Chapter 12 Tertiary major intrusions, Centre 1, Ardnamurchan

In the eastern part of the Ardnamurchan igneous complex, a number of major intrusions are arranged around the same centre (1) as the main group of volcanic vents (see (Plate 2)). They are at any rate later than those vents with which they are in contact. An upper limit to their age is set by the fact that such of them as extend westwards into the area traversed by the Outer Cone-sheets of Centre 2 are profusely cut by these sheets.

Some of the intrusions are dyke-like in form. Others occur as plugs or small bosses. The remainder are, in part at least, sheet-like, and follow the same direction as neighbouring cone-sheets attributed to Centre 1. Age relations between the various intrusions can only be determined in the case of a few individuals that are in contact with one another. As will be seen on (Plate 2), the majority are widely separated by older and younger rocks. The dyke-like masses, together with the plugs and bosses, will be described first, in the present chapter. These consist of the following intrusions:

Dyke-like intrusions

1. Porphyritic Dolerite of Glas Bheinn.

2. Old Gabbro of Meall nan Con.

3. Quartz-gabbro, west of Faskadale.

4. Granophyre, west of Faskadale.

Plugs and bosses

5. Trachyte, east of Ben Hiant (not shown on (Plate 2)).

6. Porphyritic Dolerites of Ben Hiant, in two masses.

7. Quartz-dolerite of Camphouse.

8. Augite-diorite, east-south-east of Camphouse (not shown on (Plate 2)).

The dyke-like intrusions bear a close resemblance to ring-dykes, and are clearly arranged with reference to Centre 1. They are, however, too few in number to be collectively regarded as comparable to the ring-dyke complexes of the two later igneous centres. Their association with the massive cone-sheets referred to Centre 1, in a complex so largely consisting of vent-agglomerates, is noteworthy.

The Trachyte east of Ben Hiant is probably a boss and in rock-type resembles blocks contained in the Ben Hiant vent-agglomerates. The more important of the two Porphyritic Dolerites of Ben Hiant, south of the summit, is intruded as a plug, or perhaps as a craterinfilling, into the South-west Vent. The Quartz-dolerite of Camp-house appears to be a plug or boss. Lithologically it resembles the Ben Hiant Intrusion, which is described in the next chapter. The Augite-diorite is of insignificant size, but its peculiar rock-type is a matter of interest.

It is noteworthy that porphyritic structure (felspar phenocrysts) is characteristic of two of the dolerites, and is also a feature of the fine-textured marginal portions of the gabbros. In two cases, however, where the contacts of a gabbro and a dolerite intrusion with older rocks are seen, the actual chilled margins are devoid of felspar phenocrysts, though such phenocrysts become abundant within a few inches of the contacts (*see below,* and p. 146). The phenocrysts rapidly increase in size towards the interior, and no break in rock-continuity between chilled margins and the marginal porphyritic facies is discernible. The phenocrysts would thus appear, in these cases at least, to have formed after the intrusion came into position, and not at some lower crustal level (*see* p. 98).

In the Porphyritic Dolerite of Glas Bheinn and the Granophyre west of Faskadale, xenoliths of felspathic gneiss or schist are often very abundant. They are as a rule angular, but may also have rounded outlines, and are sometimes highly altered and almost completely resorbed.

1 Porphyritic dolerite of Glas Bheinn

This intrusion is given the same index-letter and colour on the Memoir-map as the Porphyritic Dolerites of Ben Hiant. These masses resemble one another in their consistently porphyritic habit (felspar phenocrysts), and in this character differ from the other major intrusions of Ardnamurchan, though these mostly belong to the Porphyritic Central Magma-Type. The Glas Bheinn intrusion is for the most part much more acid in composition than the Ben Hiant masses, being a quartz-dolerite or quartz-gabbro of rather acid type. At its eastern extremity, however, a more basic variation occurs, containing olivine and with less copious acid residuum (S22453) [NM 5237 6491]. There is no field evidence to show that this portion is an intrusion distinct from the rest of the mass, and it is probably a local variant. The two varieties agree in the relative number of their porphyritic felspars, which are also identical in size and composition. Throughout the intrusion, except at its eastern end, xenoliths of schist are frequently met with. At a point 300 yds. west of the summit of Glas Bheinn, xenoliths of gabbro occur in addition.

The elongate outcrop of the intrusion suggests that it is dyke-like in form. Steep margins are evident west of Camphouse, where the outcrop extends without deviation up the steep, easterly slopes of Glas Bheinn. A vertical junction with the Moine Schists is exposed where the north margin of the intrusion crosses the right bank of a stream, 700 yds. W. 10° N. of Camphouse. The porphyritic dolerite becomes free of felspar phenocrysts close to the contact at which it is very definitely chilled.

Along part of its course, the intrusion runs nearly parallel to, and sometimes coincident with, the southern bounding wall of the Northern Vents. No actual junction with the agglomerates and brecciated basalt lavas mapped in contact has been located, but since the Porphyritic Dolerite is unbrecciated where it borders the vent, it is probably later.

At its eastern extremity, the intrusion enters the belt of country traversed by the massive cone-sheets of Centre r, but is not seen to be cut by them. Whether the cone-sheets are cut off by the dolerite, or have failed to penetrate it, cannot be decided in the absence of exposed contacts. The intrusion is, on the other hand, crossed by a number of basic sheets striking north-west and gently inclined to the south-west. These sheets differ texturally from the majority of cone-sheets in their variolitic character (p. 194), but in this they resemble certain associates of the great Ben Hiant Intrusion. Further, the outcrop of the Glas Bheinn intrusion is interrupted by a probably later, plug-like mass of dolerite (the Quartz-dolerite of Camphouse), of exactly similar composition and texture to the coarser types of the Ben Hiant mass. There is thus some evidence pointing to the Glas Bheinn Porphyritic Dolerite being older than the Ben Hiant Intrusion. Since there are strong arguments for connecting the Ben Hiant Intrusion with the period of the massive cone-sheets, the scale seems turned in favour of regarding the cone-sheets as later than the Glas Bheinn intrusion.

The Glas Bheinn intrusion may thus be little later than the agglomerates in age. Other porphyritic basic rocks of early date are the big-felspar basalt blocks in the vents, and an identical type that occurs as early north-west dykes (p. 347), in addition to the Ben Hiant Porphyritic Dolerites already referred to.

The relative ages of the Glas Bheinn intrusion and the Outer Cone-sheets of Centre 2 are left in no doubt. From Camphouse westwards, the intrusion runs almost at right angles to the direction of the cone-sheets, and is profusely cut by them.

On the north side of Glas Bheinn a mass of felsite in contact with the Porphyritic Dolerite is also cut by the Outer Cone-sheets. A contact-specimen (S22694) [NM 4945 6490] of the felsite and dolerite suggests the later age of the felsite (*see* p. 144). All these rocks are very highly contact altered at this place owing to their proximity to the Ring-dyke Complex of Centre 3. J.E.R.

Petrology

The eastern extremity of the Glas Bheinn intrusion is a coarsely porphyritic dolerite that represents the intrusion in its more basic and least modified form (S22453) [NM 5237 6491]. The larger constituents of the rock are a basic plagioclase felspar, olivine, and augite with subordinate ilmenite or titano-magnetite.

The porphyritic felspars range up to a centimetre in length. They are moderately well formed, clean and not greatly zoned, while their optically negative character indicates a bytownite-anorthite composition. They show strong albite lamellation as the dominant twin-structure. Olivine builds moderately large crystals, but none of this mineral now remains in a fresh condition, its place being taken by talcose and serpentinous secondary products that are highly charged with magnetite. It is probable that the olivine was one of the iron-rich varieties,

Augite of a pale greenish-brown colour occurs in fairly large crystals, ophitically related to the smaller and less basic labradorite felspars that occur in the matrix.

There is a plentiful acid residuum that is composed of acid plagioclase felspar with a little orthoclase and quartz, in a chloritized base. In this mesostasis the crystalline elements exhibit an acicular and skeletal type of growth, and occasional blade-like crystals of augite are encountered which are charged peripherally with magnetite after the manner of the augites in the quartz-dolerite of Ben Hiant (pp. 170–1).

The main mass of the intrusion is a more acid quartz-dolerite with a copious acid mesostasis. The porphyritic felspars, where in contact with the acid partial magma, have usually lost their regular outline. They have been attacked with the resulting outgrowth of oligoclase on the more basic nuclei. This secondary growth of less basic felspar either forms a definite zone to the early felspar or stretches out in skeletal formation into the mesostasis (S26097) [NM 5180 6453]. Early formed augites, also, where in contact with the mesostasis, show signs of interaction. They are occasionally surrounded by a narrow reaction rim of fibrous hornblende.

The dolerite is strung with moderately coarse granophyric matter that has basified itself by the resorption of basic felspar and augite. Remnants of basic plagioclase with ill-defined boundaries and secondary growths of oligoclase, together with chloritized biotite, represent the results of interaction between basic and acid material. The granophyre itself exhibits a beautiful coarse graphic structure around square-ended crystals of oligoclase, which mineral encloses also the remnants of more basic plagioclase of xenocrystal origin (S21485) [NM 488 647].

Near the summit of Glas Bheinn, on the northern edge of the Glas Bheinn intrusion, the dolerite is in contact with a felsite. As both rocks have come within the metamorphosing influence of the Faskadale Quartz-gabbro (Ring-dyke of Centre 3) and are more or less completely granulitized, it is difficult to be sure of their original relations. It would appear, however, that this felsite was a later intrusion than the dolerite, for it seems to have been basified by the digestion of doleritic material before contact alteration was impressed upon it.

In a specimen showing contact of the two rocks (S22694) [NM 4945 6490], the basic portion referable to the altered dolerite contains basic plagioclase felspars edged and surrounded by a more acid variety, and a mosaic of alkali-felspar within which are developed minute granules and prisms of greenish augite and rhombic pyroxene, scales of fox-red biotite, and abundant finely-divided magnetite. The ferromagnesian minerals and magnetite are unevenly distributed and represent in their most abundant development localities occupied by the augite of the original dolerite. The felsitic portion contains phenocrysts of partly original perthite set in a fine mosaic of alkali-felspar and quartz bespattered and strung by granules of both monoclinic and orthorhombic pyroxenes, and finely-divided magnetite. In the more purely siliceous areas the augite has a distinct green colour. The original basification of the felsite by incorporation of doleritic material is indicated by clots in the more felspathic portions of the rock which contain a basic felspar and are extremely rich in granular pyroxene, biotite, and magnetite, together with a little green pyrogenetic hornblende. These clots evidently represent doleritic fragments, but the whole rock, phenocrysts and xenocrysts included, is replete with granulitic pyroxenes resulting from a metamorphism later than the contamination. H.H.T.

2 Old Gabbro of Meall Nan Con

This small mass, a remnant of some larger intrusion, is only 400 yds. in length by 200 yds. wide. It obliquely crosses the north end of an elongate outcrop of older rocks on Meall nan Con, of which it forms a part, and which is hounded to west and east by ring-dykes belonging to Centre 3. In direction, it conforms to Centre 1.

The gabbro is highly metamorphosed. Its weathered surfaces have that bluish-black colour characteristic of many contact-altered rocks in Ardnamurchan which is correlated with an extreme cloudiness of the felspars as seen under the microscope, due to myriads of black specks. A northern intrusive margin of the gabbro is exposed against granulitized basalt of the screen, at which the gabbro becomes fine-grained and porphyritic.

Petrologically, the rock is a moderately coarse-textured olivine-gabbro (S21514) [NM 5014 6899] that consisted originally of large crystals of olivine, interlocking crystals of basic labradorite, ophitic augite, and small patches of indefinitely shaped magnetite. The effects of its contact alteration by the adjoining ring-dykes are described in detail on p. 314. H.H.T.

3 Quartz-Gabbro, west of Faskadale

This elongate intrusion extends from the west side of Faskadale Bay due west for 1¼ miles. It is accompanied on its northern side for three quarters of its course by a similarly oriented mass of granophyre, from which it is in part separated by screen-like masses of agglomerate. Both intrusions are arranged tangentially to Centre 1. They are seen in steep or vertical contact with the agglomerate-screen on the east side of Meall Buidhe Mòr, west of Faskadale Bay (*see* (Figure 16)). This hill is not named on the Memoir-map, but its summit at 312 feet is indicated.

The Quartz-gabbro varies in rock-type from an olivine-gabbro poor in quartz in its more easterly portion to a normal quartz-gabbro or quartz-dolerite with well-developed acid mesostasis farther west. This western portion lies next to the Great Eucrite, which is there the outermost ring-dyke of Centre 3 (E of (Plate 5), p. 201). It is consequently very greatly contact altered, together with cone-sheets belonging to Centre 2, by which it is freely cut (Figure 16). Under these conditions, the interpretation of exposures becomes very difficult, but it is apparent that this portion of the mass, as mapped, includes more than one intrusion. For example, at a point a mile west of the head of Faskadale Bay, and just north of the margin of the Great Eucrite, acid quartz-dolerite is clearly intruded into a more basic quartz-gabbro, which resembles the type found to the east.

In its eastern portion, the Quartz-gabbro grades into porphyritic dolerite at its margin. This facies is best seen along the northern edge of the intrusion, where it is in contact either with the agglomerate-screen or with the later Granophyre. A junction with the screen is well exposed on the west shore of Faskadale Bay, where the intrusion is only 20 yds. wide. It there consists solely of the porphyritic variety, with a markedly chilled edge against the agglomerate to the south. At the actual contact, phenocrysts are absent (S22644) [NM 4928 7118], but internally small scattered porphyritic felspars soon make their appearance. The latter rock grades rapidly into the normal porphyritic dolerite.

Intense shearing is developed in the outcrops along the shore.

The rock is there riddled with steep planes of movement parallel to the direction of the intrusion. J.E.R.

Petrology

The gabbro west of Faskadale Bay is a moderately coarse rock, but as described above is variable in character and composition. Further, it has suffered considerable thermal alteration and local crushing.

As represented by specimens collected near the centre of the mass (S21596) [NM 4885 7106], it is a fairly coarse-textured doleritic gabbro composed of large interlocking crystals of zoned and much twinned labradorite, a brownish ophitic augite, a few moderately large patches of iron-ore, and relatively small pseudomorphs after olivine. The olivine is of an early generation and is idiomorphic towards the felspar. The rock even here is invaded by an acid partial magma, as is so common a feature of many of the Tertiary gabbros, that has resorbed the basic felspars with which it came in contact and caused them to grow albite-oligoclase extensions. This siliceous partial magma is, as usual, rich in

apatite and has consolidated as a fine-textured aggregate of alkali-felspar and quartz.

The slight thermal alteration that the gabbro has at this point suffered at the hands of the Great Eucrite (E) shows itself chiefly in the conversion of the pseudomorphs after olivine into masses of fibrous green hornblende, and in the development of a similar hornblende with a little biotite in other parts of the rock where chloritic and serpentinous products had segregated.

As has been described above (p. 145) the mass becomes more variable and complex in its westerly extension, while to the east, towards the shore of Faskadale Bay, it takes on the form of a porphyritic quartz-dolerite and presents a fine-textured chilled edge to the agglomerate at its southern boundary. Microscopic examination of the rocks on the shore shows that all the mass has here suffered intense shattering that in many instances has almost completely obliterated original structures. Where least crushed (S22646) [NM 4957 7114] the rock is a quartz-dolerite or quartz-gabbro composed of moderately large felspars, ophitic augite frequently edged with green amphibole, and iron-ore, with the usual acid residuum. The basic plagioclase felspars are all more or less albitized. In other specimens (S22647) [NM 4957 7114] the rock is a comminuted mass of these constituents and shows the effects of intense crushing subsequent to its consolidation.

The southern fine-grained edge (S22645) [NM 4961 7116] has escaped in a measure the crushing that comminuted the coarser rock, but even it has been affected (S22644) [NM 4928 7118]. It is a non-porphyritic rock composed of irregularly bounded laths of oligoclase felspar, scattered crystals and grains of magnetite, and fibrous hornblendic pseudomorphs after augite. The residual matter, of which there is no great quantity, consists of an aggregate of alkali-felspar and quartz with the usual abundant apatite. The rock is evidently a highly albitized representative of a medium-textured quartz-dolerite with prismatic to columnar augite, and as such recalls the Talaidh type of the cone-sheets (p. 187). Such complete albitization as that exhibited by the rock in question is much less common in Ardnamurchan than it is around the Mull centre, and its cause in this instance is obscure. It may, however, together with the pseudomorphing of augite by hornblende and the development of epidote in veins, be an expression of the metamorphosing influence of the granophyre bordering it to the north. H.H.T.

(4) Granophyre, West of Faskadale

As mentioned above (p. 145), the Quartz-gabbro west of Faskadale is accompanied on its northern side by an elongate outcrop of granophyre of later age. Screen-like masses of agglomerate, by which these two intrusions are separated along the greater part of their course, are absent just south of the summit of Meall Buidhe Mòr, indicated by the trigonometrical station at 312 ft. on the Memoir-map. The Granophyre is there markedly chilled against the porphyritic marginal facies of the Quartz-gabbro. The marginal granophyre differs from the main portion in being darker in colour, but both are alike in containing numerous angular xenoliths of schist. The junction seen is a clean-cut plane, inclined south at 70°. From this exposure near the summit, the Granophyre margin runs east directly downhill, but deviates round a broad portion of the agglomerate screen, while the contact between the screen and the adjoining Quartz-gabbro runs straight down to the shore. It is evident that the intrusive junctions on this hill-side are steep, and that the agglomerate masses are truly screen-like (Figure 16).

Numerous cone-sheets cut the Granophyre, and are well seen along the shore between tide-marks, from where they extend up into the high sea-cliffs. In its eastern portion, the Granophyre is composed of an acid type. Westwards along the shore, half a mile west of the west side of Faskadale Bay, it changes to a felsite against a mass of black-weathering gabbro. The beach can here be reached down one only of the many hollows (geos) eroded in the high sea-cliffs along crush-lines. This is situated 300 yds. east of the headland at which the shore-line changes in direction to west-south-west, and is only a short way east of the outcrop of black gabbro. The gabbro is apparently a screen, 50 yds. wide, separating the acid granophyre from a less acid type to the west. The latter contains needly hornblende and is a basified granophyre (p. 149). Veins from it hybridize freely with the black gabbro. They are often coarse textured and appear to merge into the gabbro at their margins. The basified granophyre is thus different from the granophyre to the east of the screen in its marginal behaviour, and it is evidently a distinct intrusion. The gabbroscreen has not been found to extend inland, and the separation there of the two acid masses was not attempted, since exposures are sparse. For

this reason, as well as on account of its small size, the screen has not been shown on the Memoir-map.

Petrology

The granophyre that occupies the coastal region to the west of Faskadale Bay is represented by a number of specimens collected from the shore section. It has been contaminated to a considerable extent by the absorption of gneiss and possibly gabbro material but to the west is chilled against a gabbro screen. On the other side of the screen occurs a basified granophyre that has hybridized freely with the gabbro.

In its least contaminated portion (S26096) [NM 4876 7129] the eastern part of the granophyre mass is a compact greenish-grey non-porphyritic rock. Under the microscope it is seen to consist of variously orientated, more or less equidimensional patches of alkali-felspar and quartz which exhibit a perfect micrographic structure. These patches usually have as nuclei a small idiomorphic crystal of acid plagioclase or orthoclase, and these are surrounded by a micrographic growth that becomes of increasingly coarse texture in an outward direction. The basic elements which may be regarded as foreign to the original composition of the rock are certain large carbonated crystals of plagioclase and moderately abundant patches of a dark-green strongly pleochroic chlorite that is frequently charged with magnetite. The chlorite from its outline is presumably pseudomorphous after biotite and represents the result of contamination by the absorption of gneiss, In other examples (S22640) [NM 4956 7119] the granophyric texture is on even a more micrographic scale and the rock as a whole appears to be more felspathic. In such cases partially resorbed augite and plagioclase may be detected and presumably result from contamination by gabbro material; while a fair amount of chlorite after biotite, of which some still retains its original character, may be referred to a gneissic source. In some parts of the mass partially resorbed xenoliths of siliceous gneiss can be made out, and then the surrounding granophyre (S22638) [NM 4914 7126] has taken on the form of a fine-grained aggregate structure rather than the perfect granophyric structure previously described. The individual grains of quartz and felspar are separated from each other by strings and small areas of micropegmatite. Mica is well represented by chloritized flakes and patches of biotite.

Where more definitely contaminated by basic material (S22639) [NM 4911 7125] the rock still shows a fine micrographic structure, but there is a distinctly greater development of small crystals of plagioclase felspar which indicates a rise in the soda and lime content of the rock as a whole. In addition, definite groups of large labradorite felspars, involving pseudomorphous matter that represents ophitic augite, are encountered, as also are chloritic pseudomorphs after biotite, and possibly after rhombic pyroxene.

The basic screen (S22641) [NM 4872 7129], (S22642) [NM 4868 7134], (S22643) [NM 4869 7132], against which the eastern portion of the granophyre is chilled, is composed in part of a basic olivinegabbro that locally becomes peridotitic in character. The most basic portion (S22641) [NM 4872 7129] consists of moderately large crystals of bytownite-anorthite felspar, an ophitic augite, and abundant olivine. The latter is mainly fresh and occurs in both poecilitic and ophitic relation to the felspar. It is also frequently enclosed in poecilitic fashion by the augite. Hypersthene is encountered in small amount in close association with olivine, and a little biotite has developed in the vicinity of iron-ore. Where altered, the olivine has given rise to serpentinous and talcose pseudomorphs with the concomitant separation of magnetite. Other portions of the screen appear to be composed of a normal coarsely ophitic dolerite relatively poor in olivine.

The basified granophyre (S22642) [NM 4868 7134] on the western side of the screen has attacked the olivine-gabbro that forms its eastern boundary. There is practically no metamorphism of the screen except at its contact with the granophyre, where the augite of the gabbro has developed into a brown pyrogenetic hornblende such as is found to be a common product of gabbro-granophyre hybrids. Rhombic pyroxene, now pseudomorphed, has also been produced as the result of interaction, basic plagioclases have been acidified, and iron-ores have caused the development of biotite in their vicinity. The granophyre itself contains numerous patches of partially re-sorbed basic plagioclase and augite, and carries abundant large crystals of apatite near its junction with the gabbro. It is a moderately coarse rock with good graphic structure in its base. It shows the effect of basification in the crystallization of long prisms of a green-brown hornblende, which give it the appearance of a craignurite in the hand-specimen. H.H.T.

5. Trachyte, east of Ben Hiant

A small boss of trachyte forms a rocky knoll adjoining the Kilchoan–Glenborrodale road, opposite the 8-mile stone from Kilchoan. The top and sides of the mass consist of obviously chilled rock. J.B.S.

The rock is a fine-grained non-porphyritic biotite-trachyte (S24466) [NM 5552 6262]. It consists of a felted and fluxionally arranged mass of alkali-felspar microliths that measure less than one tenth of a millimetre in length. The felspars involve abundant minute prisms and grains of greenish augite, octahedra of magnetite, and fairly prevalent plates of bright-brown biotite. This rock is interesting mainly from the fact that it is distinctly alkaline in character and approaches in some measure the type of trachyte met with as fragments in the vent-agglomerate. It resembles more particularly the non-porphyritic trachytes of the vents, but may also be closely paralleled by the matrix of the porphyritic varieties. H.H.T.

6. Porphyritic dolerites Of Ben Hiant

Two masses of this rock-type are met with, one to the north, the other south, of the summit of Ben Hiant (Figure 10). The mass to the north is small and unimportant, and is surrounded by outcrops of the great Ben Hiant Intrusion, which is probably of later age. As mapped, it includes in addition to porphyritic dolerite a more acid rock (S22455) [NM 5387 6367] resembling craignurite, which is presumably a distinct intrusion.

The larger mass to the south occupies an extensive hollow high up on the south-east side of Ben Hiant, and is excellently exposed in various stream-gullies. It is intrusive against tuffs and pitchstone lava contained within the South-west Vent of Ben Hiant, but is possibly earlier than other pitchstone lavas and agglomerates belonging to the same volcanic orifice (p. 129). It seems not unlikely that it is an old crater-infilling. Without doubt it antedates the Ben Hiant Intrusion, for it is considerably contact altered in exposures next to the latter.

The southern mass is very uniform in rock-type, a black fine-grained dolerite with abundant medium-sized porphyritic felspars, of a honey-yellow colour. These phenocrysts measure about half an inch in length and are considerably smaller than those of the big-felspar basalt that occur as blocks in the agglomerates. They are on the other hand much larger than the phenocrysts of the pitchstone lavas. Locally, the ground-mass becomes slightly coarser in texture, with abundant felspar needles visible in the hand-specimen. Spheroidal weathering is characteristic of exposures of the rock along the stream-gullies.

An intrusive margin against tuff is well seen in a deep gully cut by the most easterly stream but one that crosses the mass. The plane of junction of spheroidally-weathering dolerite and baked tuff is on view for z0 ft. on the gully-sides, and is inclined steeply north-west towards the dolerite at an angle of 80 degrees.

The dolerite does not send any veins into the tuff, the junction being perfectly even. It is, however, appreciably finer in grain at the actual contact. A steep junction against agglomerate is also evident at the south end of the mass, where the margin extends steeply uphill till terminated by the Ben Hiant Intrusion.

The Porphyritic Dolerite is also in contact on its south side with a small mass of pitchstone lava contained within the Southwest Vent (p. 129). The actual junction of the two rocks is not seen, though its position can be located to within a few inches. Devitrification set up in the pitchstone adjacent to the dolerite is considered to be due to slight thermal alteration by the latter (S21462) [NM 5382 6242]. Along its north-east side, the Porphyritic Dolerite is apparently overlain by another sheet of pitchstone lava, above which an agglomerate scarp succeeds (p. 127). Here, too, the junction between pitchstones and dolerite has not been located, though very nearly determined. In this case the pitchstone retains its vitreous character close up to the dolerite, and would, therefore, seem to be later in age. If so, we must conclude that the dolerite was intruded during the infilling of the South-west Vent. Its junction with the tuff above described suggests its intrusion under no great pressure, and as already mentioned it may well be the infilling of a crater.

Petrology

(Anal. IV and V, (Table 4), p. 85). — This mass (S21254) [NM 540 626] is a dark-grey fine-textured rock that shows in the hand-specimen abundant glassy-looking porphyritic crystals of felspar which mostly range from a quarter to half an inch in length. Microscopically it consists of porphyritic basic plagioclase, a brownish ophitic augite and a dark-brown glassy

base.

The felspar of the porphyritic crystals, as judged by the mean refractive index and other optical properties, is a fairly basic labradorite, usually much twinned and occasionally somewhat zoned and albitized. The zoning is not very pronounced, but when present the ultimate product of separation was oligoclase. Albitization takes the form of irregular strings and patches of acid plagioclase within the crystals. Glass inclusions are of frequent occurrence.

The augite is often markedly ophitic (S21254) [NM 540 626], and then encloses a smaller and later generation of labradorite felspar crystals. When the augite has developed in the matrix, free from interfering felspars, it has adopted a blade-like or semi-columnar habit with a distinct tendency towards idiomorphism.

Olivine, as in the main Ben Hiant mass (p. 169), is an occasional constituent. It occurs as small porphyritic individuals, but is usually replaced by secondary products (S21464) [NM 5371 6254].

The glassy base has a dark colour due mainly to rods and disseminated magnetite or titano-magnetite. The iron-ores are more or less restricted to the base, but occur in sufficient quantity to give the rock as a whole distinct magnetic properties. Iron pyrites is often a subordinate constituent (S21463) [NM 5406 6253]. The matrix is not wholly glassy, for, in addition to the iron-ores, it contains abundant microliths and skeletal growths of oligoclase and augite (S21464) [NM 5371 6254].

Occasionally, with an increased size in the development of the later felspars and a blade-like habit of the augite, the base assumes a sub-variolitic structure (S21465) [NM 5364 6245] similar to that met with in some of the porphyritic basalts and dolerites of Central Type in Mull.<ref>H. H. Thomas *in* Tertiary Mull Memoir, 1924, p. 163 and (Figure 23), A</ref> The proportion of glass to microliths and skeletal crystals in the base varies considerably from place to place. In some cases the base is semi-crystalline with feathery growths of felspar and augite, and contains irregular green patches and strings that suggest the original presence of chlorophmite (S21254) [NM 540 626], as encountered in basic sills of the Lothians.<ref>R. Campbell and J. W. Lunn, Chlorophaeite in the dolerites (tholeiites) of Dalmahoy and Kaimes Hills, Edinburgh, *Mineralogical Mag., vol.* xx., No. to, 1925, pp. 435–440.</ref> Devitrification of the base has resulted in the production of alkali-felspar and quartz, sometimes in fine graphic relationship, but on other occasions quartz forms small isolated patches (S21463) [NM 5406 6253].

An interesting variant of this rock (S22457) [NM 5342 6275] occurs in the north-western portion of its outcrop. It adjoins the Quartz-dolerite of Ben Hiant, and its peculiar characters are probably due to the influence of the main intrusion which has produced thermal alteration of this and other rocks with which it is in contact. It is a porphyritic basalt characterized by porphyritic crystals of labradorite. These larger crystals are disposed in a matrix composed mainly of laths of oligoclase-andesine felspar, granular to hypidiomorphic enstatite-augite, and a residual glassy base that has devitrified to a feathery growth of alkali-felspar and quartz. Many of the porphyritic felspars are mottled and spongy, presenting cavities filled with glass from the matrix. The mineralogical characters of this rock, particularly the presence of enstatiteaugite, suggest a link between the dolerites of Ben Hiant and the pitchstone lavas (p. 139). The rock, however, has the appearance, like many other rocks in the Ben Hiant vents, of having been reheated and of having thereby undergone recrystallization to some extent. It is difficult to say in what measure the granular structure of this rock is original or has been produced by recrystallization, but I am inclined on the whole to regard its abnormal characters as being the result of reheating. H.H.T.

7. Quartz-dolerite of Camphouse

This plug-like mass interrupts the outcrop of the Glas Bheinn intrusion just east of Camphouse, and is therefore believed to be of later date. The small oval area occupied by it is smooth and covered by grass, anti is bounded by a raised rim of country rocks apparently baked by it. On its west side, it is bordered by the Camphouse river (Allt Choire Mhuilinn), in the high east bank of which it is well exposed. In the hand-specimen, the rock exactly resembles quartz-dolerite of Ben Hiant type, and sub-vitreous variolite-like veins traversing it are a further point of similarity. The rock is, however, too decomposed for microscopic examination.

The intrusion may be regarded as later than the Porphyritic Dolerite of Glas Bheinn, as mentioned above. It is apparently later than the cone-sheets in its neighbourhood, since its smooth, grass-covered surface is unbroken by cone-sheet featuring, though many cone-sheets both to north and south are striking at it.

8. Augite-diorite, east-south-east of Camphouse

This tiny mass is too small to indicate on the Memoir-map, but is of considerable petrographical interest. As a rock-type, it is almost unique in Ardnamurchan. It is situated 1100 yds. E. 15° S. of Camphouse, and r00 yds. north-east of the track marked on the map which extends from the main road south of Camphouse across the north side of Ben Hiant. Exposures consist of a few rock-knobs west of a scarp formed of cone-sheets, and north of an outcrop of Lower Lias limestone. No contacts with these adjoining rocks are seen, but it may be presumed, at any rate, that the mass is of Tertiary age.

The rock is very variable in texture, passing rapidly from a fine-grained dolerite into a coarse pegmatitic gabbro, in which clear yellow sphene can be seen with the unaided eye. J.E.R.

Petrology

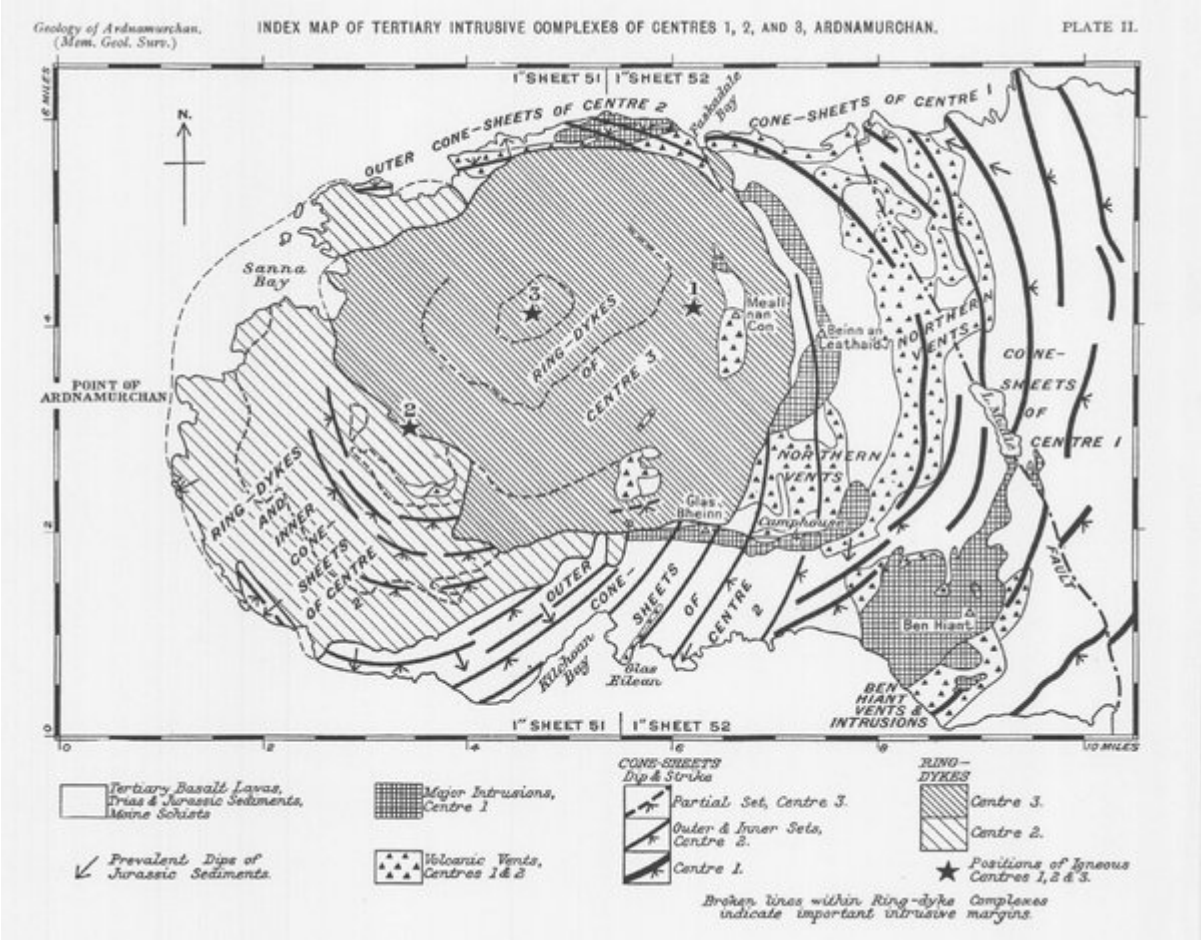
For the main part this remarkable rock is a basic-looking intrusion of coarse gabbroid texture. It has large black crystals of augite that range up to an inch or more in length, and are separated from each other by a relatively small amount of opaque white felspathic matter. In the more acid varieties the augite crystals are more elongate and more obviously idiomorphic, while the felspathic matter is more prevalent and gives to the rock a dioritic texture. A feature of this more acid type is the abundance of light-brown sphene, which may be seen in the hand-specimen to form crystals and patches measuring as much as half an inch in length. In the coarser gabbroid rock (S22225) [NM 5207 6433] the augite is a deeply coloured variety, and strongly pleochroic in shades of brownish-green and yellow or yellowish-brown, but occasionally there is that brownish-lavender tint suggestive of a titaniferous content. The felspar is labradorite and small in amount. It is frequently inter-grown with the augite in graphic relationship, but is also moulded upon augite when this mineral has developed idiomorphic outlines. It is mostly much twinned and shows signs of albitization.

In slightly more felspathic varieties (S21512) [NM 5207 6433] the augite is of similar composition and habit, but the rock as a whole takes on the somewhat unusual character of not only containing an alkaline residuum of perthitic composition, but developing large allotriomorphic patches of perthitic orthoclase. In the alkaline residuum and in the patches of alkali-felspar there has been a great concentration of apatite, crystals of which are practically unrepresented as inclusions in the minerals of earlier generation. It is the extremely felspathic varieties of this rock which are the most remarkable. In these (S22226) [NM 5207 6433] the augite crystals present sharply idiomorphic boundaries to the felspathic matrix. In their central portions they are similarly coloured and have the same pleochroic scheme as those previously described. They are, however, commonly bordered with a deep-brown variety, and less frequently with a grass-green augite that has lower extinction values and presumably an alkaline composition. The extreme outer layer is of a rich clove-brown colour, strongly pleochroic and is referable to acmite. The felspathic constituents are, as before, of two kinds, plagioclase still being the dominant variety. The felspar occurs without ophitic or graphic relationship to the augite and is generally moulded upon it. In the main it consists of partially albitized labradorite in fairly large crystals that are zoned to the composition of oligoclase, but perthitic orthoclase, with its usual concentration of apatite, is liberally developed.

The rock considered as a whole is probably pegmatoid in character. The presence of abundant sphene removes it from the gabbros, while the high content of alkali-felspar suggests a relation to the essexites or theralites. It would, perhaps, be best to refer to the rock tentatively as a somewhat alkaline augite-diorite. Portions of the mass are, as the above description indicates, quite alkaline in character, but no felspathoid minerals have been detected; if they were ever present they must be represented by certain small chloritic patches that occur within the areas of perthitic orthoclase and which occasionally show idiomorphic outlines. The abnormal character of the rock as a whole, when compared with other Tertiary intrusions, cannot but east some doubt, first on its age, and secondly on its mode of origin. If it is really related to the theralites there would be some difficulty, without more direct stratigraphical evidence than is forthcoming, in assigning

to it a Tertiary age. Further, if a Tertiary intrusion, is it a normal type that represents a definite magmatic phase, or has it arisen through a process of hybridization or contamination ? Fortunately the answer to both these questions has been furnished by the behaviour of certain acid veins that have emanated from one of the gabbros of the ring-dyke complex. A gabbro situated to the south-east of Rudha Groulin has given off felspathic veins that have penetrated, granulitized, and absorbed cone-sheet material (p. 293). Within the basic cone-sheet these veins (S22636) [NM 4740 7084] show a coarsely crystalline texture, and consist of large greenish-brown crystals of augite, and laths of decomposed plagioclase in a matrix of perthitic orthoclase charged with apatite. Further, there has been a development of sphene. The mineral assemblage here met with is practically identical with that of the augite-diorite described above. Moreover, the structural relations of the various minerals to each other are similar. Such being the case, and these veins owing their character to the assimilation of basic material by an alkaline partial magma, it is probably safe to assume that the so-called augitediorite of Camphouse is of Tertiary age, and of hybrid nature and origin.

The effects produced in the body of the cone-sheet by these veins are worthy of comment. The bulk of the rock has suffered recrystallization with a structure akin to granulitization; but in the process of reconstruction the incoming of alkaline matter has caused the augite to change over from the ordinary brownish variety of the cone-sheets (p. 187) to a yellowish-brown strongly pleochroic variety, which has a lower extinction angle, is identical with the augite of the more basic portions of the augite-diorite, and is certainly enriched in alkalis and ferric oxide. At the same time the granulitized rock is strung with veins of alkali-felspar, and has developed large crystals of sphene. H.H.T.



(Plate 2) Index map of Teriary intrusive complexes of Centre 1, 2, and 3 Ardnamurchan.

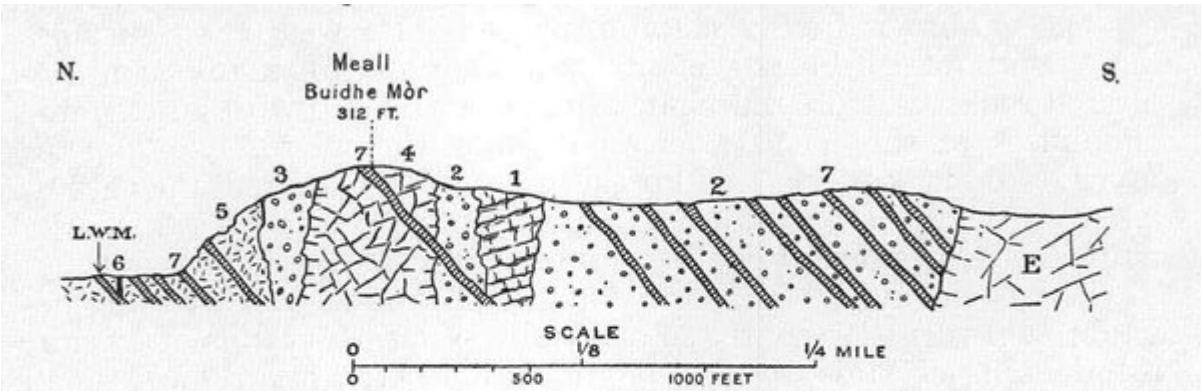
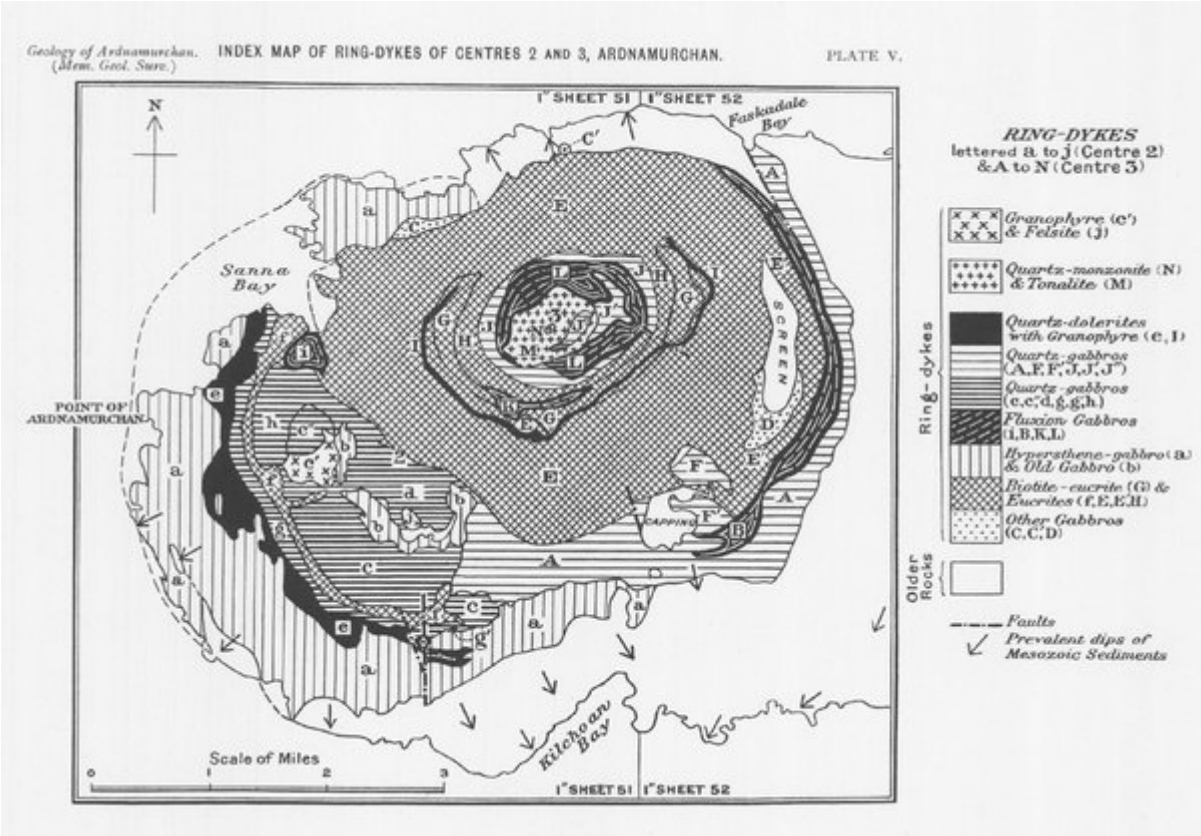


FIG. 16.—*Section, west of Faskadale Bay.*

1. *Basalt lava in vent.* 2, *Vent-agglomerate.* 3, *Screen of vent-agglomerate separating intrusions* 4 *and* 5. 4, *Gabbro of Centre* 1. 5, *Granophyre of Centre* 1. 6, *Basic E.N.E. dyke, seen to cut some cone-sheets and to be cut by others.* 7, *Cone-sheets of Centre* 2. E, *Great Eucrite Ring-dyke of Centre* 3. L.W.M., *Low-water Mark.*

(Figure 16) Section, west of Faskadale Bay. 1. Basalt lava in vent. 2. Vent-agglomerate. 3. Screen of vent-agglomerate separating intrusions 4 and 5. 4. Gabbro of Centre 1. 5. Granophyre of Centre 1. 6. Basic E.N.E. dyke, seen to cut some cone-sheets and to be cut by others. 7. Cone-sheets of Centre 2. E, Great Eucrite Ring-dyke of Centre 3. L.W.M., Low-water Mark.



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

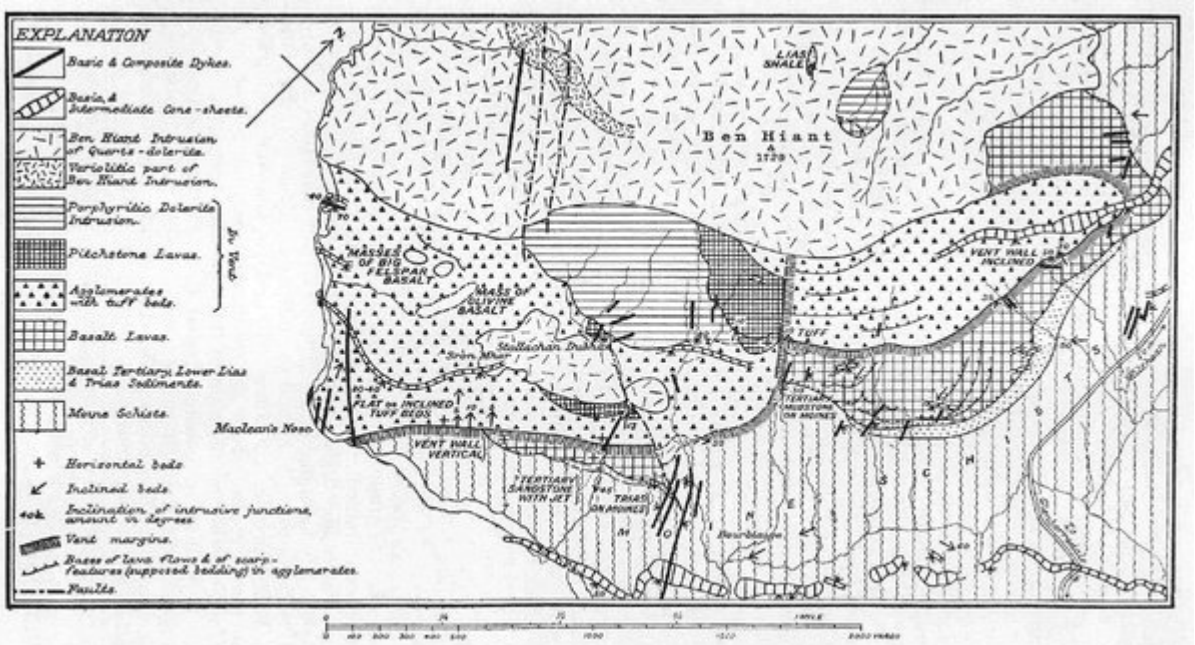


FIG. 10.—*Map of Vent-Complex, eastern side of Ben Hiant.*

(Figure 10) Map of Vent-Complex, eastern side of Ben Hiant. Geology of Ardnamurchan.

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)).

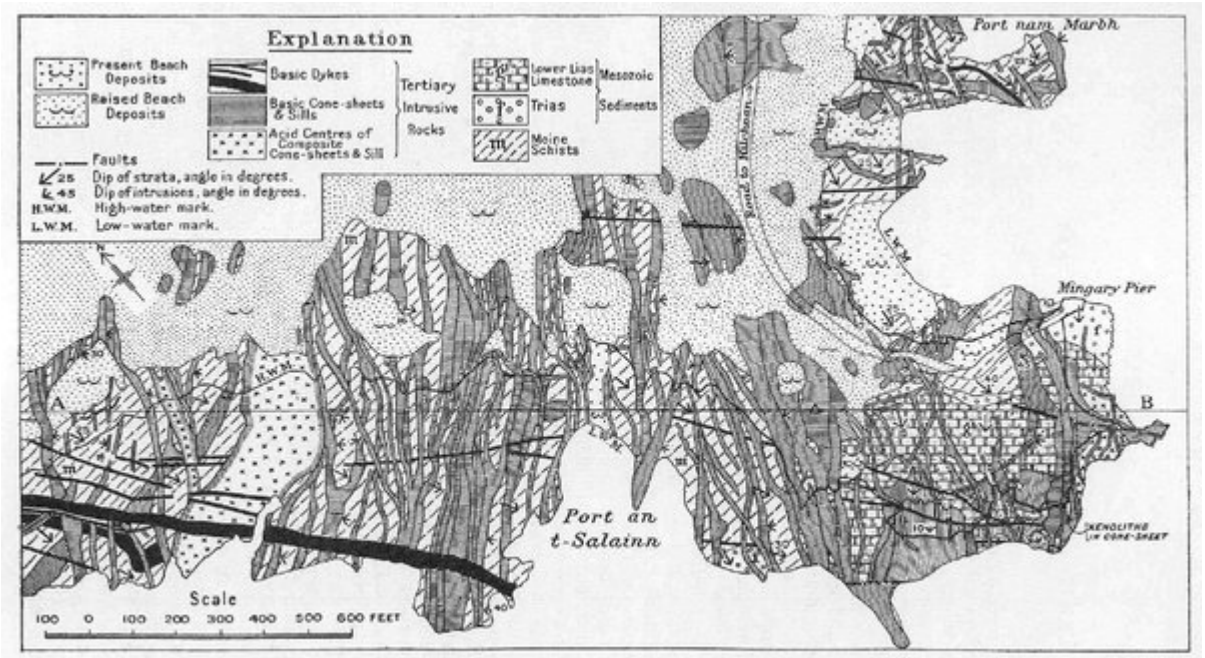


FIG. 23.—*Map of Outer Cone-sheets of Centre 2, shore south of Kilchoan.*

(Figure 23) Map of Outer Cone-sheets of Centre 2, shore south of Kilchoan.