Chapter 21 Tertiary ring-dykes of Centre 3, Ardnamurchan–(Continued)

The ring-dykes that remain to be described comprise the Interior Complex, which is surrounded by the Great Eucrite, and are as follows (*see* Index Map, p. 201 (Plate 5)):-

G. Biotite-eucrite

H. Inner Eucrite

I. Quartz-dolerite veined by Granophyre

J, (J′), and (J″) Quartz-biotite-gabbros

K. Fluxion Biotite-gabbro of Sìthean Mòr

L. Fluxion Biotite-gabbro of Glendrian

M. Tonalite

N. Quartz-monzonite

The area around Achnaha occupied by the Interior Complex is noteworthy on account of its ring-featuring. Its outer limit is set by the conspicuous circle of crags that mark the inner side of the Great Eucrite (*see* (Plate 4)). The base of these crags closely coincides with the outcrop of the narrow granophyre-veined Quartz-dolerite Ring-dyke (I), while the actual inner margin of the Great Eucrite deviates slightly on either side of this intrusion. The curving ridges of Sìthean Mòr and of Glendrian, the latter forming a practically complete ring, correspond to individual intrusions of fluxion biotite-gabbro (K) and (L). In the intervening hollow, on the south side of the Interior Complex, two other gabbros lettered (H) and (J) can be distinguished. One of them (H), termed the Inner Eucrite, along the eastern and western parts of its arcuate outcrop forms a low curving ridge flanked by less durable rocks. The Glendrian ring-ridge just mentioned is illustrated in *see* (Plate 6) surrounding a central area of lower relief, which is chiefly occupied by the Tonalite (M). Rising ground in the middle of this area is formed of a small mass of Quartz-monzonite (N). Perhaps the clearest demonstration that we are dealing with a complex of ring-dykes is afforded by the narrow Quartz-dolerite intrusion (I). Its ring-pattern is evident, and there is no doubt that it is steeply intruding the rocks traversed by it.

Time relations between many of the gabbro masses cannot be determined. Two ring-dykes can, however, be proved to be later than the Great Eucrite, viz. the Quartz-dolerite (I) and the Fluxion Biotite-gabbro of Sìthean Mòr (K). An apophysis from the outer side of (K) manifestly cuts the Great Eucrite, but on its inner side no evidence is forthcoming as to its age relations with the Inner Eucrite (H). The Inner Eucrite is with some hesitation regarded as a distinct intrusion from the Great Eucrite, and not merely as a portion of the latter, separated by younger intrusions. An element of doubt also attaches to the Fluxion Biotite-gabbro of Glendrian (L), as to whether it is a distinct intrusion from the similar rock of Sìthean Mòr; for no age relations have been with certainty established between them and the intervening intrusions (H) and (J). The Glendrian Ring-dyke is, however, in sharp contact with the Quartz-biotite-gabbro (J) outside it, and contains small masses of quartz-biotite-gabbro which may be interpreted as xenoliths derived from its walls. If this view be correct, these Glendrian and Sìthean Mòr masses are distinct intrusions. It would seem likely that the various coarse-textured Quartz-biotite-gabbros (J), (J′), and (J″), are all portions of a single intrusion that was split up by the Glendrian Ring-dyke (L) and the Tonalite (M). The Tonalite passes into a fine-grained marginal facies against the gabbros outside it, into which it is clearly intrusive. Cutting the Tonalite in turn there is the small central mass of Quartz-monzonite which marks the final episode of the Later Ring-dyke Complex.

(G) Biotite-eucrite

Biotite-eucrite forms a broad outcrop around the inner margin of the Great Eucrite (E), except to the north. It is noteworthy that a similar discontinuity to the north is a feature of various other ring-dykes of Centre 3. This in itself suggests that the Biotite-eucrite is a distinct intrusion.

The Biotite-eucrite differs lithologically from the Great Eucrite not only in containing biotite, but also in being for the most part more felspathic. The biotite is somewhat sporadic in its occurrence and is locally absent. There is no suggestion in the field, such as well-developed acid veining, that it has resulted by reaction, *in situ,* between normal eucrite and an incoming acid magma. Sparsely developed acid veining appears to be a late derivative from the mass itself, and is richer in biotite than the normal rock. An example may be seen in the Allt Màm a'Ghaill (S21478) [NM 4798 6751].

Perhaps the best locality for judging the distinctness of the Biotite-eucrite from the two intrusions that chiefly bound it, the Great Eucrite and the Inner Eucrite, is alongside the track that leads from Achnaha to Plocaig. A vertical junction with the Inner Eucrite is exposed on the east side of the track, 530 yds. north-west of Achnaha. The Inner Eucrite is easily distinguished from the Biotite-eucrite, since it is in this part of its course of medium grain, fluxioned, and olivine-rich. At the contact seen, no evidence of relative age could be obtained; for neither rock shows any appreciable marginal change against the other. The Biotite-eucrite is frequently exposed alongside the track from this point on to a ford across an easterly branch of the Allt Sanna. Just north of the ford, biotite-eucrite is abruptly succeeded by normal eucrite which is mapped as part of the Great Eucrite. No actual intrusive contact, however, is discernible, but this is not surprising since the two rocks do not differ in texture. Another locality maybe mentioned, viz. alongside the Kilchoan–Achnaha road where it curves. Around a peaty flat, west of Creag an Airgid. There also, though both types of eucrite are found in close association, no intrusive relationship could be discerned. Along the eastern limb of the Biotite-eucrite, as mapped, its margins against the Eucrite intrusions on either side have been only approximately determined. The Biotiteeucrite forms smooth, poorly exposed ground between ice-smoothed rocky country that marks the outcrops of the Eucrites. J.E.R.

Petrology

(Anal. I, (Table 4), p. 85). — This mass as represented by specimens collected from its southerly outcrop, to the east of Sìthean Mòr, is definitely eucritic in nature (S21479) [NM 4736 6718], and from this region material was collected for chemical analysis (S21250) [NM 4766 6739]. It is a moderately coarse, fresh gabbroid rock of general grey tint, composed essentially of a greasy-looking greyish felspar with bright cleavage-faces, and augite that occurs as somewhat irregular dark crystals and patches. The felspar is usually in excess of the pyroxene, but the dimensions of the respective crystals are approximately the same, and range up to one or one and a half centimetres in greatest length.

Microscopically the structure and the mineral-assemblage are those of the eucrites. Olivine occurs in a practically undecomposed condition. It is not a particularly abundant mineral, but when present builds rounded crystals several millimetres in diameter, which are usually of earlier consolidation than the felspar, although they may occasionally enclose small crystals of bytownite of earlier generation. The bulk of the felspar is, however, a much twinned but unzoned basic labradorite. It usually shows some slight mottling with a variable extinction, and is also strung to a varying degree with albite. The analysed specimen (S21250) [NM 4766 6739] shows the mottling of the felspars to great advantage, and also suggests that individual crystals have suffered resorption followed by a regrowth of felspar of less basic composition.

Augite of a somewhat dirty brown colour forms large ophitic patches and is moulded upon both olivine and felspar. In addition to the monoclinic pyroxene, hypersthene is a moderately abundant constituent. It occurs in association with olivine, and as fairly large irregular ophitic crystals moulded upon felspar. Iron-ore is not very abundant but is usually present as large ill-formed patches, which, in the analysed rock, are fringed with biotite that, with a- colourless amphibole, forms a narrow reaction zone between the iron-ore and contiguous labradorite.

There is little doubt that the rock, as represented by the analysed specimen, has suffered some slight change from its original condition.

This is suggested by the mottled appearance and local reduction in basicity of the felspars, by the interaction of iron-ore and feldspar with the production of biotite and hornblende, by the relative abundance of rhombic pyroxene, and by the fact that apatite, which is of rare occurrence in the most eucritic types, becomes prevalent in those which carry hypersthene. Some modification of the rock as the result of reheating is also suggested by the occurrence of small granulitic patches within the felspars, which are made up of minute granules of biotite, rhombic pyroxene, hornblende, and magnetite.

Although much of the mass is definitely eucritic and carries olivine, there are portions which are more augitic and are composed essentially of an ophitic diallagic augite and labradorite (S21809) [NM 4580 6833]. That the bulk of this biotite-eucrite owes its biotitic and other somewhat abnormal characters to the influence of an acid partial magma is made clear by specimens collected from various parts of the mass. In nearly all instances an acid mesostasis can be detected, and in many cases it bulks largely in the composition of the rock. It then forms a mass of turbid and often graphic perthitic felspar and quartz which carries abundant apatite (S21497) [NM 4892 6820]. The effect of this acid material has been to cause the resorption and albitization of the basic felspars and a regrowth of acid fringes at their peripheries. Also, where contact has been effected with augite, hornblende and biotite have been developed. The albitization of the basic felspars is frequently in a net-like form, in which fine strings of albite appear to follow intersecting lines of fracture in the original mineral (S21487) [NM 4879 6867]. It would appear that this fissuring of the felspars is due to a similar cause to the shattering observable in some of the other rock-masses (p. 268), but had not reached such an advanced or intense stage (S21546) [NM 4586 6901], (S21476) [NM 4573 6783]. The effects are confined to the production of a network of cracks and the occasional bending and displacement of twin lamellae (S21475) [NM 4724 6722]. This incipient disruption is in all cases followed by albitization, both phenomena being in all probability due to the pressure exerted by the crystallization of an acid magma that was charged with volatile constituents. Local hybridization of basic by acid material has produced certain mineral changes without the destruction of the general gabbroic composition and structure of the original rock. The chief changes, where the acid material is most in evidence, are the separation of large plates of biotite (S21497) [NM 4892 6820], the development of hornblende at the expense of augite, and the albitization of the original labradorite felspars. Where the action is less pronounced the effects are mainly the local deschillerization of the original diallagic augite, the production of uralitic hornblende, and the development of rhombic pyroxene in association with olivine. Such changes as these were effected on a rock that was evidently almost solid, and therefore complete interaction was outruled; but we encounter within the mass rocks that exhibit the characters of true hybrids, and in which the acid magma has sunk its identity by reason of almost complete interaction with basic material. In some cases a more or less normal gabbroic rock may be seen to pass rapidly into one of much finer texture (S21486) [NM 4915 6872], which contains moderately abundant biotite (chloritized), recrystallized augite, a good deal of iron-ore, intensely albitized remnants of basic plagioclase, and abundant apatite, in a granophyric matrix of perthitic orthoclase and quartz.

Two other abnormal types have also been detected. One is a moderately fine-grained rock, occurring as veins (S21478) [NM 4798 6751] and presenting characters reminiscent of the Tonalite and Quartz-monzonite of Centre 3 (p. 338). It consists of hypidiomorphic augite, large plates of biotite, pseudomorphs after rhombic pyroxene in fibrous hornblende, generally acidified and recrystallized plagioclase felspar and large apatites, in a matrix composed of perthitic orthoclase and quartz.

Another type, also fine-grained and occurring as narrow strips along the road between Achnaha and Plocaig (S22262) [NM 4599 6877], has a doleritic texture. It contains an abundance of augite that has assumed an ophitic, with an approach to a cervicorn,<ref>H. H. Thomas and E. B. Bailey *in* Tertiary Mull Memoir, 1924, p. 302.</ref> structure. It has developed large areas of ophitic hypersthene and large plates of biotite that is moulded upon felspar. The felspars are elongated individuals with a prismatic to platy habit, and have a composition varying from labradorite to oligoclase. There is a small amount of acid mesostasis containing alkali-felspar and a little residual quartz, and moderately abundant magnetite that occurs mainly in association with the rhombic pyroxene. H.H.T.

(H) Inner Eucrite

It cannot be demonstrated whether the Inner Eucrite is a portion of the Great Eucrite or a distinct intrusion. There is, however, a sharp contact with the Biotite-eucrite (G), as described above (p. 322).

In its eastern portion the Inner Eucrite forms a slight curving ridge, and further evidence of its arcuate shape is there provided by the changing directions of longitudinal pegmatite veins that traverse it. The veins are found as far north as the point where the Inner Eucrite and Great Eucrite come together. Exposure here becomes poor, but at one place, west of a patch of peat and 500 yds. south-east of the summit of Meall Clach an Daraich, outcrops are more continuous. A steep junction was noted there between olivine-rich eucrite of fairly fine grain (perhaps the inner margin of Great Eucrite) and coarse-textured felspathic eucrite with large irregular olivine-aggregates (perhaps the outer margin of Inner Eucrite). The relative ages, however, of the two rocks in contact could not be ascertained. Southwards, east of the Kilchoan–Achnaha road, eucrite with pegmatite veins gives place westwards, along the course of the ring-dyke, to eucrite with fluxioned felspars, a type that is difficult here to separate from the adjoining Fluxion Biotite-gabbro of Sìthean Mòr (K). Farther west, however, along the north side of the curving Sìthean Mòr ridge, these two masses are quite distinct in rock-type. The Inner Eucrite next to the Fluxion Biotite-gabbro is here fairly fine grained, is rich in olivine, and contains pegmatite veins, while a few yards away towards its interior it becomes an extremely coarse-textured rock with large plate-like augites. West of Achnaha, normal eucrite forms a low curving ridge that is bordered externally by fluxion eucrite. North of Achnaha, alongside a track leading to Plocaig, this fluxion rock is especially well exposed and contains abundant olivine in crystals or crystal-aggregates arranged parallel to the direction of flow. It may be remarked that the prevalence of olivine and absence ofbiotite usually serve to distinguish fluxion eucrite from fluxion biotite-gabbro.

It is not certain whether this fluxion eucrite forms an integral part of the Inner Eucrite. Gradation from the normal type into the fluxion eucrite seems, however, to take place.

Petrology

This ring-dyke is composed of an olivine-rich rock most nearly comparable with the basic portions of the Great Eucrite (E). It has often approximately the same texture as the Great Eucrite, and appears for the greater part to be unmodified. It consists of fresh olivine, diallagic augite, and felspar, ranging in composition from labradorite to bytownite. The olivine is the usual magnesian-iron variety, which is of early consolidation but, like the olivine of the Great Eucrite, frequently encloses small rounded crystals of early felspar (S21481) [NM 4802 6786]. It occasionally has hypersthene developed in close association with it, a development that is marked by the separation of magnetite in dendroid form (S21492) [NM 4596 6831]. The mass as a whole appears to be more uniformly basic than the Great Eucrite and occasionally is definitely allivalitic in composition (S21547) [NM 4603 6862]. In such cases the rock consists essentially of olivine and basic plagioclase, augite being quite subordinate. H.H.T.

(I) Quartz-dolerite veined by granophyre

As already mentioned (p. 321), this narrow, curving outcrop of quartz-dolerite furnishes the clearest example of a ring-dyke within the Interior Complex. Contacts with adjoining rocks provide evidence of its distinctness as an intrusion and of its steep dyke-like form. Occurring as it does, exactly at the foot of the Great Eucrite scarp, it was there identified at an early stage in the mapping of the Interior Complex, and was the first good evidence to be obtained in Ardnamurchan of the ring-form of the major intrusions.

The characteristics of this composite intrusion are similar to those already described in the case of the ring-dyke of Sgùrr nam Meann (e) (p. 256). The main differences are that biotite is of general occurrence in the doleritic portion of (I), and that the granophyre occurs in thicker net-veins. The restriction of the acid net-veining to the narrow outcrop of the ring-dyke is a most -remarkable feature. The walls of the intrusion are nowhere veined, though the granophyre was intruded subsequently to the consolidation of the quartz-dolerite. Sometimes the granophyre forms distinct masses between the doleritic portion and the wall, or may even occur alone, as at the north-west extremity. The two stages of magma-injection were therefore restricted to the same ring-fracture. The quartz-dolerite was intruded, became consolidated, and was then brecciated before the granophyre magma entered its cracks and fissures. The quartz-doierite grades rapidly in places from the normal basic rock to a more acid type, but is everywhere in sharp or hybridized contact with the veins of granophyre. The granophyre cannot be a late segregation product of the crystallization of the quartz-dolerite, at any rate at its present exposed level.

The replacement of the normal net-veined quartz-dolerite by a breccia composed of the rocks forming its walls has been already briefly described (pp. 212–3). This occurs at the north-eastern termination of the Ring-dyke, and furnishes an indication of its mode of intrusion.

The most extensively exposed contact between the intrusion and its wall is on its eastern side, just north of the outwardly projecting arm of the intrusion shown on the Memoir-map. The outer margin of the Quartz-dolerite, varying greatly in composition, can be traced to a chilled edge against the Great Eucrite. The plane of junction is well exposed on a steep face of eucrite, and though somewhat irregular is, taken as a whole, inclined eastward at about 70 degrees, outwards from the Achnaha Centre (3). Other chilled junctions may be seen farther south and west, for example in the tributary stream south-west of the Allt Màm a'Ghaill, on the outer margin of the Ring-dyke. Along its inner margin in this stream, granophyre forms a mass distinct from the quartz-dolerite portion, and presents a vertical unchilled contact against the Biotite-eucrite within it.

In the Allt Màm a'Ghaill, the quartz-dolerite portion is separated from both walls by granophyre, by which the dolerite is abundantly net-veined. In contrast, the granophyre sends broad tongues into the walls of Biotite-eucrite on either side, but does not net-vein them. J.E.R.

Petrology

A considerable portion of the mass has the appearance of a moderately fine-grained quartz-dolerite (S21495) [NM 4834 6779], but the development of much uralitic hornblende and fairly abundant biotite suggests a hybrid origin. More localized portions of the intrusion are definitely of hybrid nature (S21496) [NM 4931 6950]; and consist of a mass of short prisms of labradorite and patches of less basic plagioclase enveloping occasional large crystals of albitized basic plagioclase, an abundance of small hypidiomorphic crystals of augite, uralitic pseudomorphs after rhombic pyroxene, clots of brown-green hornblende with occasional biotite, and abundant magnetite.

The acid veins that string through the more basic portions of the intrusion show evidence of basification. They are granophyres (S21536) [NM 4795 6753], (S22263) [NM 4591 6889] that consist mainly of perthitic alkali-felspar and quartz, the former often tending towards a porphyritic development. A plagioclase felspar, however, with strongly acidified margins is occasionally present. Relics of basic material exist in the form of irregular patches of iron-ore, hornblende, and pseudomorphs after biotite. The quartz–felspar matrix exhibits a coarse and somewhat ill-defined graphic structure. H.H.T.

(J), (J′), And (J″) Quartz-biotite-gabbros

Quartz-biotite-gabbro occurs in three distinct masses separated by two intrusions both probably of later date (p. 322). The rock is very variable in grain, but for the most part extremely coarse-textured and comparable to pegmatite. In containing iron-ore, in large crystals, and biotite, it differs from eucrite; while quartz can usually be seen in the more acid, felspathic, portions or in drusy cavities. Olivine is frequently present, and in some places the rock approaches eucrite in composition. Epidote is often developed, usually in the more acid quartz-bearing portions.

As already stated, it is considered probable that the three masses here described together are parts of one intrusion. In the case of the two inner masses (J′) and (J″), this is practically certain, for they are separated only by the Tonalite, which is demonstrably of later date. Their former connexion with the outermost and largest mass (J) is not improbable. This mass is separated from (J′) by the Fluxion Biotite-gabbro (L) which appears, by such evidence as is available (p. 334–5), to be later than (J).

While the distinctness of the two larger masses, (J) and (J′), from adjoining intrusions is evident at many places, it should be stated that, in the eastern parts of both, great difficulty was experienced in the field in separating them from adjoining gabbros. The difficulty is, partly at least, a matter of sparseness of good exposure. Possibly, however, had more time been available, the mapping in this part of the area, around Glendrian farm and farther east, might have been improved.

The screen-like mass (J″) is mapped as a unit but, besides the normal coarse-textured gabbro, includes a finer-grained type that may belong to another intrusion (*see* p. 337). J.E.R.

Petrology

(Anal. VI, (Table 4), p. 85). — The mass (J) is identical in character, and presumably in origin, with the gabbro-screen in the Tonalite (J″, p. 340) and with the Quartz-biotite-gabbro **(**J′**).** The original rock would appear to have been an olivine-gabbro. Representative specimens (S21480) [NM 4818 6917] exhibit albitization of basic felspar and formation of biotite from augite and iron-ore, while there is the usual concentration of apatite. Micrographic alkali-felspar and quartz fill the interstices between the larger crystalline constituents, and are presumably referable to a hybridizing partial magma.

The mass (J′) is a moderately coarse augitic gabbro that has suffered considerable modification. The changes that the gabbro has experienced are the intense albitization of the basic plagioclase (S21538) [NM 4795 6848], the deschillerization of the augite with the formation of spangles of biotite and hornblende-fringes, and the introduction of an apatite-rich alkaline and siliceous magma that has crystallized as perthitic orthoclase and quartz (S21477) [NM 4819 6849]. Olivine was occasionally an original constituent of the gabbro (S21256) [NM 4811 6931]. Biotite has been developed, usually at the expense of original iron-ore. H.H.T.

(K) Fluxion biotite-gabbro of Sìthean Mòr

This arcuate mass forms the curving steep-sided ridge of Sìthean Mòr, and also extends eastwards across the Kilchoan–Achnaha road. It is separated from the Glendrian Ring-dyke (L), which is similarly composed of fluxion biotite-gabbro, by the Inner Eucrite (H) and the Quartz-biotite-gabbro (J), as already mentioned (p. 321).

The rock is typically medium-grained and dark in colour, and its felspars are markedly fluxioned. Biotite is plentiful, and also iron-ore in small crystals. In the middle part of its course, west of the Kilchoan–Achnaha road, the intrusion, as mapped, consists of three portions, the normal fluxion gabbro on the north, coarse-textured quartz-biotite-gabbro on the south, and an intervening portion composed of the two bordering gabbro-types in alternating bands (Figure 47). The coarse gabbro weathers white and thus contrasts with the darker-weathering fluxion gabbro; biotite is plentiful and quartz easily detected. It is, in fact, exactly similar to the Quartz-biotite-gabbro last described (p. 328).

In the banded portion, individual bands are usually inclined inwards towards the Achnaha Centre (3), but are sometimes vertical or inclined outwards. Where inclined, the angle is always steep.

The banding phenomenon is quite different from that found in the Hypersthene-gabbro (a) for example (p. 221), which is due to flow-movement during the crystallization of a homogeneous magma. The bands are too wide, and besides they are formed of two distinct rock-types. In this banded zone a third rock-variety occurs which bears a resemblance to the other two, and seems to have resulted from their intermixture; for the banding becomes indistinct in this apparently mixed rock. The banding is best seen at a point 200 yds. west of where the intrusion is crossed by the Kilchoan–Achnaha road. There, on the inner or northern side of the intrusion, the normal type, a medium-grained dark-coloured fluxion biotite-gabbro, occurs alone. On the outer or southern side, coarse-textured unfluxioned quartz-biotite-gabbro is similarly developed as a rock-mass by itself. In the middle, banded zone, the conspicuous white bands of the coarse gabbro vary from an inch or so in width on the north side to, a yard or more on the south side. These broad bands are sharply defined, and are seen to extend for many yards without change of direction or width. A similar variation in the width of the intervening bands of the darker gabbro also occurs, except that in this case the increase in width takes place towards the north. The widest bands are, in fact, found next to the mass, to which they correspond in composition.

A variation in the character of the white gabbro bands is noteworthy. Where these are wide, the rock is coarsely or indeed very coarsely crystallized, and there is no fluxion arrangement of the minerals. In contrast, the associated bands of the darker gabbro show perfect fluxion arrangement of the felspar crystals, parallel to the edges of the bands. But, where the white gabbro is in thinner bands, their crystallization is finer and the felspars frequently show fluxion parallel to the banding. It is in this part of the banded zone that the banding often becomes indistinct, and the intermediate mixed type of gabbro is developed.

From the above observations the conclusion is drawn that two distinct magmas found their way into the same ring-cavity, and along their mutual junction formed a banded gabbro. The condition of these two magmas was different. The fluxion gabbro was evidently in a partially crystallized state while it flowed in interbanded fashion with the other magma. The narrower bands of the white gabbro, however, must have started to crystallize before flow-movement had ceased, since their felspar-crystals are often fluxioned. As already stated, it is in this part of the banded zone that intermingling of the two magmas appears to have often taken place, producing the intermediate type of gabbro. In the outer, southern part, where the magma that gave rise to the broad bands of white gabbro remained liquid till flow-movements had ceased, the individual bands are in perfectly sharp contact. It seems necessary to assume that the two magmas were here inhibited from mixing with one another. This may perhaps be in some way connected with the fact that the magma which formed the darker gabbro was in a partially crystallized state while the other remained altogether fluid.

Marginal relations

The Sìthean Mòr intrusion is of importance because of its marginal relations to the Great Eucrite (E). Half a mile west of the Kilchoan–Achnaha road an apophysis from it can be traced out into the Eucrite (Figure 46). The protrusion consists of a fine-grained marginal portion in contact with the Eucrite, and a central more coarsely crystallized portion. The marginal portion presents a chilled edge to the Eucrite, and contains xenoliths of eucrite identical in texture with that forming its walls. Its later age is unquestionable. Yet this marginal portion appears in the field to be itself a baked rock, and is found in microscopic section to be granulitized. This apparent anomaly is of considerable interest. Between the two portions of the apophysis the change in texture is everywhere abrupt, and a sharp contact was located, at which the baking of the marginal rock is intense, while the coarser interior is apparently unbaked. Two stages in the infilling of the fissure are thus indicated. A first injection of magma cooled quickly as the fine-grained marginal rock, and was granitzed by a second injection forming the interior of the apophysis.

Further details concerning the apophysis may be added. At a point l00 yds. west of the Kilchoan–Achnaha road it extends out from the Fluxion Biotite-gabbro for a short way into the Eucrite, and then runs westwards for a distance of 250 yds. parallel to the parent mass, which it then rejoins. At this end it is very narrow, being only about 12 ft. wide, and the fine-grained marginal type occurs alone. Exposures are discontinuous for a few yards where the apophysis should connect on to the main mass, but they are so alike in rock-type, fine grained, fluxioned, dark, and with plentiful biotite, that their continuity cannot be doubted.

The small xenoliths of eucrite are found all along the outer marginal portion, which is well exposed. They are usually of normal eucrite, but at about the middle of the apophysis they consist of pegmatitic eucrite with large plate-like augites. At this point similar coarse-grained eucrite bounds the apophysis on its northern side, and it is therefore concluded that the xenoliths are derived from the eucrite forming the walls. A short way west of this the xenoliths are especially well seen, just east of a stone-wall that crosses the apophysis (Figure 46), where they occur in all stages of disintegration. A chilled junction between marginal rock and eucrite was located to the north-west near to where the apophysis rejoins the main mass. The darker chilled skin of the marginal rock is easily seen in a hand-specimen. The internal junction between baked marginal rock and the central coarser type is exposed to the south-east, along the outer side of the apophysis, not far from where it branches from the main mass.

Though the junctions of the Sìthean Mòr intrusion with both the Biotite-eucrite (G) and Inner Eucrite (H) can be determined to within a few feet, no actual contacts have been found. Consequently the relative ages of these three intrusions are not known. Where the eastern arm of the apophysis branches from the main mass it is, however, in intrusive contact with a narrow outcrop of biotite-bearing eucrite or gabbro that would appear to belong to the Biotite-eucrite. There are therefore some grounds for considering the Biotite-eucrite to be earlier than the Sìthean Mòr intrusion.

Segregation-veins with ill-defined margins were noted in the Fluxion Biotite-gabbro in a small burn just east of Sìthean Mòr, south of where the Kilchoan–Achnaha road crosses a stream–the Allt Uamha na Muice. The rock contains large crystals of biotite and is akin to tonalite (S21540) [NM 4738 6734]. J.E.R.

Petrology

This mass, from a petrological point of view, has much in common with the Biotite-eucrite (G), which it adjoins. These two intrusions, although demonstrably distinct, have undoubtedly a similar history, both being fundamentally eucritic in nature. The variable character of the Sìthean Mòr mass is presumably due to the hybridizing influence of an acid magma on a partially crystallized basic magma of eucritic composition. It presents characters that were encountered locally in the Biotiteeucrite, and it possibly represents a more advanced stage of hybridization than the adjoining mass exhibits. The mineral assemblages however, are similar in both cases.

Where the mass is obviously eucritic, it is a moderately coarse-grained basic gabbro (S21482) [NM 4806 6781] that exhibits no serious modification of its original constituents. It is built up of large and small rounded crystals of olivine in close association with a coarsely ophitic brownish-green augite and large plates of much-twinned bytownite. Still recognisably eucritic, but in a modified condition (S21537) [NM 4759 6753], the rock assumes the form of a coarse hypersthene-gabbro in which the place of augite is almost completely taken by rhombic pyroxene and uralitic hornblende. The felspars are patchily reduced in basicity.

Veins in the mass may be described as basic granophyre (S21540) [NM 4738 6734]. They consist of a few large crystals of albitized labradorite in a finer-textured mass of less basic plagioclase, recrystallized hypidiomorphic augite, biotite, large plates of alkali-felspar of late consolidation, and an ultimate residue of alkali-felspar and quartz in coarse graphic intergrowth. The most acid portions are rich in large crystals of apatite.

A specimen collected from the white-weathering gabbro of the banded zone (p. 330) is gabbroic in texture (S22628) [NM 4731 6727]. It consists of albitized labradorite, augite which has been attacked with the development of scales of biotite and peripheral fibrous green hornblende, little nests of actinolite needles and biotite in association with alkali-felspar or quartz, and large irregular grains of magnetite. The finer-grained fluxion biotite-gabbro of the banded zone is sub-granulitic in texture (S22627) [NM 4731 6727], consisting of hypidiomorphic schillered augite, abundant irregular grains of magnetite, brown hornblende, plates of biotite, and prisms of moderately basic plagioclase. The hornblende and biotite occur sparingly and usually in association with the iron-ore.

The abnormal character of the mass of quartz-biotite-gabbro on the outer side of the banded zone is evident in specimens collected (S21475) [NM 4724 6722]. Much of the mass is strongly acidified (S22254) [NM 4666 6720], and the amount of interstitial granophyric matter is considerable. In some parts of a thin section an original doleritic texture can still be distinguished; but the augite has been altered, biotite and hornblende developed, and basic felspars albitized, resorbed, and regrown with more acid peripheries that, like the graphic interstitial matter, are rich in apatite.

The interesting apophysis of the Fluxion Biotite-gabbro (K), which stretches out into the Great Eucrite and which has been referred to in detail above (p. 331), has a fine-textured sharp margin against the Great Eucrite. The junction of the two rocks can be examined in the area of a thin section. The marginal portion of the Sìthean Mòr mass (S22252) [NM 4653 6718] is found to consist of an open mesh of small elongated crystals of oligoclase-andesine felspar with a fine granulitic matrix of augite, hypersthene, oligoclase-andesine, and magnetite. It includes a few small porphyritic crystals of a more basic plagioclase edged with oligoclase, and has ill-defined clots of coarsely crystallized material in which hypersthene is the more abundant pyroxene, and in which sporadic biotite has been developed. The turbid, schillerized, nature of the porphyritic felspars, and the pronounced granulitic texture of the rock as a whole, clearly indicate that the mass has been subjected to an elevated temperature since it assumed the solid state. As Mr. Richey suggests, this granulitization has probably been produced in the chilled edge of the intrusion (K) by reheating consequent on a fresh influx of magma from the same source.

The Eucrite (E) at the junction shows signs of crushing which are absent from the fine-grained rock in contact with it, but this crushing has been followed by a granulitization of the broken-down material. The basic felspars are intensely albitized both marginally and by veins of soda-felspar that traverse them in all directions. This intense albitization is undoubtedly connected with the later intrusion. Augite has passed over to uralitic hornblende, and there has been a small development of biotite.

At the actual contact, there has been a certain amount of give and take between the two rocks involved. On the Eucrite side there has formed a narrow zone of somewhat coarsely crystalline rhombic pyroxene and biotite with a recrystallized felspar of moderately acid composition. The rhombic pyroxene is pseudomorphed by fibrous hornblende, as also is the olivine occurring in the eucrite. This amphibolitization is presumably part of the process of thermal alteration to which both rocks have been subjected. The interior of this apophysal mass (S22253) [NM 4671 6707] has already been referred to as having a coarser texture than its edge (p. 331). It is a somewhat fine-grained olivine-gabbro that has been considerably modified. Its structure is ophitic, but the augite has gone over in part to uralitic hornblende, while biotite has developed in association with it and with the small pseudomorphs after olivine. The original felspars have been albitized to some extent, and quartz and alkali-felspar charged with apatite occur interstitially. H.H.T.

(L) Fluxion biotite-gabbro of Glendrian

The almost complete ring-ridge formed of this intrusion is one of the striking features of the Achnaha district (*see* (Plate 6)). The rock-type is similar to that forming the main portion of the Sìthean Mòr intrusion, except that small equi-dimensional crystals of magnetite appear to be more plentiful. In containing magnetite it differs from the adjoining coarse-textured Quartz-biotite-gabbros (J and J′) in which the iron-ore occurs as ilmenite in large crystals with two obliquely crossing cleavages. In the hand-specimen no two rocks could be more unlike, though in the field their line of separation is sometimes difficult to determine. Small masses of the coarse-textured gabbro are enclosed by the Fluxion Biotite-gabbro as, for example, near the outer southern margin of the intrusion, east of an old track that leads to Glendrian from the Achnaha road. Their mode of occurrence suggests that they are xenoliths. At other points, elongate inclusions of the same rock are also found, as, for example, 200 yds. east of Achnaha, and again three quarters of a mile north-east of this small village, between a basic north-irest dyke and a stream. At the latter locality the elongate mass can be traced from where it ends against alluvium for I00 yds. uphill, parallel to the outer margin of the Fluxion Biotite-gabbro. These masses are probably portions of the walls caught up by the intruding magma. They furnish the only direct evidence that the Fluxion Biotite-gabbro is later than the Quartz-biotite-gabbros.

Sharp contacts between the Fluxion Biotite-gabbro and Quartzbiotite-gabbro outside it are exposed, on the south margin, along a scarp overlooking the Kilchoan–Achnaha road ((Figure 46), $_{P.}$ 323). At the contacts both rocks are quite unchilled and give no indications of their relative ages. The plane of junction at one contact is vertical, while at another it is inclined steeply inwards towards the Achnaha Centre (3).

The distinctness of the Fluxion Biotite-gabbro on its inner side from the coarse Quartz-biotite-gabbro (J′) is most evident where their junction has been mapped across a stream 500 yds. southwest of Glendrian farmhouse. In a steep scar forming the right bank, the Quartz-biotite-gabbro can be followed in exposures to within a few yards of where the Fluxion Biotite-gabbro outcrops. The actual contact of the two rocks is not seen.

Petrology

(Anal. I, (Table 5), p. 89). — The Fluxion Biotite-gabbro of Glendrian is a basic gabbro more than usually rich in titaniferous iron-ore. All the specimens collected show an abundance of titaniferous magnetite more or less uniformly distributed throughout the rock in the form of irregular equidimensional grains and patches. As in the case of most other fluxion gabbros, such as that of Faskadale (p. 290), there are abundant signs of modification by an acid magma.

The analysed specimen (S21249) [NM 4744 6781], which may be regarded as typical of the mass, is a moderately fine-grained dark rock in which the fluxion structure is brought out by. the parallel arrangement of closely packed lustrous plates of felspar, which measure up to a quarter of an inch along their edges (S21488) [NM 4786 6907], (S21489) [NM 4803 6827]. The fluxion structure is most clearly seen when the plates are viewed edge-on, and both in the field and in thin section it may be lost sight of if the rock be viewed normally to the larger tabular faces of the felspar crystals. Apart from this fluxion structure, the chief peculiarity of the mass is its high percentage of iron and titanium, constituents that find expression in an abundance of titano-magnetite and impart to the rock strong magnetic properties. On account of the abnormal segregation of iron-ore the mass is one of the most basic encountered in Ardnamurchan. It does not fit in with the normal differentiates of the Porphyritic Central Magma-Types, but shows a close similarity in composition to rocks leading towards the ilmenitenorites, and would find a place amongst such iron-ore rich bodies as those of the Ekersund-Soggendal district of Norway. Chemically its relations appear to be with the basic members of the

TonaliteQuartz-monzonite Series, and for this reason its unmodified character is suspect.

As mentioned above (p. 334), it is not uncommon to encounter large included masses of normal gabbroid material, which are quite unmodified. These Mr. Richey regards as of xenolithic origin, and microscopic evidence supports his view. One such mass from the eastern portion of the Fluxion Biotite-gabbro's outcrop (S21806) [NM 4812 6853] is eucritic, very similar to the Great Eucrite (E) in type. It is free from iron-ore, rich in fresh olivine, and has basic labradorite as the dominant felspar.

The Fluxion Biotite-gabbro consists generally of large fluxionally arranged plates of intensely zoned and albitized basic labradorite, much augite frequently fringed with uralitic hornblende, and abundant titano-magnetite that occurs chiefly in association with the augite. Occasionally, the felspars are unzoned and appear to have escaped any serious albitization. In such cases, they have an optically negative sign and are of bytownite composition (S21489) [NM 4803 6827]. Where an excess of acid material shows itself in the rock as interstitial alkali-felspar and quartz in micrographic intergrowth, and in the crystallization of residual perthitic alkali-felspar, albitization of the basic felspars is the rule (S21808) [NM 4697 6917]. Also, the augite, in addition to exhibiting the usual deschillerization, may be largely converted into hornblende (S21490) [NM 4838 6863]. Biotite is developed, in such cases, both in the augite (S21807) [NM 4704 6902] and in association with the iron-ore (S21491) [NM 4658 6844]. That olivine was an occasional constituent of the gabbro is inferred from pseudomorphs in chlorite and fibrous hornblende. A rhombic pyroxene, also, appears to have been present, as judged by certain pseudomorphs. It apparently occurred as a product of acidification, either as isolated crystals or replacing augite, with which it exhibits intimate relations (S21491) [NM 4658 6844]. When fresh the rhombic pyroxene is a highly pleochroic variety referable to hypersthene.

Apatite has undergone a concentration in the acid portions of the rock, similar to that observed in the tonalitic and quartz-monzonitic masses, and forms crystals nearly 2 mm. in length (S21249) [NM 4744 6781], (S21808) [NM 4697 6917].

There is little doubt that this Fluxion Gabbro owes many of its somewhat unusual physical and mineralogical characters to the intervention of an acid magma. It is difficult to say to what extent the rock-mass is to be regarded as of hybrid nature, but that it was in a modified condition before intrusion appears to be more than probable. H.H.T.

(M) Tonalite

The Tonalite is in plan an oval-shaped mass, the longer axis of which is directed east-north-east, in conformity with other ring-dykes of Centre 3. Its margin has, however, many minor irregularities, as may be seen where it makes contact with the gabbros outside it, along a scarp that borders the road a quarter of a mile south-east of Achnaha. The striking difference in composition between the Tonalite and the surrounding gabbros enables its margin to be accurately traced.

The rock is everywhere of the same general type, with conspicuous biotite set in a greyish felspathic ground-mass, the dominant felspar being lath-shaped plagioclase. The rock varies in grain from place to place, though medium textures are most usual. Between an elongate screen-like mass of Quartz-biotite-gabbro (J″) and the outer wall, fine-grained types are chiefly met with, while at a point north-west of the western end of this screen the rock is unusually coarse.

Along its outer margin the Tonalite becomes much finer grained and at the same time more acid in composition. A gradual passage outwards from typical tonalite to this more acid margin can be established on the north-west and northern sides of the mass. The fineness of texture is a result of chilling, and not due to the change in composition, for on the north side the acid marginal type becomes finer grained close to the margin than it is farther away. The exposures concerned are along the eastern arm of a stream-loop which the junction crosses. In rock-type this acid margin is quartz-monzonite. Reference may be directed to Chap. 15, p. 209, where the significance of such acid margins is discussed.

The screen-like mass of Quartz-biotite-gabbro (J″), enclosed in the south-eastern part of the Tonalite, is seen at one point in contact with the Tonalite, which is chilled against it. This contact is located on the south side of the gabbro-screen, midway between two north-westerly hollows that cross the west part of the mass, and mark the course of two basic dykes. The western half of the gabbro is composed of a fine-grained type, and the eastern half of extremely coarse pegmatite-like gabbro. No contacts could be found between these two rocks owing to lack of exposure, but they may well be separate intrusions. Both may be classed as quartzbiotite-gabbro, though the more easterly rock is certainly more acid and must approach tonalite in bulk composition. Fluxion biotite-gabbro is a third rock-variety found in the screen, and forms its narrow south-western end.

The quartz-biotite-gabbro and fluxion biotite-gabbro of the screen correspond in position to similar gabbros, (J′) and (L), that form the opposite, outer wall of the Tonalite. They are evidence of the slightly transgressive nature of the Tonalite mass relatively to other ring-dykes, as is further brought out by the mapping of the Glendrian Ring-dyke (L). This intrusion, otherwise a complete ring, is broken through by the Tonalite for a short distance on its south-west side.

Acid veins traverse the gabbro walls of the Tonalite, and are abundant alongside the Achnaha road, a quarter of a mile southeast of Achnaha. They were classed as granophyre in the field. They have not been examined microscopically, but are of interest as being the acid expression of the Tonalite magma.

An example of hybridization *in situ* is well seen at the southwest termination 'of the gabbro-screen described above. There, xenoliths of the gabbro are contained in the Tonalite, and may be observed in all stages of dissolution. Patches of basified-looking tonalite probably represent completely digested xenolithic material. It may be remarked that no other instance of such hybridization was noted within the Tonalite. J.E.R.

Petrology of the tonalite

(Anal. II, (Table 5), p. 89)

The Tonalite, with its related central intrusion of quartz-monzonitic type, is of especial interest, not only because it is one of the largest masses of this character met with in the Tertiary Province, but because it exhibits peculiarities of petrogenetic importance which point more or less conclusively to a hybrid origin.

In its most homogeneous and most normal occurrence, such as to the north and north-east of the Quartz-monzonite, it is a moderately fine-grained holocrystalline rock of grey-green colour, in which felspar and elongated crystals of hornblende occur in about equal proportions. Elongated much-twinned plagioclase felspars, up to a quarter of an inch in length, are common, but the bulk of the felspar is of later formation and occurs as a matrix to the other constituents. This later felspar frequently has a decided pink tinge.

Biotite is usually subordinate to hornblende but occurs in small deep-brown flakes.

The structure of the rock is granitic, and the constituents, as proved by microscopic examination, are plagioclase felspar, hornblende, biotite, augite, perthite, and quartz; with some apatite, magnetite, and sphene (S21248) [NM 4735 6873].

The plagioclase occurs as much fissured, resorbed, and intensely albitized crystals of labradorite, zoned with oligoclase and fringed with perthitic orthoclase (S21468) [NM 472 686]. Oligoclase may also build elongated lath-shaped crystals. The biotite is a deep-brown variety that occurs in moderately large ragged plates, and is frequently chloritized. The hornblende is generally of a greenish-brown colour with moderate pleochroism (S22260) [NM 4742 6880], and together with biotite forms about half to a third of the rock. Perthitic orthoclase, often inter-grown with quartz, occurs as large turbid shapeless crystals that envelop all the other constituents (S21470) [NM 4735 6873]. Augite is not particularly abundant in the more widely distributed type, but becomes a more important constituent in some portions of the mass, particularly to the south-east of the screen (p. 337). When present, it occurs as fairly large ill-formed almost colourless individuals that generally exhibit a partial pseudomorphosis to hornblende, giving a mottled appearance to the crystals as a whole (S21468) [NM 472 686]. Apatite in the coarser tonalitic rocks occurs as extremely large and abundant crystals. Such crystals often exceed a millimetre in length, which is far in excess of the dimensions of apatite as encountered in any of the normal rocks of Ardnamurchan. There has evidently been a strong concentration of phosphoric acid and volatile constituents in the more alkaline and siliceous portions of the magma; for apatite seldom occurs in the basic felspars, but is almost restricted to the acid plagioclase and perthite, with quite subordinate amounts carried by the ferromagnesian constituents, more especially by the biotite and hornblende. Magnetite occurs sparingly as fairly large irregularly bounded masses, most frequently in association with augite or hornblende. Sphene is uncommon, and is chiefly encountered in granular form associated with chloritized biotite.

To the south of the monzonitic mass, the tonalite in its central portions is of the same type as that described above, except perhaps that augite is a little more abundant (S21541) [NM 4702 6839], and that here and there the rock becomes almost pegmatitic in character. In these pegmatitic portions (S21549) [NM 4693 6823] the rock is coarser in texture, biotite is more abundant and occurs in large plates, and the perthitic felspar forms irregularly bounded pink patches of more than half an inch across. Commonly the perthite is graphically intergrown with quartz.

Between the screen of biotite-gabbro and the eastern margin of the mass, the usual type of tonalite is encountered (S21469) [NM 4759 6813], but generally the rock is somewhat different in both aspect and composition. The main difference lies in its more augitic nature. In some instances, the normal structure of the tonalite is maintained while augite, partly recrystallized and partly xenocrystal, occurs with a fair amount of biotite and brownish-green hornblende (S22257) [NM 4715 6790]. In other cases, augite is the dominant ferromagnesian mineral, and biotite and hornblende though present become quite subordinate (S22255) [NM 4740 6803]. Such rocks have a microporphyritic structure imparted to them by numerous small resorbed and albitized labradorite felspars that are set in a somewhat granulitic matrix of small hypidiomorphic crystals of augite, stumpy crystals of oligoclase-andesine felspar, and irregular grains of magnetite. The general family resemblance of these and all other rocks in the tonalite and quartz-monzonite masses, however, lies chiefly in the occurrence of large crystals of greenish-brown hornblende, biotite, and patches of perthite, and in segregation of apatite. The effects of granulitization and hybridization of a basic rock are evident in this eastern portion of the tonalitic mass (S21472) [NM 4747 6807], (S21542) [NM 4731 6802].

Towards the outer margins the rock becomes finer in grain and more acid in composition. It is noticeable that biotite ultimately becomes the dominant ferromagnesian constituent, and with a certain amount of augite gives to the mass a quartz-monzonitic or mica-felsite character. Towards the western and northern margins the tonalite retains its dominantly hornblendic nature for some distance (S22260) [NM 4742 6880], (S21467) [NM 4665 6826], but then passes gradually into a much paler rock composed essentially of lath-shaped crystals of turbid oligoclase-albite, perthitic orthoclase, and graphic quartz, with biotite and iron-ore (S21474) [NM 4737 6889], (S22258) [NM 4731 6897]. In extreme cases of acidification the ferromagnesian minerals fail altogether (S22259) [NM 4731 6897], but in others biotite is abundant as small ragged flakes. In the latter cases, the rock consists mainly of biotite, short prisms of oligoclase, and granules of magnetite in a base of large shapeless crystals of perthite, with a certain amount of quartz. Augite may occur occasionally as long partly uralitized crystals (S21539) [NM 4755 6876]. In these acid rocks it may be remarked that there is no strong concentration of apatite such as is a feature of the more definitely tonalitic mass.

The xenocrystal nature of the Tonalite, the presence of hornblende and biotite of late generation, and the lateral passage into rocks of quartz-monzonitic type along its peculiar acid margin, are features that all point to this intrusion being a gabbro-granophyre hybrid. It is, however, equally certain that the hybridization was an accomplished fact before the intrusion of the mass into its present position, as in the case of the marscoite masses of Skye; but, instead of the acidification of a basic magma, as in the Skye occurrences, we are presumably dealing here with the basification of an acid magma.

The Quartz-biotite-gabbro Screen (J″)

This screen-like mass within the tonalite is definitely of gabbro-origin. It has, however, suffered greatly at the hands of an invading acid magma, and like other biotite-gabbros shows unmistakably the effects of hybridization. In fact, the changes that have taken place are just such, given full expression, as would lead to the formation of tonalitic and quartz-monzonitic types. For instance, a moderately coarse augitic gabbro (S21543) [NM 4745 6838] that forms the western part of the screen shows intense albitization of its basic felspar. Its augite has been locally deschillerized with the production of small scales of biotite. Further, introduced alkaline and siliceous magma has solidified as microperthitic felspar and quartz between the albitized gabbro-felspars, and has controlled the formation of biotite. Apatite in some of these modified gabbros forms large and abundant crystals (S21257) [NM 4762 6845]. Acid portions of the screen might be described as perthite-granophyre, as the rock is composed almost entirely of large areas of cryptoperthite graphically intergrown with quartz (S22458) [NM 4736 6823]. H.H.T.

(N) Quartz-monzonite

As a rock the Quartz-monzonite may be distinguished from the surrounding Tonalite by the following criteria, Biotite is more plentiful and in larger crystals than in the Tonalite. The felspathic portion of the rock is finer textured, and it is possible to distinguish in the hand-specimen the darker plagioclase from a lighter and compact orthoclase-quartz portion. The latter constitutes about a half to a third of the rock.

The little central mass of Quartz-monzonite is separated as a distinct intrusion froth the Tonalite, on account of an intrusive junction seen on its north-west side. There, a sharp contact between the two rocks exists, and while the Tonalite does not change in grain, the Quartz-monzonite is markedly finer textured for an inch or so away. The Quartz-monzonite is situated at the actual centre of the Interior Complex, and is the latest intrusion of the whole ring-dyke suite.

Petrology

(Anal. III, (Table 5), p. 89). This mass, which on mineralogical and structural grounds is best described as a quartz-monzonite, is of a medium-grey fairly compact rock in which small porphyritic felspars about 4 or 5 mm. in length, and more or less evenly distributed biotite in plates of somewhat larger dimensions, are the conspicuous minerals (S21548) [NM 4699 6843], (S21471) [NM 4703 6826], (S21247) [NM 4699 6843].

Microscopically (Figure 48) the rock is seen to be holocrystalline; it consists of a few moderately large crystals of labradorite, strongly zoned to oligoclase, an abundance of small elongate crystals of oligoclase-andesine, large ragged plates of biotite, scattered small hypidiomorphic crystals of an almost colourless to pale-green augite and magnetite, in an apatite-rich base composed of albite-perthite and quartz.

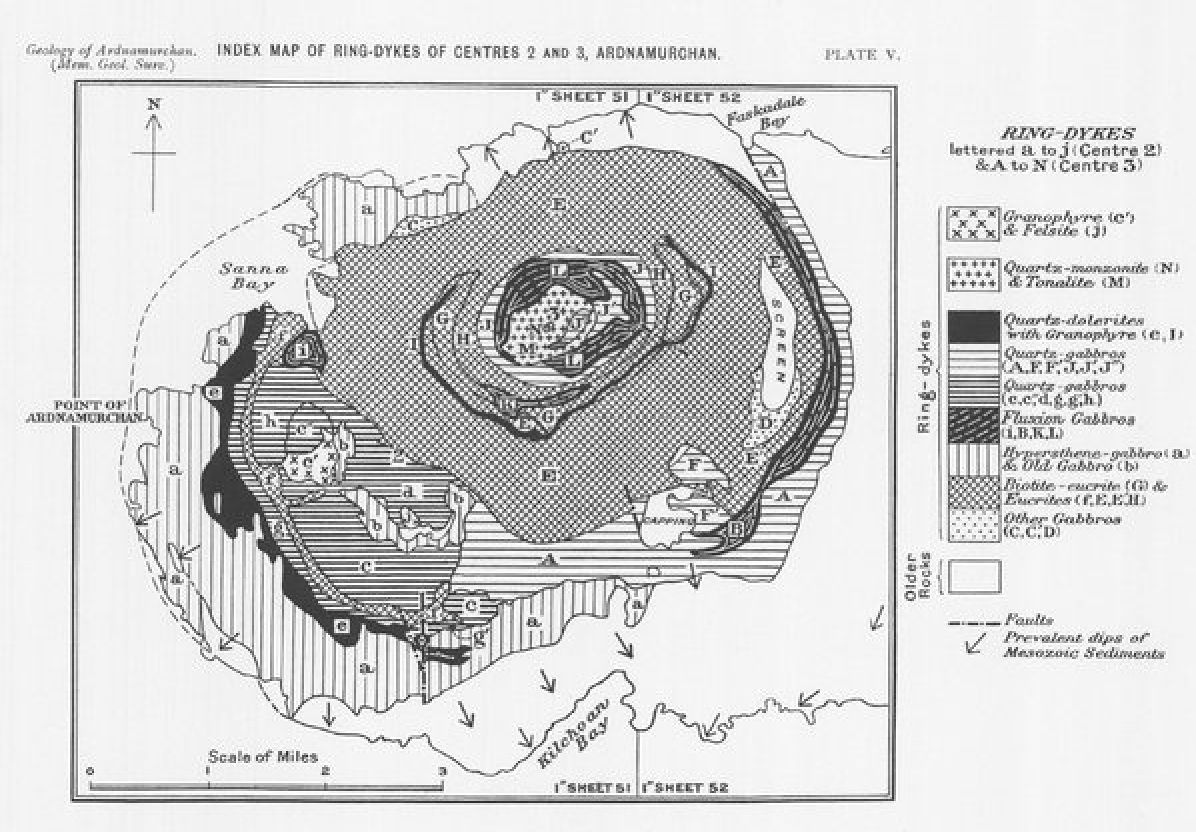
The amount of labradorite is small, for it exists only as somewhat infrequent centres to some of the larger plagioclase-crystals that are deeply zoned with less basic varieties, and which usually have oligoclase peripheries.

The biotite is a deep-brown variety. It frequently encloses crystals and patches of oligoclase felspar, but the perthitic alkali-felspar and quartz are moulded upon it. It is more or less devoid of other inclusions, except occasional apatite, and does not exhibit pleochroic halos. When decomposed it passes into chlorite with, sometimes, the separation of granular sphene.

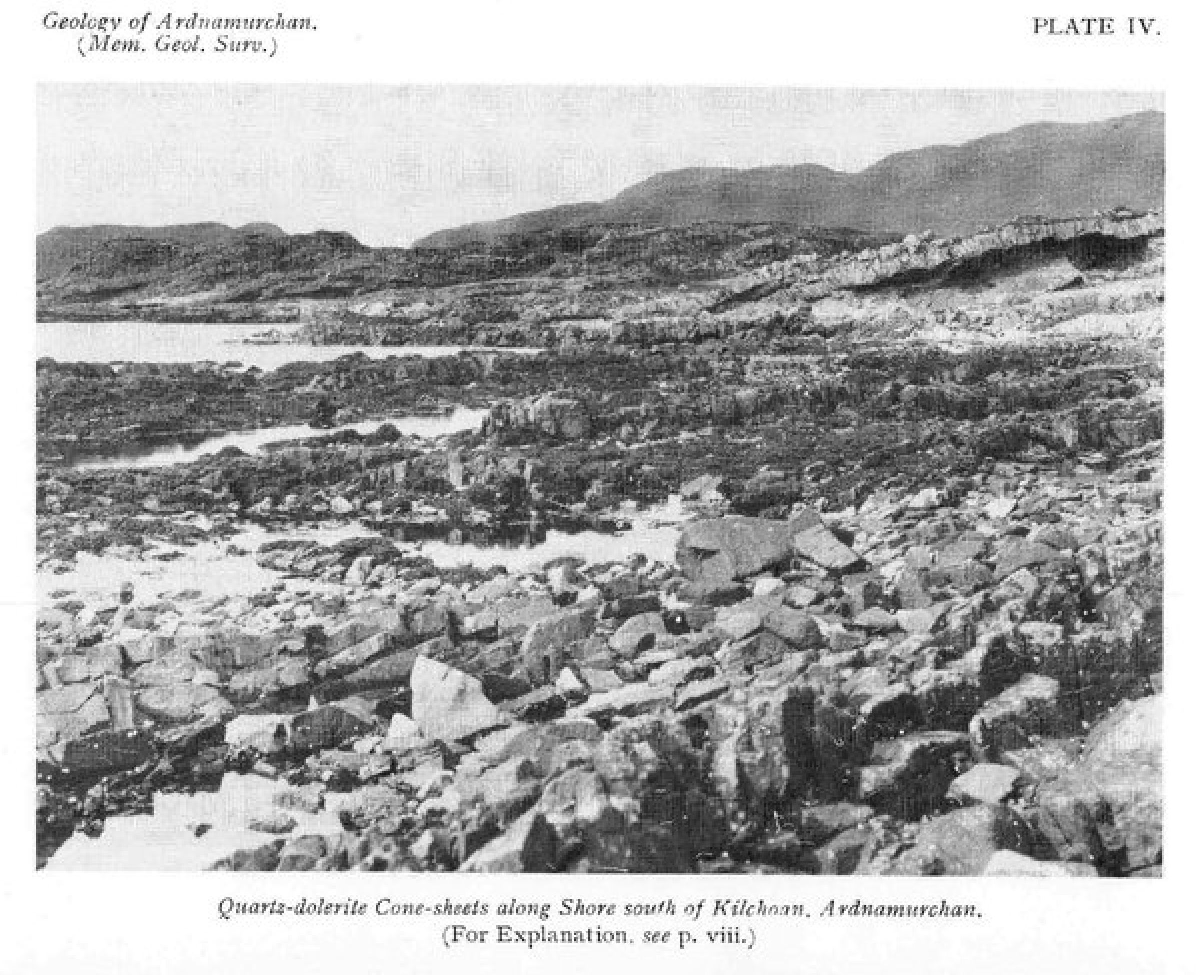
The augite is scattered indiscriminately throughout the rock, generally as small ill-formed crystals but occasionally as prisms and stumpy individuals with fairly good crystal-outlines. It has the wide extinction and moderately large axial angle of a normal aluminous augite, but its colour is similar to that of the recrystallized augite of the modified gabbros that have been frequently referred to in earlier pages.

The perthitic felspar builds the largest individual crystals in the rock, and embraces all the other constituents. It is usually intensely turbid and in it, and in the oligoclase, is concentrated the bulk of the apatite. As in most other Ardnamurchan rocks of this nature, it is clear that the constituents of apatite are concentrated in the alkaline and more siliceous portions of the magma, and the period of crystallization of the mineral is mainly concurrent with that of biotite and acid plagioclase, including the albite-perthite. It is seldom encountered in the quartz except as crystals projecting from neighbouring felspars.

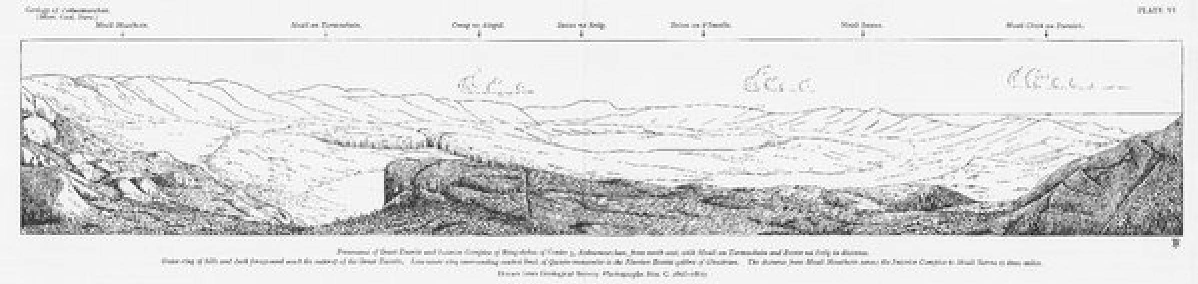
This monzonitic mass is genetically related to the tonalite described above; and chemically, as will be seen from the analyses ((Table 5), p. 89), the two rocks have many points in common. It is not surprising, therefore, to find represented at the margin of the tonalitic mass, rock of quartz-monzonitic character; we may, in fact, regard this monzonitic mass as a further stage in the hybridization of a eucritic rock, or magma, with a magma of definitely siliceous. and alkaline composition, rich in volatile constituents. H.H.T.



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



(Plate 4) Quartz-dolerite cone-sheets along shore south of Kilchoan, Ardnamurchan. The cone-sheets are inclined away from the camera, and show well-developed cross-jointing. (See (Figure 23), p. 174.) Geological Survey Photograph, No. C2826.



(Plate 6) Panorama of Great Eucrite and Interior Complex of Ring-dykes of Centre 3, Ardnamurchan, from north-east, with Meall an Tarmachain and Beinn na Seilg in distance. Outer ring of hills and dark foreground mark the outcrop of the Great Eucrite. Low inner ring surrounding central knob of Quartz-monzonite is the Fluxion Biotite-gabbro of Glendrian. The distance from Meall Meadhoin across the Interior Complex to Meall Sanna is three miles. Drawn from Geological Survey Photographs Nos. C2806, C2807, C2808, C2809.

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)).

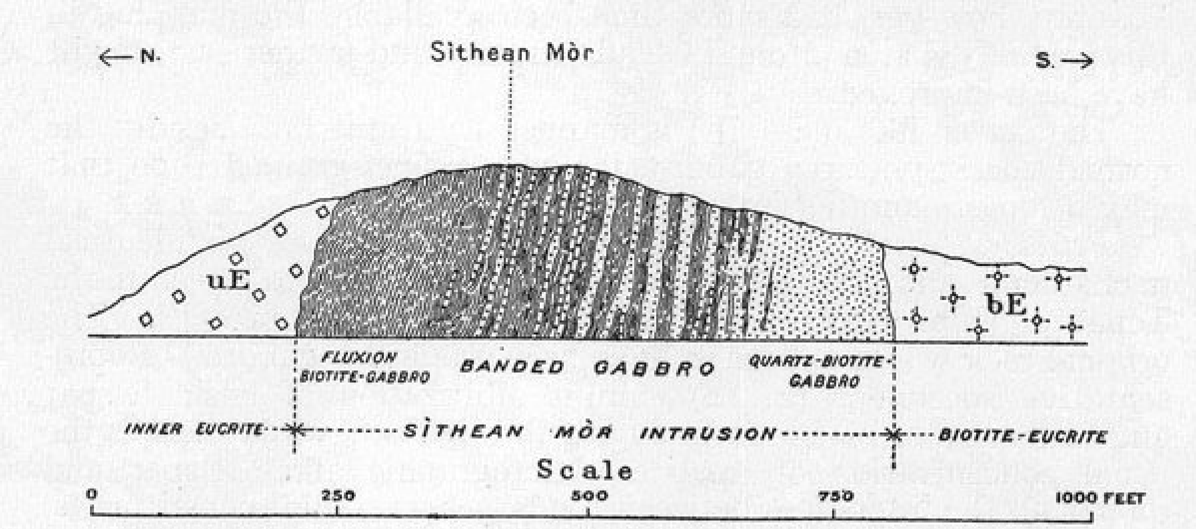


FIG. 47.—*Diagrammatic section across Sìthean Mòr Ring-dyke.*

(Figure 47) Diagrammatic section across Sìthean Mòr Ring-dyke.

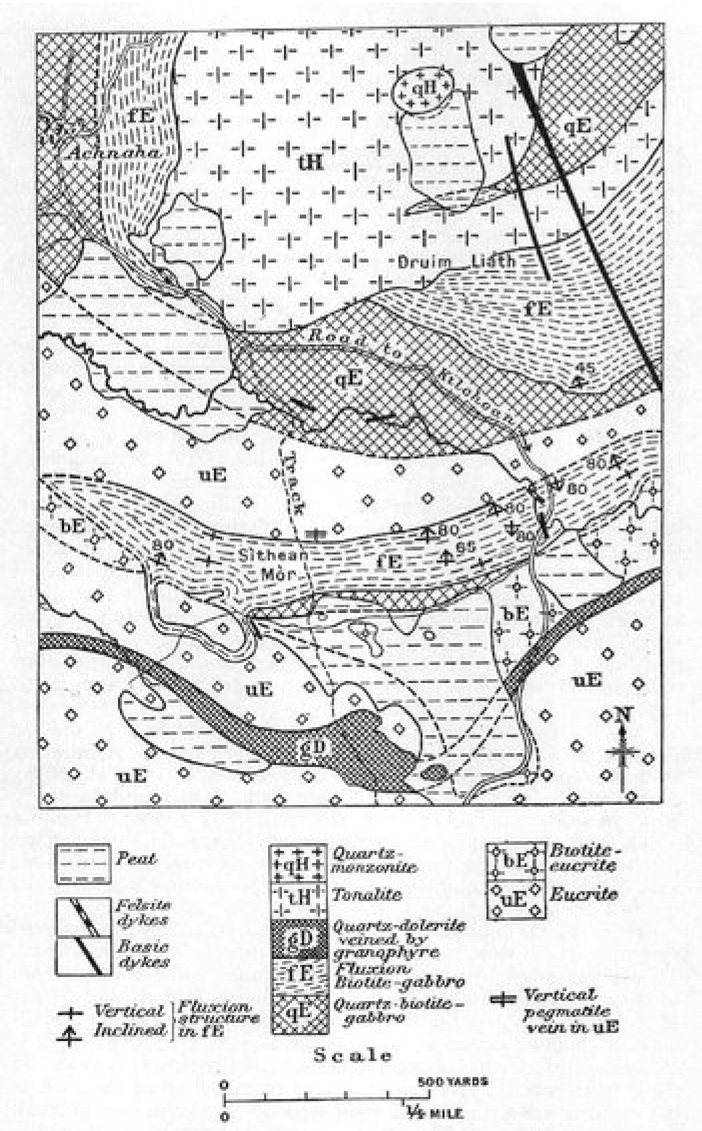


FIG. 46.—*Map of south portion of Interior Complex of Ring-dykes (Centre 3).*

(Figure 46) Map of south portion of Interior Complex of Ring Dykes (Centre 3).

TABLE V

TONALITE AND QUARTZ-MONZONITE MAGMA-SERIES (*see* Fig. 8).

	GABBRO.	TONALITE–QUARTZ-MONZONITE.				GRANITE.			
	I.	II.	A.	B.	III.	C.	D.	E.	F.
SiO_2	44·50	51·59	54·00	54·20	59·16	68·15	70·48	73·09	75·65
Al_2O_3 ..	13·00	16·76	13·09	15·73	16·50	15·95	14·24	14·15	11·89
Fe_2O_3 ..	8·25	2·26	3·53	3·67	3·23	0·74	} 3·72	(0·70	1·19
FeO	9·97	7·49	8·45	5·40	3·66	3·24		(1·03	1·02
MgO ..	6·31	3·85	3·49	3·40	2·70	0·04	0·40	0·47	0·15
CaO ..	11·10	7·41	5·55	8·50	4·40	1·88	1·48	1·04	0·91
Na_2O ..	1·88	3·04	3·27	3·07	3·66	3·40	3·66	3·76	3·44
K_2O	0·25	1·95	1·80	4·42	3·72	5·00	4·26	4·21	4·26
$H_2O > 105°$	0·83	1·36	1·71	} 0·50	(0·83	0·22	} 1·59	(0·70	0·40
$H_2O < 105°$	0·29	0·30	1·26		(0·44	0·65		(0·60	0·41
TiO_2	2·99	2·15	2·83	0·40	1·21	0·20	—	0·22	0·28
P_2O_5 ..	0·06	0·66	0·31	0·50	0·28	0·12	—	0·09	0·16
MnO ..	0·49	0·40	0·37	0·70	0·27	trace	—	0·00	0·26
CO_2	0·14	0·79	0·25	—	0·08	0·00	—	0·00	0·09
FeS_2	0·00	0·00	0·14	—	0·00	—	—	—	0·00
Fe_7S_8 ..	0·00	0·00	—	—	0·00	—	—	—	—
(Co, Ni)O	0·00	0·00	0·00	—	0·00	—	—	—	0·02
BaO	0·00	0·00	0·02	—	0·00	—	—	—	0·03
Li_2O	0·00	0·00	trace	—	0·00	—	—	—	0·00
	100·06	100·01	100·07	100·49	100·14	99·59	99·83	100·06	100·16

I. (21249; Lab. No. 734.) Fluxion Biotite-gabbro. Glendrian Ring-dyke, Centre 3, Ardnamurchan. Ridge ¾ mile E. 17° S. of Achnaha, *Anal.* E. G. Radley.

II. (21248; Lab. No. 733.) Tonalite. Ring-dyke, Centre 3, Ardnamurchan. Knoll at edge of moss ⅜ mile W. 33° S. of Glendrian. *Anal.* E. G. Radley.

A. (24459; Lab. No. 828.) Quartz-dolerite. Garbad sill, Arran. Gorge in Allt Dhepin, ¼ mile E.N.E. of Trigonometrical Station at 873 ft. O.D., Cnoc an Fheidh, Whiting Bay. Quoted from G. W. Tyrrell, 'The Geology of Arran,' *Mem. Geol. Surv.*, 1928, pp. 147–148. *Anal.* E. G. Radley.

B. Monzonite. Monzoni, Tyrol. Quoted from W. C. Brögger, 'Die Eruptivgesteine des Kristianiagebietes. II. Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Südtyrol.' Kristiania, 1895, p. 24. *Anal.* V. Schmelck.

III. (21247; Lab. No. 732.) Quartz-monzonite. Boss, Centre 3, Ardnamurchan. Small summit in low ground ½ mile E. of Achnaha. *Anal.* E. G. Radley.

C. Hornblende-granite. Granite 1, Mourne Mountains. Eagle Rock,

(Table 5) Tonalite and Quartz-monzonite Magma Series (see (Figure 8)).

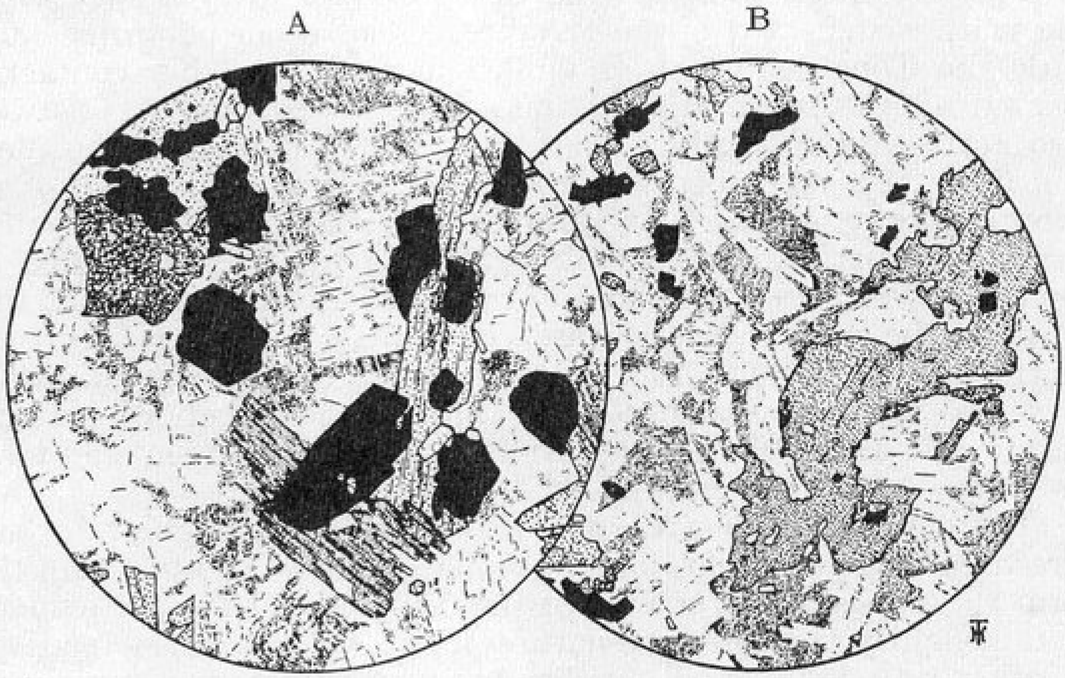


FIG. 48.—*Tonalite and Quartz-monzonite.*

A. (21248) × 20. *Tonalite. Biotite, hornblende, and augite with plagioclase felspar, perthite, and quartz. Magnetite and apatite are abundant accessories. The alkali-felspar is mainly turbid.*

B. (21247) × 20. *Quartz-monzonite. The section shows a large plate of biotite, with subordinate augite, abundant elongate crystals of oligoclase-andesine felspar, in an apatite-rich turbid base of albite-perthite and quartz.*

(Figure 48) Tonalite and Quartz-monzonite.A. (S21248) [NM 4735 6873] × 20. Tonalite. Biotite, hornblende, and augite with plagioclase felspar, perthite, and quartz. Magnetite and apatite are abundant accessories. The alkali-felspar is mainly turbid. – B. (S21247) [NM 4699 6843] × 20. Quartz-monzonite. The section shows a large plate of biotite, with subordinate augite, abundant elongate crystals of oligoclase-andesine felspar, in an apatite-rich turbid base of albite-perthite and quartz.