and traverse granulitized cone-sheet rock. These veins are largely composed of pyroxene, but contain layers and spots of felspar together with green epidote, honey-yellow sphene, and long brown needles of apatite. The latter minerals are large enough to be easily distinguished in the hand-specimen. On its north-west side, the gabbro is found at its actual contact with the cone-sheet rock to grade rapidly into a marginal skin of dolerite, and no pegmatite veins are seen. J.E.R.

Petrology

Themain mass of this gabbro is a moderately coarse-grained olivine-hypersthene-gabbro of eucritic composition (S22635) [NM 4738 7082], in many respects similar to the Hypersthene-gabbro of Centre 2. The olivine is a fresh iron-magnesian variety, and forms small rounded crystals that occur either isolated or as glomeroporphyritic groups embedded in large crystals of bytownite. The augite is coarsely ophitic and is associated with what iron-ore the rock contains. The rhombic pyroxene, which is not a highly pleochroic variety, is also ophitic towards the felspar but has been pseudomorphed to a great extent by fibrous green hornblende.

A development of biotite as scales within the augite and in the ferriferous pseudomorphs after olivine, as also the production of actinolitic hornblende, suggest some reheating of the mass and slight thermal alteration, probably at the hands of the Great Eucrite (E).

One of the most interesting features connected with this mass is the passage, as veins, of alkaline residual matter from the consolidating gabbro into the neighbouring cone-sheet complex. The alkaline magma has hybridized with the cone-sheet material, forming rocks rich in alkaline felspars and pyroxenes, and of strikingly abnormal composition. Similar hybrid types have been produced in the cone-sheet complex by alkaline emanations from the Great Eucrite (p. 311, (S22274) [NM 4416 6942]. Their nature and likeness to the augite-diorite hybrids of Camphouse have already been discussed (p. 155). H.H.T.



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

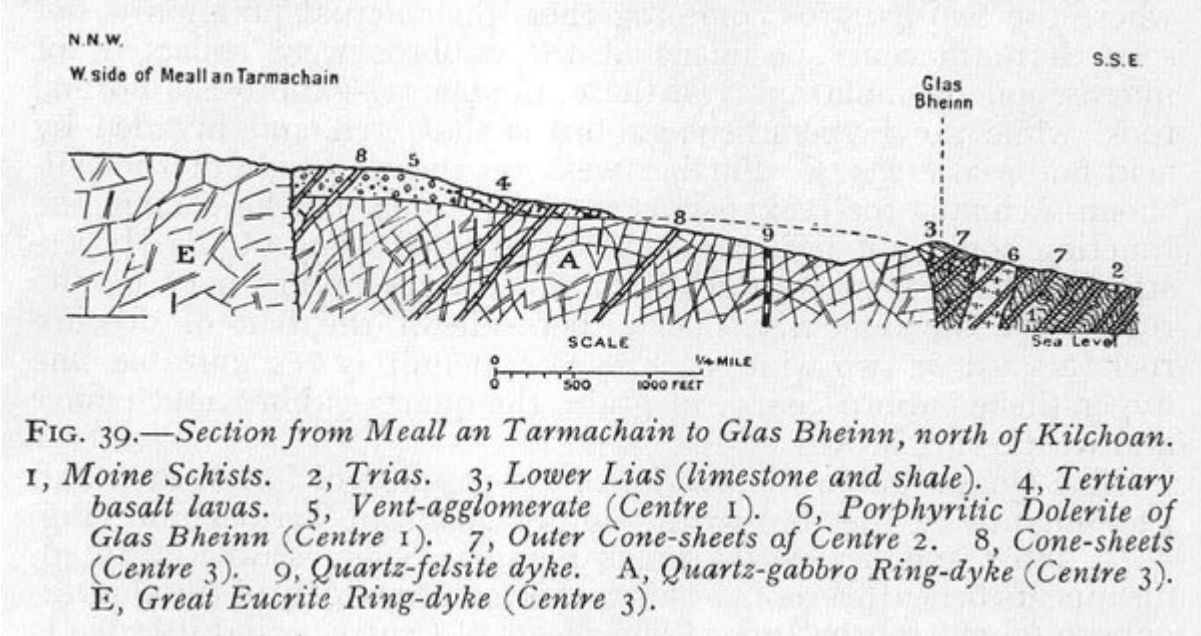


FIG. 39.—*Section from Meall an Tarmachain to Glas Bheinn, north of Kilchoan.*
1, *Moine Schists.* 2, *Trias.* 3, *Lower Lias (limestone and shale).* 4, *Tertiary basalt lavas.* 5, *Vent-agglomerate (Centre 1).* 6, *Porphyritic Dolerite of Glas Bheinn (Centre 1).* 7, *Outer Cone-sheets of Centre 2.* 8, *Cone-sheets (Centre 3).* 9, *Quartz-felsite dyke.* A, *Quartz-gabbro Ring-dyke (Centre 3).* E, *Great Eucrite Ring-dyke (Centre 3).*

(Figure 39) Section from Meall an Tarmachain to Glas Bheinn, north of Kilchoan. 1, Moine Schists. 2, Trias. 3, Lower Lias (limestone and shale). 4, Tertiary basalt lavas. 5, Vent-agglomerate (Centre 1). 6, Porphyritic Dolerite of Glas Bheinn (Centre 1). 7, Outer Cone-sheets of Centre 2. 8, Cone-sheets (Centre 3). 9, Quartz-felsite dyke. A, Quartz-gabbro Ring-dyke (Centre 3). E, Great Eucrite Ring-dyke (Centre 3).

TABLE IV

PORPHYRITIC CENTRAL MAGMA-TYPE (*see* Fig. 7)

	EUCRITE, GABBRO, AND BASALT.								
	I.	A.	II.	III.	B.	IV.	V.	VI.	
SiO_2 ..	47·26	47·28	47·75	48·28	48·34	49·60	49·78	50·12	SiO_2
Al_2O_3 ..	22·80	21·11	19·46	20·38	20·10	15·06	18·82	15·98	Al_2O_3
Fe_2O_3 ..	2·21	3·52	2·31	1·78	1·97	5·29	5·58	4·91	Fe_2O_3
FeO ..	5·41	3·91	6·28	6·70	6·62	5·00	4·85	6·31	FeO
MgO ..	7·76	8·06	7·50	7·93	5·49	4·44	4·15	4·43	MgO
CaO ..	10·93	13·42	11·32	11·80	13·16	9·69	10·40	10·86	CaO
Na_2O ..	1·72	1·52	2·46	1·75	1·66	2·62	3·04	3·60	Na_2O
K_2O ..	0·29	0·29	0·24	0·14	0·98	0·70	0·56	0·70	K_2O
$H_2O > 105°$	0·90	0·53	0·50	0·76	0·44	1·29	1·35	0·53	$H_2O > 105°$
$H_2O < 105°$	0·11	0·13	0·18	0·09	0·02	2·65		0·46	$H_2O < 105°$
TiO_2 ..	0·38	0·28	0·43	0·23	0·95	2·38	1·34	1·76	TiO_2
P_2O_5 ..	0·06	trace	0·62	0·02	0·04	0·29	trace	0·08	P_2O_5
MnO ..	0·31	0·15	0·17	0·28	0·32	0·19	0·28	0·18	MnO
CO_2 ..	0·10	—	trace	0·03	0·11	0·44	—	0·21	CO_2
FeS_2 ..	0·00	—	0·16	0·04	0·00	0·00	0·00	0·05	FeS_2
Fe_7S_8 ..	0·00	—	trace	0·00	—	—	—	—	Fe_7S_8
SO_3 ..	—	—	trace	—	—	0·40	0·00	trace	SO_3
Cr_2O_3 ..	—	—	0·05	—	—	0·02	0·00	0·04	Cr_2O_3
(Co, Ni)O ..	0·00	—	—	0·00	0·00	0·00	—	—	(Co, Ni)O
BaO ..	0·00	—	—	0·00	0·10	trace	0·03	0·04	BaO
Li_2O ..	0·00	—	trace	0·00	0·00	trace	—	trace	Li_2O
C	—	—	—	—	—	—	traces	—	C
Organic matter ..	—	—	—	—	—	trace	—	—	Organic matter
	100·24	100·20	99·83	100·21	100·30	100·06	100·18	100·26	

I. (21250; Lab. No. 735.) Biotite-eucrite. Ring-dyke, Centre 3, Ardnamurchan. Bank of stream, 1 mile E. 33° S. of Achnaha. *Anal.* E. G. Radley.

A. (8194; Lab. No. 19.) Olivine-gabbro. Major Intrusion. Coir' a' Mhadaidh, Cuillins, Skye. Quoted from A. Harker, 'Tertiary Igneous Rocks of Skye,' *Mem. Geol. Surv.*, 1904, p. 103. *Anal.* W. Pollard.

II. (22821; Lab. No. 790.) Hypersthene-gabbro. Ring-dyke, Centre 2, Ardnamurchan. In side of hollow ¼ mile W. 33° S. of Trigonometrical Station at 1123 ft., Beinn na Seilg, and 1000 yds. E. 27° N. of

(Table 4) Porphyritic Central Magma-Type (see (Figure 7)).

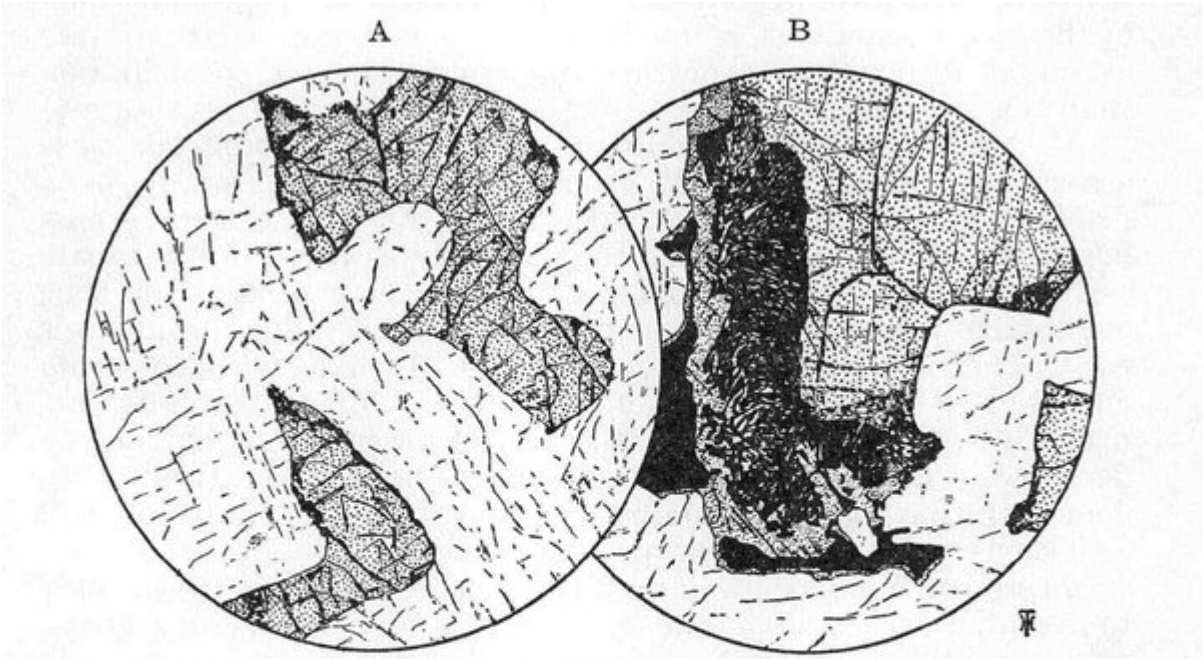


FIG. 42.—*Great Eucrite.*

A. (22675) × 20. *Eucrite, typical of the Great Eucrite of Centre 3. The section shows olivine with slight marginal development of secondary magnetite, and plagioclase that varies in composition from basic labradorite to bytownite.*
B. (22355) × 20. *Same type with well-developed reaction border between olivine and felspar. The reaction border consists of dendroid magnetite and hypersthene.*

(Figure 42) Great Eucrite. A. (S22675) [NM 4680 6659] × 20. Eucrite, typical of the Great Eucrite of Centre 3. The section shows olivine with slight marginal development of secondary magnetite, and plagioclase that varies in composition from basic labradorite to bytownite. B. (S22355) [NM 4422 6816] × 20. Same type with well-developed reaction border between olivine and felspar. The reaction border consists of dendroid magnetite and hypersthene.