Chapter 18 Tertiary ring-dykes of Centre 2, Ardnamurchan–(Continued)

The earlier ring-dykes that remain to be described are as follows (*see* Index Map, p. 201 (Plate 5)):-

(e) Quartz-dolerite of Sgùrr nam Meann, veined by granophyre.

(f) Eucrite of Beinn nan Ord.

(g) and (g′) Quartz-gabbros of Loch Caorach and Beinn na Seilg.

(h) Younger Quartz-gabbro of Beinn Bhuidhe.

(i) Fluxion Gabbro of Portuairk.

(j) Felsite, South of Aodann.

All the above intrusions are later than the Inner Cone-sheets, excepting the Quartz-dolerite (e). This intrusion and the ring-dykes (f) and (g) keep together as a group throughout the greater part of their course, and it is convenient to describe them consecutively in the same chapter. Their slightly curving form seems sufficiently to establish their connexion with the Aodann Centre (2 of (Plate 5)), though another explanation of the conformation of the Eucrite (f) might possibly be entertained. This intrusion might be regarded as an outer arm of the Great Eucrite of the Later Complex, which had inserted itself between certain of the Earlier Ring-dykes, and so come to conform to the Earlier Centre. The matter becomes a question of the age relationship of these two eucrite masses. This cannot be directly determined, since the two are nowhere seen in contact, their nearest outcrops being separated by Sanna Bay. Farther south, however, there is evidence of an age difference between them, since the Beinn nan Ord Eucrite (f) is clearly intruded by the Quartz-gabbro (A) on the north-east side of Beinn na Seilg, while there is every reason for regarding the Great Eucrite as later than this Quartz-gabbro.

The relations of the Younger Quartz-gabbro (h) and Fluxion Gabbro (i) to one another and to contiguous masses proved difficult to determine. Whether, indeed, they belong to the Earlier or Later Complex could not be decided in the field, but they seem more conveniently to be classed with the former. On the other hand, it is possible that the Younger Quartz-gabbro is connected underground with the Quartz-gabbro (A) of Centre 3, which disappears under roof to the north of Beinn na Seilg (p. 285). Such a continuation would, perhaps, explain the contact alteration of certain intervening surface rocks, *e.g.* the Felsite (j) (p. 279), which cannot be ascribed to any visible intrusion. Again, the position of the Fluxion Gabbro (i) at the outer margin of the Great Eucrite (E) seems to suggest its correlation with the Fluxion Gabbro (B).

Under the heading of the Felsite (j), a number of other small intrusions of similar felsite which are found within the area of the Earlier Complex will also be described.

(e) Quartz-dolerite of Sgùrr nam Meann, veined by granophyre

Along the greater part of its course, this ring-dyke, together with the Quartz-gabbro (g) immediately inside it, occupies a belt of low ground between the more durable Hypersthene-gabbro (a) and the Eucrite (f). Near its eastern termination, the Quartz-dolerite, south of the southern peak of Beinn na Seilg, traverses the Hypersthene-gabbro, and appears to be fingering out. To the north, it forms the steep-sided hill of Sgùrr nam Meann, which, in contrast to the scenic relations farther south, is flanked to the east by a hollow along which the Beinn nan Ord Eucrite extends. Its harder nature in this vicinity is the result of baking, though the contact alteration seems only attributable to the two intrusions that accompany it here and elsewhere on its inner side — the Quartz-gabbro of Loch Caorach (g) and the Eucrite of Beinn nan Ord (f).

The separation of the Quartz-dolerite in the field from the Quartz-gabbro (*g*)is in some places a difficult matter, but north and south of Sgùrr nam Meann, the writer found that contacts could be established, and search at other places where

rock-exposures are sufficiently continuous has corroborated the evidence there noted. It should be emphasized that a very careful examination is necessary to locate these contacts, and that the impression is given at first sight that one rock grades into the other. This, indeed, was the first opinion held. Apart from the direct evidence of the distinctness of the two masses (p. 271), this view in itself presents an element of improbability. For we should then have a single, elongate intrusion with an outer half composed of quartz-dolerite, and an inner half of quartz-gabbro, the former rock frequently containing porphyritic felspar and evidently quickly cooled, the latter coarse in texture except where passing into a quartz-dolerite at its actual contact with the Eucrite of Beinn nan Ord inside it.

The type of rock composing this ring-dyke is a remarkable one, and is also met with in the narrow ring-dyke (I) of the Interior Complex. The main body of the rock is a quartz-dolerite, frequently porphyritic, which is almost everywhere riddled with veins of granophyre (Figure 34). These veins form reticulated patterns recalling the acid veinings characteristic of many intrusive margins in Ardnamurchan and elsewhere, to which the name 'intrusion-breccia' is applied. But unlike the marginal intrusion-breccias, the net-veining ' is found throughout the length and breadth of the mass. It is as abundant on the summit of Sgùrr nam Meann, about a quarter of a mile from the outer margin, as it is close to this margin along the shore to the west. Locally it may be absent, but one cannot go far at any place without encountering it. Similar veining is fairly frequently met with in many of the quartz-gabbros, but is never so strikingly developed as in the present instance. A comparable occurrence appears to be the peridotite mass of the Cuillins, Skye, which Dr. Harker has described as everywhere net-veined, though in this case with a basic magma.<ref>The Tertiary Igneous Rocks of Skye, *Mem. Geol. Surv.,* 1904, pp. 77, 78.</ref>

The consolidation of the quartz-dolerite was complete before its brecciation and the injection of granophyre. No mixing of the two magmas is apparent, such as is found in composite intrusions (p. 184). To some extent the granophyre has incorporated small fragments of the quartz-dolerite, as shown by their rounded outlines, and also by the hybrid nature of the granophyre in contact, but the angularity of the blocks of quartz-dolerite is on the whole a striking feature in the field. Though intruded distinctly later than the quartz-dolerite, the granophyre magma must have risen in the same ring-fissure, since, except for stray masses and veinings of granophyre which are locally of common occurrence in the adjoining Hypersthene-gabbro (a), the granophyre is confined to the elongate area occupied by the Quartz-dolerite. The granophyre was certainly not a residual magma derived from the adjacent and later Quartz-gabbro of Loch Caorach (g). This follows because the net-veining on Sgùrr nam Meann is as highly contact altered as the Quartz-dolerite itself, as are also cone-sheets by which the net-veining is cut; while the adjacent Quartz-gabbro (g) is free of cone-sheets and apparently unbaked. In fact the Quartz-gabbro (g) is concluded to be partly the cause of the contact alteration. On the west side of this hill, a mass of granophyre, apparently part of the Sgùrr nam Meann intrusion, and perhaps a break-through of granophyre in bulk, is also slightly baked.

It therefore seems necessary to regard the brecciation and subsequent infilling of the cracks by granophyre as due to an uprising granophyre magma that entered the ring-fissure in which the quartz-dolerite consolidated. The brecciation is attributed to explosive gases given off from the acid magma that was injected into the cracks thus formed. So complete is the brecciation over great portions of the Ring-dyke that there is a striking likeness between the resulting veined rocks and volcanic breccias, such as those of Glas Eilean, that have their cracks and crevices infilled by acid tuff (p. 133).

Relations along outer margin

Itcan be fully demonstrated that the Quartz-dolerite is later than the Hypersthene-gabbro (a) forming its outer wall. West of Beinn na Seilg where the Hypersthene-gabbro is well banded, the banding is cut across by the porphyritic margin of the Quartz-dolerite. The best exposures of this junction are to be found immediately west of a narrow strip of peat-covered alluvium that extends along the course of the more westerly of two N.–S. faults shown on the published geological maps. Here, steeply inclined Inner Cone-sheets are numerous and resemble in type the porphyritic edge of the Quartz-dolerite, but can be easily distinguished from it by their darker weathering hues. A diagrammatic sketch of junctions seen in the face of a cliff about 20 ft. high; along the west side of the alluvium, is given in (Figure 35). Immediately west of this cliff the junction of the two ring-dykes is also well displayed. It may be mentioned that the cone-sheet shown in the figure as almost obliterating the junction is steeper than usual, and is a double intrusion with a central coarsely crystalline portion and porphyritic fine-grained margins. Xenoliths of the Hypersthene-gabbro are found in the marginal portion of the Quartz-dolerite; and corroborate the other evidence of the relative ages of these two

intrusions.

Sharp contacts such as that just described are usually a feature of the outer margin of the Quartz-dolerite, as far north as the right bank of the stream east of the Point of Ardnamurchan; but north of this along the shore north-east of the Pier, east of the Lighthouse, the most intricate junctions imaginable occur between the two rocks. The Hypersthene-gabbro appears to be literally honeycombed by the Quartz-dolerite. Still farther north, south of a stream that flows west along a hollow north of Sgùrr nam Meann, there is a semblance of gradation from one rock into the other, through an apparent transition zone some 30 yds. wide. Some portions of this zone consist of what appears in the field to be shattered and acidified hypersthene-gabbro, fairly coarse in grain. Other portions, more especially close to where the Quartz-dolerite occurs, are finely granular, and appear to resemble the Quartz-dolerite. Xenoliths of the latter material are, however, enclosed in the Quartz-dolerite, while perfect gradation may sometimes be seen, in one and the same exposure, from obvious hypersthene-gabbro into the granular rock. A microscopic slice of this granular material shows that it consists chiefly of shattered hypersthene-gabbro that has been subsequently contact altered (S24439) [NM 4275 6908]. North of the stream this belt of shattered rocks is even wider, and, though well exposed, is most difficult to interpret. Coarse augitic gabbros occur in sharp contact with granular gabbros, while much acid veining intensifies the difficulties presented. Adjacent angular blocks enclosed by this net-veining may be of quite different materials, such as augitic gabbro, coarse quartz-gabbro, granular gabbros, and also quartz-dolerite. The locality should repay more study than it has been possible to give to it, but two lessons may be learnt from it. In the first place it illustrates the difficulties that are to be met with in dealing in the field with ring-dyke margins, and shows how an apparent transition from one rock into another may be entirely misleading. Similar marginal relations between rocks of similar texture, such as coarsely crystallized eucrite and quartz-gabbro, might render it quite impossible to locate any contact between them. Secondly, the locality affords a good example of intense brecciation affecting the wall of a ring-dyke. The appearance of the brecciated Hypersthene-gabbro suggests brecciation by explosive gases rather than by earth-stresses. The brecciation must, however, have preceded the coming into position of the Quartz-dolerite, since the latter encloses xenoliths of the brecciated rock.

Associated acid masses

Stray masses and sheets of granophyre are found in the Hypersthene-gabbro (a), which may have been derived from the granophyre magma responsible for the veining of the Quartz-dolerite (e). Whatever may have been their origin, they well serve to demonstrate that net-veining can be produced by such a magma. A good example is provided by a westerly inclined sheet of granophyre, which is shown on the published maps north-west of Sgùrr nam Meann. This, and an adjoining sheet, are well exposed at their south ends along coastal cliffs that bound a sandy beach. Reticulating veins of granophyre are abundant in their roofs, and are demonstrably in continuity with the underlying sheet, from which they were evidently injected. These net-veins are more slender, and the brecciation less pronounced, than in the case of the Quartz-dolerite (e).

Xenoliths in these granophyre sheets are of interest. They consist of hypersthene-gabbro, apparently not much altered immediately below the roof, from which they were evidently detached. Farther down, towards the centre of the sheet, they are much metamorphosed, and progressively with depth below the roof become paler in colour and finer in texture, as a result of their impregnation by the acid magma. If an opinion had to be based on their composition alone, the origin of these altered xenoliths might indeed be difficult to surmise.

The granophyre itself is more or less hybridy in character throughout (S21520) [NM 4268 6799]. Usually, contacts with its roof are sharply defined, but at one point in the more southerly sheet the granophyre is much basified for an inch or two from the gabbro (S24437) [NM 4267 6799], into which it thus appears to merge. J.E.R.

Petrology

The description of this Ring-dyke given above indicates that we are here dealing with a variable, moderately basic intrusion that has been shattered and injected in a most intricate manner by acid material of granophyric composition. In this mass not only are we confronted with the effects of assimilative processes acting upon the basic material, but, in addition, have the superimposed results of contact metamorphism due to adjoining later intrusions.

The basic mass, where least shattered and permeated with granophyric matter, is a moderately coarse ophitic dolerite with abundant ilmenite (S22630) [NM 4250 6749] and with labradorite as the dominant felspar. A certain amount of interstitial granophyric matter is always present and occurs sometimes in such a manner as to suggest that it was an original constituent; and this fact, coupled with the general absence of olivine, is in favour of the rock being in part at least a true quartz-dolerite or quartz-gabbro.

The whole mass, however, has suffered an invasion by an apatite-rich granophyric magma that in the cases of veination has been accompanied by slight local assimilation. In more extreme cases a fine-textured blotchy rock has resulted, to which the term hybrid is undoubtedly applicable. In the former case the basic rock although brecciated retains its original basic character, and the acid material is restricted to the vein-like infillings. In the other case the basic rock has almost completely lost its individuality, such fragments as remain are swamped in a heterogeneous mass that is neither gabbro nor granophyre but clearly results from the contamination of an acid magma by basic material that has been incompletely absorbed. All stages of basification of the acid magma can be studied.

Considering the veined gabbro first, in which the basic rock was solid and relatively cool before the injection of the acid magma, we find that where actual veins can be seen to traverse the rock either as filaments (S24169) [NM 4258 6763] or as a network of coarser structure, such veins are either granophyric or felsitic in character. They usually carry a little biotite (S22346) [NM 4300 6791] as the chief ferromagnesian mineral and this increases in amount, in the wider veins, towards the contact with the basic rock. The margins of such veins are often quite indefinite and contain abundant pyroxene in granules and small idiomorphic crystals (S22279) [NM 4528 6414]. The basic rock itself is, in such cases, of a hybrid type with resorbed augite and felspars.

The larger veins (S24437) [NM 4267 6799] exhibit interesting contamination phenomena. They are commonly basified with the separation of abundant pyroxene in small idiomorphic crystals (S24437) [NM 4267 6799], while the basic rock contains recrystallized augite together with hypersthene, the latter often in large subophitic plates.

Many of the apparently homogeneous, fine-grained portions of this ring-dyke are certainly not normal rocks and must result from the complete assimilation of basic material by acid magma. They are composed of more or less fine-grained rocks that consist of pyroxene, regrown and albitized moderately basic plagioclase, iron-ore, and a residuum of alkali-felspar and quartz. The monoclinic pyroxene has usually recrystallized with a tendency towards idiomorphism, but the outstanding feature is the general prevalence of a rhombic pyroxene (S22409) [NM 432 662], which may be regarded as the natural outcome of acidification ((Figure 33) B, p. 248). The rhombic pyroxene is frequently pseudomorphed (S23588) [NM 452 642]. The larger felspars are mainly a labradorite of gabbro origin. They have suffered resorption and irregular regrowth as well as local albitization, while physical effects such as bending and fracture are often discernible. Fresh small felspars of less basic composition result from recrystallization. Augite occurs both as a product of recrystallization and as partially resorbed *remanié* crystals. This resorption is a familiar feature and is always accompanied by a granulitization or regrowth, together with the separation of microscopic magnetite. The recrystallized augite is frequently idiomorphic and endeavours to assume a columnar habit.

Apatite is practically restricted to the acid mesostasis, and to such areas of the basic rock as, by their recrystallization and modification, show the influence of the invading acid magma.

With a still further increase in the amount of acid material the acid mesostasis usually present (S23588) [NM 452 642], (S23589) [NM 452 642] becomes obviously in excess, and imparts to the rock a lighter colour and more speckled appearance. The microscope in such cases shows that there has been intense marginal modification of the older felspars with regrowth upon them of wide irregular borders of albite-oligoclase.

They are locally albitized, and penetrated and embayed by micrographic orthoclase and quartz. The original pyroxene has undergone almost complete absorption and its place has been taken by freshly formed granules and crystals of both monoclinic and orthorhombic varieties (S23597) [NM 452 642]. There has been the usual attendant separation of magnetite. The amount of acid mesostatic material is fairly large and has a micrographic structure. Where this material is in contact with older constituents the corrosive effect is well marked (S23590) [NM 452 642], (S23591) [NM 452 642], (S23592) [NM 452 642], sometimes including the formation of biotite (S22350) [NM 4294 6801], (S24436) [NM 4280

6765].

Metamorphism by the Quartz-dolerite

The metamorphic effects attributable to the intrusion are most noticeable in the Hypersthene-gabbro (p. 258) which forms its outer margin, and in the xenolithic masses of this rock which it encloses. They are primarily intense shattering of the older gabbro followed by a granulitization of the ferromagnesian and felspathic constituents (S24437) [NM 4267 6799], (S24439) [NM 4275 6908].

Within the intrusion, in addition to the usual granulitic gabbros, etc., certain dark xenolithic masses, noted to the north-west of Sgùrr nam Meann, have a banded structure and abnormal composition. In thin section (S24440) [NM 4283 6815] the darker bands are seen to be composed mainly of dark-green spinel, as crystals that range up to a quarter of an inch in size, set in a matrix of magnetite ((Figure 32) B, p. 234); lighter bands of no great thickness contain the same spinel in small crystals that are scattered through a mass of small twinned crystals of basic plagioclase felspar (bytownite-anorthite). Contrary to exp2ctations the rock contains no cordierite, but a little biotite is present in the more felspathic areas and is due presumably to interaction between ferriferous and felspathic constituents.

The origin of these xenolithic masses is obscure and the abnormality of their composition difficult to interpret. It is hard to regard them as being cognate to the gabbro, although rocks with a similar spinellid have undoubtedly been formed by the reheating of basic gabbroic segregations (p. 317). It is a well-known fact that the re-fusion of an anorthite-olivine segregation, such as might reasonably be expected in connexion with certain of the gabbro masses, would yield spinel, which, in a gabbro-melt might concentrate sufficiently to form such spinel-rich masses as are occasionally encountered.<ref>O; Anderson, The System Anorthite-Forsterite-Silica, *Amer. Journ. Science,* vol. xxxix., 1915, p. 407.</ref>

It may be, however, that they have resulted from the metamorphism of some highly ferriferous and aluminous rock of sedimentary origin, which has been modified by the diffusion of lime from the gabbro magma. There is some likeness, in the association of the green spinel (pleonaste-hercynite) with basic plagioclase, to the assemblage exhibited by the spinel-bearing accidental xenoliths of the Loch Scridain sills in Mull.<ref>H. H. Thomas *in* Tertiary Mull Memoir, 1924, pp. 274–278.</ref>

Metamorphism of the Quartz-dolerite

Such alteration as the Quartz-dolerite has itself undergone is in part attributable to the Quartz-gabbros (g) and (g′) that are intruded along its inner margin, and in part to the influx of hot acid magma forming the net-veins. Its metamorphism next to the Quartz-gabbro (g′) takes the form of granulitization in specimens collected west of Beinn na Seilg (S23591) [NM 452 642], (S23592) [NM 452 642], (S23637) [NM 4532 6421]. But, that much of the metamorphism was accomplished after the injection of the rock by acid magma is quite obvious. It is easy to detect the effects of hybridization and see that these have been followed in most instances by a general granulitization of both basic and acid material (S23591) [NM 452 642], (S22279) [NM 4528 6414]. Such is noticeable also near, or at, the contact of the mass under description with the Quartz-gabbro of Loch Caorach (g) where the rocks have been both acidified and granulitized (S22633) [NM 4283 6717], (S23635) [NM 4451 6435], (S24435) [NM 4283 6717]. The metamorphic influence of later intrusions can be detected even in the acid veins, which also share in the granulitization (S22346) [NM 4300 6791].

Cone-sheets cutting the Quartz-dolerite

Suchcone-sheets as are encountered within the Quartz-dolerite belong to the Inner Set of Centre 2 and are mainly porphyritic dolerites (p. 192). Others of quartz-dolerite composition and referable to the Talaidh type (S22347) [NM 4299 6791] are met with on the summit of Sgùrr nam Meann where they have experienced considerable metamorphic changes (p. 292). Their finer-grained constituents have been recrystallized and a general granulitization has extended throughout their mass. A microporphyritic type is here also represented (S21521) [NM 4301 6791] containing small porphyritic crystals of augite and plagioclase felspar in a fine-textured quartz-doleritic matrix that has been more or less completely granulitized. H.H.T.

(f) Eucrite of Beinn Nan Ord

Like other Ardnamurchan eucrites, this intrusion is highly durable, and for the most part forms higher ground than quartz-gabbros on either flank. The craggy northern summit of Beinn na Seilg, for example, is composed of a narrow inwardly projecting arm of the Eucrite ((Figure 36) and (Plate 6). The elongate ridge of Beinn nan Ord also owes its shape largely to the Eucrite that is well displayed in steeply rising crags on its south-west side. The valley between these two hills, where crossed by the Eucrite, has followed the course of N.–S. lines of crush. Northwards of Beinn nan Ord the intrusion also extends along lower ground, but here its deterioration in durability may be, in part at least, attributed to its intensely brecciated condition.

Most usually, olivine is abundant and the rock practically an allivalite, but augite-rich types also occur. From a point eastward of Sgùrr nam Meann northwards to the south shore of Sanna Bay, an augitic type predominates, the augite forming large plates. An intermixture of the two types may be seen in the more northerly of the two inwardly projecting arms of the intrusion, west of the Allt Grigadale. There, small rounded masses of coarsely ophitic augite-rich eucrite occur in an allivalitic matrix. The masses may perhaps be in the nature of cognate xenoliths. East of Sgùrr nam Meann, in addition to the type with large augite plates, acidified gabbro or eucrite has been included as part of the intrusion. The acidification seemed to be an original character of the rock. The Eucrite, whatever its composition, varies much in grain and often quite abruptly. Fine-grained xenolithic material is a frequent feature. It usually forms streaks and layers drawn out and often contorted by flow-movements, as may be seen along Beinn nan Ord, and on the east side of the valley immediately east of this hill. It weathers with a reddish hue, as though olivine-rich, and is cognate to the Eucrite, as is shown by microscopic examination (S21576). Xenolithic material in regular-running bands is prevalent along the south shore of Sanna Bay, and is frequently traversed by acid veins. It has the appearance of being granulitized quartz-dolerite, and the single specimen sliced bears a resemblance to the Talaidh type characteristic of the cone-sheets (S24173) [NM 4368 6839].

The dyke-like form of this intrusion is perhaps better displayed than by any other ring-dyke in Ardnamurchan. But, even in this instance, there is nowhere sufficient depth of section to allow us to conclude what may be the prevailing inclination of its walls. The intrusion is exposed to a depth of about 600 feet on the sides of the valley separating Beinn na Seilg from Beinn nan Ord. The view from Beinn nan Ord across the valley, with its minor ridges and hollows, due to erosion along crush-lines, shows how abruptly the margins of the Eucrite cross all these surface irregularities (Figure 36). The view looking towards Beinn nan Ord is equally striking, for the Eucrite extends straight up this steep hillside to the summit of the ridge, 300 feet above the level of the stream-course at its base.

It is noteworthy that the two inwardly projecting arms of the Eucrite are directed towards the Aodann Centre. Both arms can be proved by practically unbroken outcrops to be continuous with the main mass. The more southerly arm, that forms the north summit of Beinn na Seilg, is dyke-like in form, and not a sheet-like tongue; for its intrusive margin against the Quartz-gabbro of Garbh-dhail (c) is practically vertical, where seen on its west side just north of its bifurcation from the main mass. These arms appear to mark the position of radial fissures in continuity with the main ring-fissure. The only other instance of such an occurrence in Ardnamurchan is a radial prolongation from the outer side of the Quartz-dolerite Ring-dyke (I) of the Interior Complex, to the north of Meall Meadhoin (*see* Memoir-map).

Age relations

There is a considerable amount of evidence to show that the Eucrite is later than the Garbh-dhail Quartz-gabbro (c), which accompanies it along much of its inner margin. Along the east slope of Beinn nan Ord the Quartz-gabbro (c) is traversed by abundant shear-lines and by bands of black flinty crush-rock. These are in turn crossed by a plexus of basic sheets, quite uncrushed, some of which at least belong to the Inner Cone-sheet Complex. None of the sheets penetrate the adjoining Eucrite, nor is linear crushing apparent in the latter. Similarly, the inwardly projecting arm of the Eucrite, forming the northern half of Beinn na Seilg, is not crossed by a single cone-sheet, though on its east side cone-sheets traversing the Quartz-gabbro can be actually traced to within a few feet of its margin. Along the western side of this arm, the Quartz-gabbro is in an absolutely comminuted condition (S24447) [NM 4561 6476] next to perfectly sound Eucrite (S24446) [NM 4561 6476]. It proved difficult in the field to fix exactly the contact of the two rocks, for the brecciation

causes the Quartz-gabbro, which contains olivine, to appear not unlike the fine-textured Eucrite. A definite contact, however, was located on the hill-slope, just east of the stream east of Beinn nan Ord. The Eucrite there becomes finer grained and fluxioned at its contact with the fine-grained baked margin of the Quartz-gabbro (S24449) [NM 4501 6455]. As already stated (pp. 242–3), this fine-grained marginal facies of the Quartz-gabbro in a highly baked condition extends all along the outer margin from Beinn na Seilg to the northern end of Beinn nan Ord, and forms the actual summit of the Beinn nan Ord ridge. The baking appears most intense next to the Eucrite, which contains xenoliths of a similar rock at a point on the ridge opposite the north end of Loch Caorach. In addition, at this place, non-porphyritic grey felsite occurs in irregular sheets and dykes cutting both the sheared Quartz-gabbro and the unbroken porphyritic cone-sheets that traverse it (p. 280), and felsite of the same type cuts the baked fine-grained margin of the Quartz-gabbro next to the Eucrite, and seems in the field to be baked to a like degree — an appearance confirmed by the microscope ((S24401) [NM 4335 6574], p. 281). There is thus sufficient evidence to prove that the Eucrite is later than both the Garbh-dhail Quartz-gabbro and the Inner Cone-sheets.

Subsequently, as it appears, to the intrusion of the Loch Caorach Quartz-gabbro (g), the Beinn nan Ord Eucrite was shattered along a portion of its length, from Beinn nan Ord northwards to Sgùrr nam Meann. Microscopic examination shows that the Quartz-gabbro (g) at one point at least is similarly affected. The minute brecciation of the crystals can be seen with a pocket lens, while under the microscope, Dr. Thomas finds that these shattered rocks have been subsequently granulitized. Further details will be given below in the petrological section, and the significance of the brecciation has been already referred to (p. 214). It may here be stated that the shattering is quite different in character to the linearly directed crushing found near by in the Garbh-dhail Quartz-gabbro. The shattering seems due to the explosive action of gases, for some reason almost entirely confined to the Eucrite, the crushing to earth-stresses. J.E.R.

Petrology

The Eucrite of Beinn nan Ord, where it outcrops on the foreshore of Sanna Bay (S21556) [NM 4345 6843], is a moderately coarse-textured rock composed of fairly abundant olivine, an ophitic greenish-brown augite associated with large crystals of iron-ore, and somewhat elongated interlocking crystals of basic plagioclase.

The olivine is mainly fresh, almost colourless in thin section, and free from inclusions; when decomposed it has passed into an aggregate of magnetite and talc, which demonstrates its ferruginous and magnesian nature. As usual, it is commonly associated with a little biotite and also develops peripheral hypersthene. The felspars range from labradorite to bytownite, and for the most part exhibit a fine schillerization due to parallel orientated opaque hair-like inclusions. The augite frequently shows a schiller structure that is probably original, but the similar structure in the felspar is more likely to have been superinduced as the result of metamorphism.

To the west of Grigadale (S22634) [NM 4301 6710], the rock locally shows abundant signs of shattering, followed by granulitization and acidification.

Remnants of original augite and basic plagioclase still remain, but much of the augite has been recrystallized. The introduction of acid magma has resulted in the widespread crystallization of alkali-felspar and small patches of quartz and orthoclase in graphic intergrowth.

A little farther to the south, west-south-west of Grigadale, the mass to a great extent resumes the normal character of an olivine-rich eucrite (S24171) [NM 4300 6709], with subordinate diallagic augite, and a little biotite and hypersthene in association with the olivine. At the same time, however, local acidification and the consequent separation of strings and patches of granophyric matter (S22678) [NM 4297 6712] are attendant conditions. Similarly, to the west of Loch Grigadale, a coarsely ophitic augitic type, relatively poor in olivine, shows marked albitization (S24170) [NM 4300 6687] and schillerization of the felspars, together with a recrystallization of granulitic augite.

South of Grigadale the ring-dyke is composed almost entirely of the usual olivine-rich variety of eucrite, but it presents features that were only feebly represented farther to the north. From the neighbourhood of Loch Grigadale southward towards Beinn na Seilg, the eucrite has been profoundly shattered by the explosive activity of a subterranean magma, and subsequently metamorphosed with the occasional introduction of acid magmatic matter.

A careful traverse ((Figure 37), p. 266) was made by Mr. Manson south-westwards from the Grigadale Granophyre (c′) across the outcrops of the Eucrite and of the rocks that bound it on either side, in order that all variations of the Eucrite, both as regards texture and type, might be collected. It was found that almost the whole mass of eucrite (S22391) [NM 432 662], (S22392) [NM 432 662], (S22393) [NM 432 662], (S22394) [NM 432 662]; 3–12 of (Figure 37)) along this line was of an olivine-rich nature and approached an allivalitic composition. But, it had suffered throughout its whole mass an intense shattering that had broken up the larger crystalline elements and reduced the rock to a thoroughly fragmental condition. Subsequently to the shattering a recrystallization and granulitization was impressed upon the mass; processes that in a measure healed the scars, but failed to obliterate completely the kataclastic structure. Further, it is obvious from the acid outgrowths upon the shattered basic felspars, and also from the occasional introduction of granophyric matter between the crystal-fragments, that a granophyre magma was responsible for the shattering and subsequent metamorphism.

Close to the northern margin of the Eucrite an olivine-dolerite, the marginal portion of the Quartz-gabbro (c), shows some signs of disruption. Its main feature, however, is the manner in which it had been injected with acid magma that had consolidated as a fine aggregate of alkali-felspar and quartz, charged with minute needles of apatite (S22390) [NM 432 662], 2 of (Figure 37). This apatite-rich acid magma had albitized the basic felspar with which it came in contact, and produced less basic growths upon the felspar-fragments.

Followed along the line of the traverse, this type gives place in a few yards to a somewhat augitic eucrite with large crystals of olivine set in a matrix of somewhat broken up and regrown labradorite-bytownite felspar, recrystallized augite, rhombic pyroxene, and subordinate iron-ore. Thermal metamorphism of late date is suggested by the transformation of chloritic aggregates to biotite.

From this point onward, the shattering of the eucrite becomes more intense and reaches a maximum about the centre of the outcrop. Nearly every individual crystal of original formation has been separated from its fellows ((S22392) [NM 432 662]; 4 of (Figure 37)) and broken up, so that the larger fragments lie in a fine matrix that consists now of a granulitized mass of broken felspars and recrystallized augite. The fine-grained fragmental matrix has responded most readily to the metamorphic influences and has been also acidified to some extent, for, although there is often no actual interstitial acid material, the felspars have regrown with a generally more acid composition. One of the results of metamorphism is particularly noticeable in the olivine, which in all the eucrite of this region has assumed a highly characteristic schiller-structure ((S22393) [NM 432 662], 5 of (Figure 37)). It gives the mineral a grey tint by transmitted light and is due to the separation of minute rod-like inclusions arranged in two planes parallel to the cleavages (010) and (100).

Occasionally, portions of the mass lying between shattered belts have escaped disruption (S22394) [NM 432 662]; 6 of (Figure 37)), but by far the greater part of the rock exhibits shattering followed by granulitization (S22395) [NM 432 662], (S22396) [NM 432 662]; 7 and 8 of (Figure 37)). The most intense shattering of all, however, is observed about the centre of the Eucrite outcrop (S22397) [NM 432 662]; 9 of (Figure 37)), where the original rock has been broken down in a most complete manner before recrystallization set in (Figure 38). The larger felspars are shattered and partly albitized, original large augitecrystals have been broken and their cleavage-traces flexed, while even the olivine, which often escapes disruption, is broken up and occasionally granulitized ((S22398) [NM 432 662]; ro of (Figure 37)).

Certain more augitic varieties of the Eucrite ((S22399) [NM 432 662]; 11 of (Figure 37)), which more properly come under the heading of gabbro, occur in the traverse, towards the southern boundary of the Eucrite. In addition to the effects of shattering, they may show the general acidifying influence of an invading magma by the albitization of the basic plagioclase and the development of interstitial alkali-felspar. Actually at the margin of the Eucrite, specimens were collected which appear to have escaped shattering and which, apart from subsequent granulitization, are normal olivine-rich eucrites ((S22400) [NM 432 662]; 12 of (Figure 37)).

Another traverse was made farther south across the outcrop of the Eucrite on the northern slope of Beinn nan Ord, north-east of the south end of Loch Caorach. The specimens collected indicate that the rock here is of the same olivine-rich type as previously noted. The olivine is fresh but schillered, and the amount of augite somewhat variable. In some instances augite is feebly represented (S22413) [NM 436 658], but in others it plays an important part in the mineral-composition (S22411) [NM 436 658].

The shattering that was such a marked feature of the Eucrite farther north is still present, and in some cases is intense (S22414) [NM 436 658]; as before, it has been followed by the healing process of granulitization, and there are instances of actual penetration by acid magma (S22419) [NM 436 658]. To the west, towards Beinn na Seilg, the Eucrite is seemingly less shattered, but exhibits extensive albitization of its felspars. Just to the west of Beinn na Seilg, and close to its southern margin, the Eucrite is an augite-rich rock that appears to have undergone some modification (S22677) [NM 4491 6441]. It has a roughly banded structure, is moderately fine-grained, and is composed about equally of augite and plagioclase. The augite has a greenish tinge, is hypidiomorphic, and is remarkable for an almost constant simple twinning parallel to (100).

The felspar is much twinned but practically unzoned labradorite of medium basicity. It is possible that the rock here is in a modified condition, for occasionally there is obvious penetration by acid magma that has enveloped and attacked the older gabbro constituents (S24450) [NM 4563 6451], and left an interstitial residuum of alkali-felspar and quartz in graphic intergrowth.

A review of the microscopic evidence is in favour of the marked disruptive effects noticed in the Beinn nan Ord Eucrite being due to an explosive shattering of the rock by a subterranean acid magma. There is very little evidence of true crushing due to earth movement, and only a single thin band of flinty crush-rock, such as is so prevalent in the neighbouring Quartz-gabbro of Garbh-dhail (c), has been encountered in the Eucrite on Beinn na Seilg (S21472) [NM 4747 6807]. It is composed of finely comminuted felspar and augite through which pass fluxion bands of opaque material containing drawn-out whisps of felspar and augite.

A very interesting enclosure in an inwardly projecting portion of the Eucrite occurs east of the Allt Grigadale, half a mile southeast of Loch Grigadale. It is a fine-grained rock composed of olivine, augite, and labradorite with scattered crystals of magnetite. Olivine occurs, as in the Eucrite, as fairly large irregularly bounded crystals, but is not abundant. Augite is plentiful as ill-formed crystals that look like broken fragments of larger individuals. The felspar is present as somewhat elongated small crystals of oligoclase-andesine composition and appears brown by transmitted light owing to a superabundance of minute inclusions. The rock has all the appearance of a hybrid, and also of having suffered reheating with attendant schillerization of the felspar. H.H.T.

(g) and (g′). Quartz-Gabbros of Loch Caorach and Beinn Na Seilg

These two masses are grouped together in (Plate 5) as portions of a single ring-dyke, which in all probability they are. They will be separately referred to in this description, chiefly because they differ in rock-type. The Loch Caorach Quartz-gabbro is practically everywhere a characteristically grey-black gabbroid rock dappled with white spots and patches of acid residuum. Its black hue is to be correlated with its schillerized plagioclase felspar (p. 274). The Beinn na Seilg Quartz-gabbro is a coarse-textured speckly black and white rock that closely resembles the neighbouring Eucrite, but differs in containing a small though definite amount of acid mesostasis and large crystals of iron-ore, and in possessing little olivine. The boundary between the two types coincides roughly with the hollow between Beinn nan Ord and Beinn na Seilg.

The main interest of these Quartz-gabbros lies in their relation to the Quartz-dolerite (e) and Eucrite (f) that accompany them on either flank. The eviden& of their relative ages is set out below and seems to establish the later age of the Quartz-gabbros, though the finding of more contacts is perhaps to be desired. The outer margin of the Loch Caorach Quartz-gabbro against the Quartz-dolerite (e) was located south of Sgùrr nam Meann, about 100 yds. north of the track that runs from Grigadale to the Lighthouse. The Quartz-gabbro is quite a coarse-grained rock about 25 yds. from the margin, and of the characteristic black colour with spots of acid material. Close to the margin it changes to a relatively fine-grained quartz-gabbro, which is strung with coarser augite-rich gabbro and veins of gabbro-aplite. The augite-rich strings look like thin pegmatite-veins. Both kinds of veins run parallel to the margin. They are evidently marginal features, and are probably the infillings of contraction-cracks developed in the cooling rock. The Quartz-dolerite alongside carries abundant felspar phenocrysts, but a tendency to porphyritic structure is also found in the marginal quartz-gabbro. The issue is thus complicated. Sharp junctions of the marginal quartz-gabbro and the porphyritic quartz-dolerite could however be made out. The latter rock has the appearance of being greatly baked, and this has been confirmed on

microscopic examination by Dr. Thomas (S22633) [NM 4283 6717].

North of Sgùrr nam Meann, the line of demarcation between the two rocks can be traced vertically down the steep, north side of an east–west gully. The Quartz-dolerite, lighter coloured on weathered surfaces and evidently the more acid rock, ends off abruptly against the darker Quartz-gabbro, which is a coarser-grained basic-looking rock with acid spots. Yet, though the distinctness of the two rocks is evident, their actual contact is most difficult to locate. A junction specimen was collected from one point on the side of the gully, showing quartz-dolerite in contact with somewhat fine-grained quartz-gabbro, and under the microscope the quartz-dolerite appears to be the older rock (S24438) [NM 4313 6819].

Acid net-veining is a feature of the Quartz-gabbro close to its margin. Cone-sheets that cut the acid-veined Quartz-dolerite are present north of Sgùrr nam Meann and also on the summit, where specimens collected prove that both cone-sheets and acid-veined Quartz-dolerite are highly baked (S21521) [NM 4301 6791], (S22347) [NM 4299 6791]. The alteration is no doubt in part due to the Quartz-gabbro, which shows no signs of contact alteration. The outcrop of the Quartz-gabbro, however, is interrupted, as though the intrusion were running underneath Sgùrr nam Meann, and this hill is bounded to the east by the Eucrite of Beinn nan Ord. Probably, therefore, the Eucrite may also have been concerned in effecting the unusually intense alteration of the Quartz-dolerite. Mention may be made of rude columnar jointing developed in the Quartz-dolerite on the east side of Sgùrr nam Meann, and inclined east at 45 degrees. This appears to be the result of the baking, and may be compared with jointing found in the much baked capping to the Quartz-gabbro (A) on Meall an Tarmachain (p. 286).

The Quartz-gabbro of Beinn na Seilg (g′) is certainly a separate intrusion from the Quartz-dolerite (e), since the two part company west of the southern summit of Beinn na Seilg, and run one to the north, the other to the south of this peak, which is formed of the Hypersthene-gabbro (a). To the west, where they come into contact, just east of a strip of peat-covered alluvium, the Quartz-dolerite becomes dull black in colour on fractured surfaces, and baked in appearance, next to the fine-grained margin of the Quartz-gabbro. This quartz-dolerite is found by Dr. Thomas to be granulitized (S23637) [NM 4532 6421].

The relationship between the Loch Caorach Quartz-gabbro and the Beinn nan Ord Eucrite is obscured along a large part of their mutual contact by the brecciation that affects not only the Eucrite but also the adjoining portion of the Quartz-gabbro (p. 267). At one point, north of Loch Caorach, an unbroken junction was located, at which the Quartz-gabbro becomes finer in grain towards a sharp contact with the Eucrite. The junction is seen on the east side of a slight hollow about 80 yds. south-east of a stream and fence shown on (Figure 37), p. 266, and 500 yds. north of the north end of Loch Caorach. More continuous rock-exposures are available along the rocky southern shore of Sanna Bay; and yet, though the two gabbros are here of contrasted types, their actual contact could not be determined satisfactorily. A vague line of junction could be seen, but there was no indication to the eye as to which rock was intruded first. It would appear as if there was little difference in age between them, and that one injection followed closely upon the other. On the other hand, the rocks were not examined microscopically, and it is possible that brecciation similar to that which obscures the contact of these intrusions on Beinn nan Ord, and which is difficult to discern with the unaided eye, may be responsible for the vagueness of the junction on the shore.

In the same way, between the Quartz-gabbro of Beinn na Seilg and the Eucrite (f), junctions are very difficult to locate, and in this case there is the further difficulty that the two rocks are very similar. At the base of the steep west face of the central mass of Beinn na Seilg, there appears to be a contact at which quartz-gabbro cuts eucrite, and the boundary line was traced from there straight up the hillside (*see* (Figure 36), p. 264). J.E.R.

Petrology

Like most of the so-called quartz-gabbros of Ardnamurchan, this mass exhibits considerable variation, more particularly in the amount of acid material of late consolidation, and in the effects of this partial magma upon the earlier-formed constituents. In addition, however, there are mineralogical variations that are presented by those portions of the mass which are more than normally rich in aluminous pyroxene and iron-ore. Traverses were made across the outcrop of the ring-dyke, one over the low ground to the west of Beinn na Seilg and another southwards from Grigadale. The result of this serial collection has been to emphasize the variability of the mass and to show that different varieties are not

restricted in their occurrence. Similar rock-types and variations are encountered in the Older Quartz-gabbro of Beinn Bhuidhe (p. 249) and are closely paralleled by those of the Beinn Bheag gabbro of Mull.<ref>H. H. Thomas *in* Tertiary Mull Memoir, 1924, p. 256</ref>

In its most basic or least modified form, as on the western flank of Beinn na Seilg, the magma has crystallized as an olivinegabbro of eucritic affinities (S21503) [NM 4570 6439]. The rock is of medium texture, grey colour, and is composed of olivine, augite, and a basic labradorite with subordinate iron-ore. The olivine is usually decomposed, but its pseudomorphs are often easily detected and show that the original mineral was an iron-magnesian variety, which frequently occurred in close association with hypersthene. In much of the mass, however, olivine is wanting. In some cases its former presence may be inferred, but in others it does not appear to have existed as an original constituent.

The whole mass exhibits signs of general reheating which are partly textural, partly mineralogical in character, such as granulitization and the respective destruction or production of schiller-structures in augite and felspar. In addition the mass has been profoundly affected by the introduction or migration of an acid magma that has produced both structural and mineralogical changes in the earlier-formed and more basic constituents. This acid magma, rich in alkalis and volatile matter, has in certain cases hybridized with the earlier crystallizations, and where in excess has formed an unmodified mesostasis of alkali-felspar and quartz. Compared with true hybrids, in which there has been more or less complete commingling of magmas and the development of new minerals such as biotite, hornblende, etc., the effects of the acid magma in the case of the Loch Caorach gabbro are of a less intense nature. The phenomena are chiefly those of resorption and recrystallization, closely associated with general albitization. An explanation of this difference, which is also applicable to other quartz-gabbro masses, is probably forthcoming if we assume that the original rock was for the most part solid and relatively cool before the migrating acid magma invaded it. Such an explanation would also account for the rapidly changing relative proportions of acid and basic material.

The shattering that was so marked a feature of the Garbh-dhail gabbro (c), and to a less extent of the Beinn nan Ord Eucrite (f), is reproduced in the Loch Caorach gabbro to a limited degree, and is more particularly a feature of the Beinn na Seilg gabbro (g′) to the west of Beinn na Seilg. The phenomena are of a similar character to that met with in the Eucrite (f), and in extreme cases consist of intense shattering of the original basic felspars followed by albitization and a general granulitization. Where less pronounced, the shattering is restricted to bands traversing otherwise sound rock, and the granulitization has then only affected the more finely comminuted material.

At the northern end of its outcrop, on the flanks of Sgùrr nam Meann (S23638) [NM 4318 6815], the gabbro is a moderately coarse rock containing pseudomorphs after olivine in magnetite and talc, which are associated with hypersthene. The felspars are turbid and schillerized. They have been resorbed and albitized while the original brownish diallagic augite has been deschillerized locally with a further production of rhombic pyroxene. The rock carries an abundance of acid mesostasis that has been largely responsible for the albitization of the older felspar, and other mineral changes, and has itself crystallized as an interstitial feathery mass of alkali-felspar and quartz.

To the west of Grigadale (S23639) [NM 4294 6687] the mass is somewhat more augitic, but the felspars exhibit the same schillerization and albitization accompanied by a granulitic development of hypersthene, hornblende, and magnetite in small patches within them. A somewhat similar type occurs close to the Beinn nan Ord Eucrite, to the west of Beinn nan Ord (S21483) [NM 4393 6492].

A traverse made across the outcrop to the south of Loch Grigadale yielded a series of specimens which exhibits well the explosive shattering that the mass has suffered, together with the adjoining Eucrite of Beinn nan Ord (p. 268). The rocks are predominantly augitic, although olivine pseudomorphs may occasionally be detected ((S22406) [NM 432 662]; 17 of (Figure 37)). The shattering has been followed by albitization of the basic felspars and by a recrystallization of augite ((S22401) [NM 432 662]; 13 of (Figure 37)), also by a general granulitization of the comminuted material ((S22402) [NM 432 662]; 14 of (Figure 37)). Where the shattering does not affect the whole rock it is often possible to detect narrow zones along which disruption has taken place ((S22403) [NM 432 662]; 15 of (Figure 37)), and which have had their fine-grained material more or less completely granulitized. All these rocks have recrystallized augite that exhibits slightly different characters from the original mineral. The, main differences are that the new augite is free from schiller-structure, tends towards idiomorphism, and is of a distinctly greenish hue, due, no doubt, to the introduction of alkalis from the

migrating acid mesostasis. The acid quartzo-felspathic, and frequently micrographic, material is often abundant and quite impartially distributed ((S22407) [NM 432 662]; 19 of (Figure 37)), but in some cases is definitely segregated into veins ((S22408) [NM 432 662]; 18 of (Figure 37)).

Another traverse made about half a mile to the west of Beinn na Seilg demonstrated that the mass is there of similar constitution. The rocks are medium to coarse-textured gabbros that carry hypersthene (S22385) [NM 446 642], and which have suffered the usual deschillerization and recrystallization of their augite (S22383) [NM 446 642]. The belt of shattering continues and some of the shattered rocks show remarkably well the results of the superinduced albitization and granulitization (S22386) [NM 446 642]. Acid mesostasis of a granophyric nature is often extremely abundant, and is remarkable for the large amount of apatite it may carry. The crystals of apatite are usually quite small, but in some cases may reach a length of two or three millimetres (S22280) [NM 4526 6418], (S22384) [NM 446 642].

In many of these rocks all trace of original olivine, if ever present, has been lost. Pseudomorphs, however, do occur occasionally (S23594) [NM 452 642], and, as we have seen (p. 273), the mass on the western flank of Beinn na Seilg (g′) was decidedly eucritic in nature. It appears probable that in much of the gabbro-mass the olivine has been decomposed by a pneumatolytic process akin to that which operated in Central Mull,<ref>E. B. Bailey in Tertiary Mull Memoir, 1924, P. 94.</ref> and that the place of this mineral has been taken by pyroxene and iron-ore as a consequence of acidification and reheating. H.H.T.

(h) Younger Quartz-gabbro of Beinn Bhuidhe

This mass is of irregular shape and varies much in rock-type. It may include more than one intrusion, as is suggested by an apparently intrusive junction that occurs within the mass as mapped, 130 yds. south of the northern summit of Beinn Bhuidhe. A coarse-grained white-weathering quartz-gabbro is there in contact with fluxion-gabbro that is apparently the margin of a dark quartz-gabbro with acid patches found along the summit of the ridge.

No contacts have been made out with the Fluxion Gabbro (i) to the north, but there is definite evidence of its relations to the Older Quartz-gabbro of Bheinn Bhuidhe (c″), and to the Eucrite (f). As the Quartz-gabbro (c″) is traced up the rocky southern slope of Beinn Bhuidhe, it becomes baked in appearance, as do also the Inner Cone-sheets by which it is cut. At the top of the hillside, where these rugged rocks give place to smooth grassy ground, on the east side of a conspicuous hollow eroded along a line of crush, the baked dark-coloured Quartz-gabbro (c″) is intruded by quartz-dolerite. The latter grades rapidly northwards into the Quartz-gabbro (h), which is nowhere cut by the Inner Cone-sheets. To the east of this contact, the Quartz-gabbro (c″) is intruded, as though along joints, by hybridy-looking quartz-dolerite that is presumably connected with the Younger Quartz-gabbro (h). That the Eucrite (f) is also earlier than the Younger Quartz-gabbro is equally clear. A well-exposed contact occurs n0 yds. north-north-west of the north summit of Beinn Bhuidhe, on a steep slope above a cross-country track leading from Grigadale to Portuairk. Eucrite, baked in appearance, is there in vertical contact with quartz-dolerite which grades rapidly uphill into the Quartz-gabbro (h). The eucrite may be a screen-like mass, isolated from the main body of the Beinn nan Ord Intrusion. It exactly resembles the local variation of the Beinn nan Ord Eucrite in containing large plate-like augites, and no doubt of its identity is entertained. Quartz-gabbro, mapped as part of the Younger Quartz-gabbro, is in contact with the Eucrite (f) south of the junction of the Allt Grigadale with Grigadale Loch ((Figure 37), p. 266). At the contact the quartz-gabbro has a well-developed acid mesostasis, and the eucrite appears to be highly acidified (S24434) [NM 4332 6648]. In this neighbourhood the Eucrite is usually in a completely shattered condition (p. 267), and the fact that the quartz-gabbro alongside is quite sound suggests that the eucrite is the older rock (*see* p. 206). No boundary has been fixed between (h) and (d) but, as already mentioned (p. 251), (d) is cut by a cone-sheet referred to Centre 2, while (h) is later than these sheets. J.E.R.

Petrology

As pointed out in the field descriptions given above, this mass is irregular in form, variable in character, and may include more than one intrusion. Such a state of affairs is certainly borne out by microscopic examination, which confirms the variability, and shows that the migration of an acid mesostasis has produced local mineralogical and structural changes

that give a general hybridy appearance to the resultant rocks. In its most normal condition and where most free from acid veins and mesostasis, as at and near the summit of Beinn Bhuidhe, the rock is a moderately coarse ophitic dolerite composed of a brownish augite that ophitically encloses well-formed unzoned crystals of bytownite (S21553) [NM 4383 6777]. Olivine was apparently an original constituent, but in the majority of cases its former presence can only be inferred from ill-formed serpentinous or chloritic pseudomorphs. It is, however, clear that the most basic and least modified portions of the mass approximate to eucrite in composition. Even within the area of a thin section the presence of an acid magma makes itself evident, and it is seldom that either an augite or a plagioclase felspar is observed which does not show signs of disturbed equilibria (S21554) [NM 4378 6770]. The effect of the acid magma and emanations on the original augites is often most marked (S22345) [NM 4373 6780], for it has brought about a cleansing of the mineral by the local destruction of the schiller-structure ((Figure 45) A, p. 320) and has been responsible for some recrystallization, sometimes as augite and at other times as rhombic pyroxene. Also, there has been a general production of minute scales of biotite within the augite of the attacked areas.

To the south of Grigadale the amount of acid material is much greater. It has not only affected radical changes in the augite and generally reduced the basicity of the felspars, but occupies ill-defined areas throughout the rock, in which it appears as an apatite-rich microcrystalline and often micrographic mixture of alkali-felspar and quartz (S22389) [NM 432 662], (S22390) [NM 432 662]. Against the acid mesostasis the felspars are albitized and often fringed with orthoclase, while augite shows corrosive effects involving recrystallization and the local development of hornblende and rhombic pyroxene. The acidified felspars are peripherally charged with apatite, often continuous from the acid mesostasis, while the original basic felspars are particularly free from this mineral. It is in those portions of the mass which appear to have carried original olivine that the development of rhombic pyroxene is most pronounced (S22375) [NM 4360 6691]. It occurs associated with much modified augite enveloping talcose pseudomorphs after olivine, and from its fairly strong pleochroism appears to be hypersthene.

In the neighbourhood of Achosnich (S22351) [NM 4390 6770] the rock is a moderately coarse ophitic dolerite without much acid mesostasis. The felspars, however, are intensely albitized (Figure 45) in a patchy manner, and riddled with albite-veins. There is a good deal of iron-ore present which has developed biotite at its peripheries.

At the edge of the mass, to the north-west of Achosnich, where it is in contact with the Great Eucrite, it takes on the character of a fine-grained granulitic rock composed of small irregular crystals and granules of augite, somewhat stumpy prisms of much twinned clear plagioclase of very variable composition, and abundant magnetite with a little biotite developed at the expense of the iron-ore (S22352) [NM 4399 6767]. The rock has the appearance of having been in a great measure recrystallized, probably as the result of reheating effected by the intrusion of the Great Eucrite.

The gabbro occasionally encloses small strips of what seems to be older material which are more or less completely recrystallized. They are subgranulitic in texture and one of them is remarkable for its abundance of rhombic pyroxene (enstatite). This rock (S22353) [NM 4387 6782] suggests not so much a recrystallized normal gabbro as a recrystallized hybrid. The rock forming the screen to the northwest of the summit of Beinn Bhuidhe, and referable to the Beinn nan Ord Eucrite, is a coarsely ophitic dolerite that shows abundant signs of contact metamorphism (S22625) [NM 4379 6789]. The felspars have become intensely turbid with schiller inclusions, enclose little granulitic patches of pyroxene and magnetite, and are strung with slender veins of albite. Interstices between the felspars are filled with epidote, sphene, actinolite in fibrous masses, prehnite, and quartz charged with vermicular chlorite. H.H.T.

(i) Fluxion Gabbro of Portuairk

This mass is in contact with three other intrusions, relations with which are obscure. It has been mapped as a separate intrusion, chiefly because it differs from its neighbours in rock-type. Its characteristic fluxion structure is developed almost everywhere. Biotite is a frequent constituent and is easily seen where the rock is soft and decomposed, as, for example, along a scarp bounding the fields south of Portuairk. On the coast it is well exposed and often presents the fuzzy, white-weathering appearance of a quartz-gabbro. There, numerous bands of fine-grained granulitic rock are to be seen, while to the east, next the Great Eucrite (E), vertical west-north-west joints are conspicuous. Possibly these may be contraction joints due to cooling that followed the heating up of the mass by the Great Eucrite.

An apparent contact with the Great Eucrite occurs at high-water mark, where the boundary line has been drawn on the map (p. 303). Its junction with the Eucrite (f) to the west could not be determined satisfactorily, although exposures along the coast are excellent.

Petrology

Although mappable as a unit, this mass is clearly of mixed nature, and has been produced by the modification of gabbroic or eucritic material by an acid magma. As developed on the shore north of Portuairk (S22373) [NM 4398 6822], the rock is an intensely acidified gabbro in which the old augite has been deschillerized, and locally recrystallized and charged with minute scales of biotite. In some parts of the rock the augite has been converted into uralitic hornblende and the original basic felspars albitized. The matrix in which these gabbro elements are set is rich in alkali-felspar and quartz, but also contains abundant rhombic pyroxene, now pseudomorphed by fibrous green hornblende, and a growth of plagioclase of fairly acid composition. Biotite occurs in association with the iron-ores and also as a chloritized constituent of the matrix.

To the west (S21557) [NM 4378 6836], and a little inland from the shore (S22354) [NM 4393 6804], the rock has a moderately coarse ophitic structure and is obviously modified. The augite is corroded and deschillerized in the usual manner with the development of scales of biotite and patches of uralitic hornblende. Further, there is a general albitization that chiefly affects the marginal portions of the basic plagioclase crystals, but also traverses them as narrow veins. The acid mesostasis, where present, consists of albite-perthite and quartz, and its local modifying influence is strongly marked. Abundant biotite, as large scales, occurs in connexion with the iron-ore, and rhombic pyroxene occasionally occupies moderately large areas.

The Great Eucrite (E) close to the margin of the Portuairk Gabbro also exhibits fluxion to some extent (S22355) [NM 4422 6816], but its eucritic nature is practically unimpaired. It contains abundant crystals of unaltered olivine, but is perhaps rather richer than usual in rhombic pyroxene (hypersthene). The augite shows local deschillerization and there is slight albitization of the basic plagioclase.

In places the invasion of the gabbro (i) by acid material is obvious in the field, and in such extreme cases (S22374) [NM 4406 6692] the rock appears as an acidified gabbro or basified granophyre. The augites of gabbro origin are much corroded and the original basic plagioclases have been resorbed, rendered turbid by schillerization, and fringed by a regrowth of albite-perthite which also strings through them in all directions. The acid magma has crystallized as an interstitial turbid mass of alkali-felspar and quartz, frequently showing graphic structure and charged abundantly with apatite. One of the chief pieces of evidence for the resorption of the basic plagioclase and its subsequent regrowth as a more acid variety, is furnished by the fact that the abundant apatite of the mesostasis is included in the soda-rich plagioclase that borders the more basic felspar. At the same time, albitization in its generally accepted sense, that is to say, molecular change effected by the introduction of the soda molecule in solid-solution, has also taken place to a limited extent, as is proved by the strings of soda-plagioclase which penetrate into the interiors of the basic felspars.

Certain granulitic masses (S22365) [NM 4393 6830] enclosed by the gabbro (i) are fine-grained rocks that suggest cone-sheet or some other fine-textured intrusive rock that has been thermally altered by the surrounding mass. One such mass shows an open lattice of felspar-laths embedded in a more or less completely granulitized matrix of augite, oligoclase felspar, and magnetite, with abundant biotite. Acid veins emanating from the surrounding intrusion often string through the granulitized xenolithic masses, and by absorption of basic material have greatly modified their original composition. Near their junctions with the basic rock they have developed an abundance of green hornblende, while in the body of the veins large plates of biotite are common. For the rest, the vein is a soda-rich granophyre composed of oligoclase-albite, albite-perthite, and quartz, with, here and there, small flakes of biotite and slender needles of green hornblende. The basified rock, both in the development of hornblende and biotite, and in the abundance of perthitic alkali-felspar, assumes a likeness to the tonalites and monzonites (p. 99) which we have reason to believe are rocks of hybrid nature.

A review of the Fluxion Gabbro as a whole certainly gives the impression that we are dealing with an abnormal mass that owes its peculiarities largely to the interaction of acid magma with a basic rock already in a solid or partially solid

condition. That such interaction took place in the main before the intrusion of the mass into its present position appears probable, although the further migration of acid magma has locally exaggerated the effects. H.H.T.

(j) Felsite, South of Aodann

This small mass consists of a dark-grey non-porphyritic felsite, and forms a prominent rocky hill. On its east side the felsite cuts the Aodann Quartz-gabbro (d). The latter is granulitized at the contact (S22337) [NM 4519 6590], while 50 yds. away it is quite unaltered. The felsite in turn is cut by an inclined sheet of grey-black dolerite that is definitely chilled against it, and also by thin basic dykes. The dolerite sheet is considered by Dr. Thomas to be certainly baked (S24403) [NM 4514 6580], as it indeed appears to be in the field. Yet there is no visible intrusion in the neighbourhood of later age than itself. It therefore seems necessary to postulate some younger intrusion below ground (*see* p. 255).

The same type of felsite as the above is found in smaller masses, usually sheet-like in form though with irregular. margins. These are of frequent occurrence in the western half of the Old Gabbro (b). Farther west, they are also met with across the belt of country traversed by the Inner Cone-sheets, which they are found to cut. For example, west of the Allt Grigadale on a scarp that borders a tributary stream, and just north of the projecting arm of the Beinn nan Ord Eucrite (f) ((Figure 37), p. 266), an interesting series of events can be made out. The Garbh-dhail Quartz-gabbro (c), which is much sheared, is cut by porphyritic cone-sheets that are quite sound, and that run at right angles to the side of the scarp. Along the edge of the scarp, transgressing across the cone-sheets and chilled against them, is a dyke-like intrusion of the dark, nonporphyritic felsite. The baking of felsite of the same type as the above, which occurs in this vicinity next to the Beinn nan Ord Eucrite, has been already mentioned (p. 267). J.E.R.

Petrology

This mass (S21577) [NM 4509 6586] is a medium-grey splintery rock without macroscopic structures or porphyritic crystals. It is traversed by irregular narrow veins filled with greenish to white material, and contains a few scattered crystals of pyrites. Under the microscope, viewed with a low power, it appears to be a more or less normal fine-grained felsite with a few quite small phenocrysts of albite-perthite. The matrix is largely felspathic and has the appearance of having been glassy. It carries small irregular inclusions of a xenolithic nature which are rich in iron-ore and exhibit a microcrystalline structure. These xenoliths suggest some basic rock, probably basalt lava, as the felsite is in contact with such rocks on its southern margin.

A higher magnification reveals the fact that the Felsite has been intensely metamorphosed. The fine felsitic matter has been granulitized with the formation of abundant minute rounded granules of pale-green pyroxene and crystals of magnetite of similar dimensions which are scattered throughout the rock. The granules average from 0.005 mm. to 0.01 mm. In the veins and cracks the granulitic texture is somewhat more coarse and the granules reach 0.03 mm. in diameter; also, the green colour of these veins, visible in the hand-specimen, is found to be due to an abundance of a deep-green alkali-pyroxene that is strongly pleochroic in shades of green and yellow. This pyroxene is similar to that present in the Augite-diorite of Camphouse (p. 154) and in certain contaminated rocks to which it appears to be related. A further likeness is furnished by the occurrence of sphene in both cases.

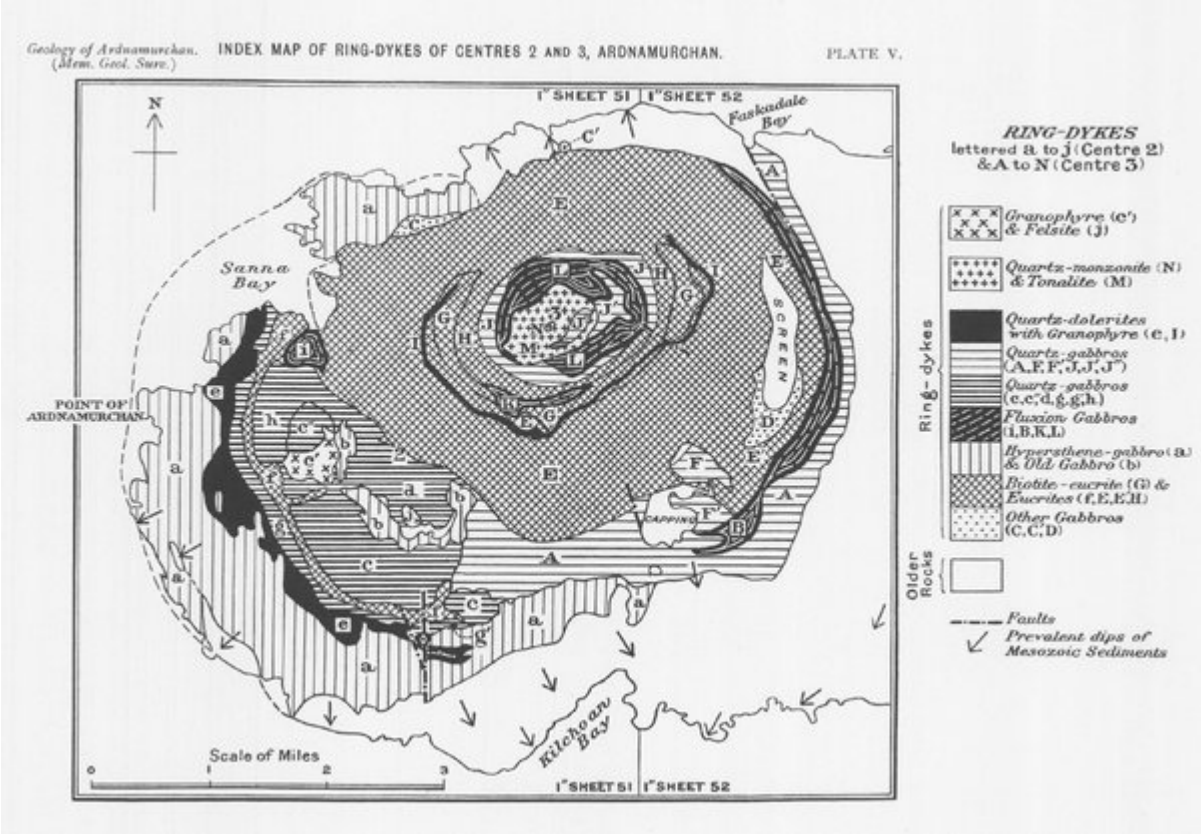
The Aodann Felsite is cut by a thick basic sheet (S24403) [NM 4514 6580], which has also shared in the metamorphism that has affected the earlier intrusion. This sheet is a quartz-dolerite of basic Talaidh type, in which contact alteration has produced a general turbidity of the felspars and a development of biotite in association with iron-ore, and in the chloritized mesostasis.

The fact that the Aodann Felsite appears to be younger than all the other intrusions with which it is in contact, apart from the dolerite sheet, makes it difficult to account for the pronounced thermal alteration those two rock-masses have suffered. It may be, as Mr. Richey has suggested, that the metamorphism is due to some later underground intrusion that does not reach present surface-levels.

Felsite similar to that of Aodann occurs as dyke-like masses farther west. A rock from a point 360 yds. east of the northern end of Loch Caorach is of this nature (S24401) [NM 4335 6574], but it has suffered a more or less complete

granulitization at the hands, probably, of the Beinn nan Ord Eucrite. The ground-mass is now a microgranulite replete with small granules of yellowish-green pyroxene and magnetite, the abundance of which suggests an intermediate composition for the original rock.

Another mass of dyke-like character which cuts the gabbro to the south-south-east of Grigadale (S24430) [NM 4365 6617] is a fine-grained dark-grey rock with small porphyritic felspars, and glomero-porphyritic groups of felspar and augite in a microcrystalline matrix. The felspar is a moderately alkaline plagioclase (andesine to oligoclase) while that of the matrix appears to be mainly oligoclase with some albite and orthoclase. The felspathic matrix contains abundant small elongated crystals of augite intergrown with magnetite, and there is a suggestion that its original structure was akin to that of the craignurites of Mull. The rock has, however, been modified to a considerable degree by subsequent granulitization, perhaps due to the adjacent Eucrite of Beinn nan Ord. H.H.T.



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

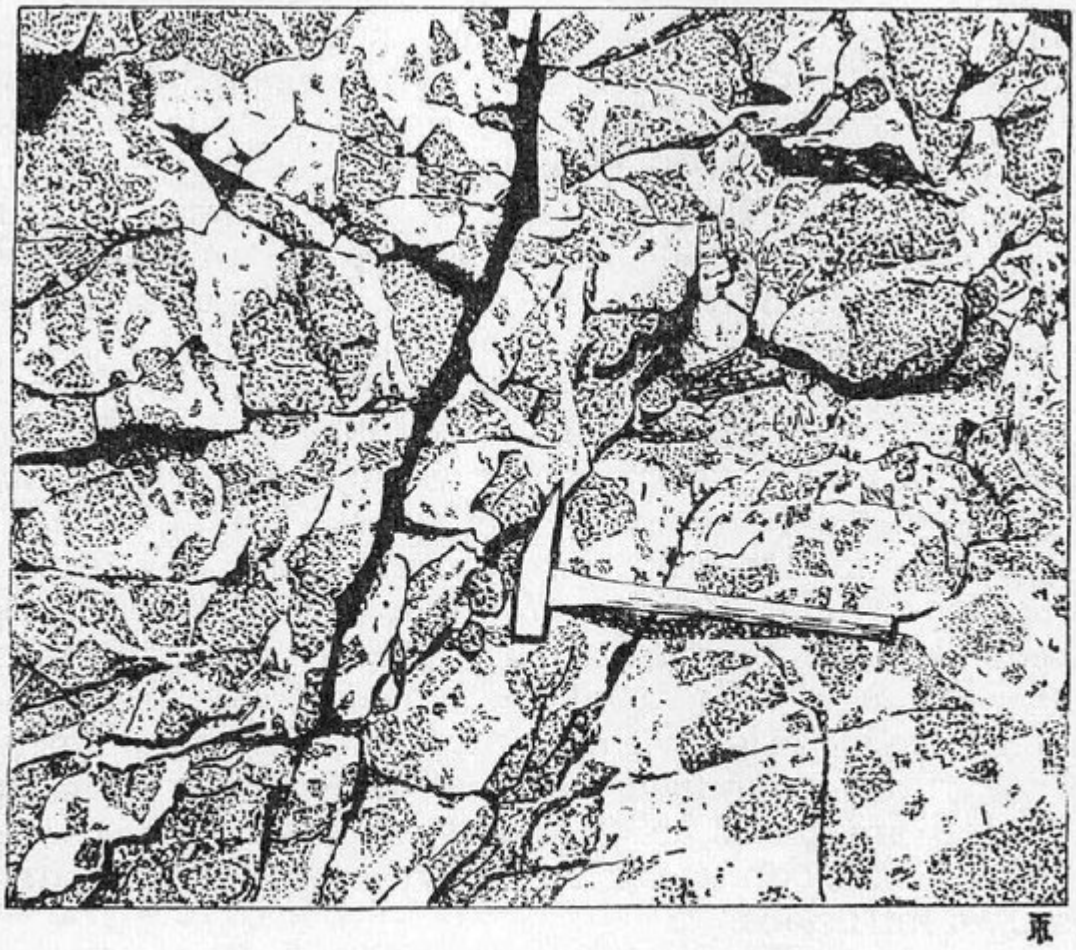


FIG. 34.—*Quartz-dolerite net-veined by granophyre, Sgùrr nam Meann Ring-dyke, on shore south-west of Sgùrr nam Meann.*
Drawn from Geological Survey Photograph, No. C. 2773.

(Figure 34) Quartz-dolerite net-veined by granophyre, Sgùrr nam Meann Ring-dyke, on shore south-west of Sgitrr nam Meann. Drawn from Geological Survey Photograph, No. C. 2773.

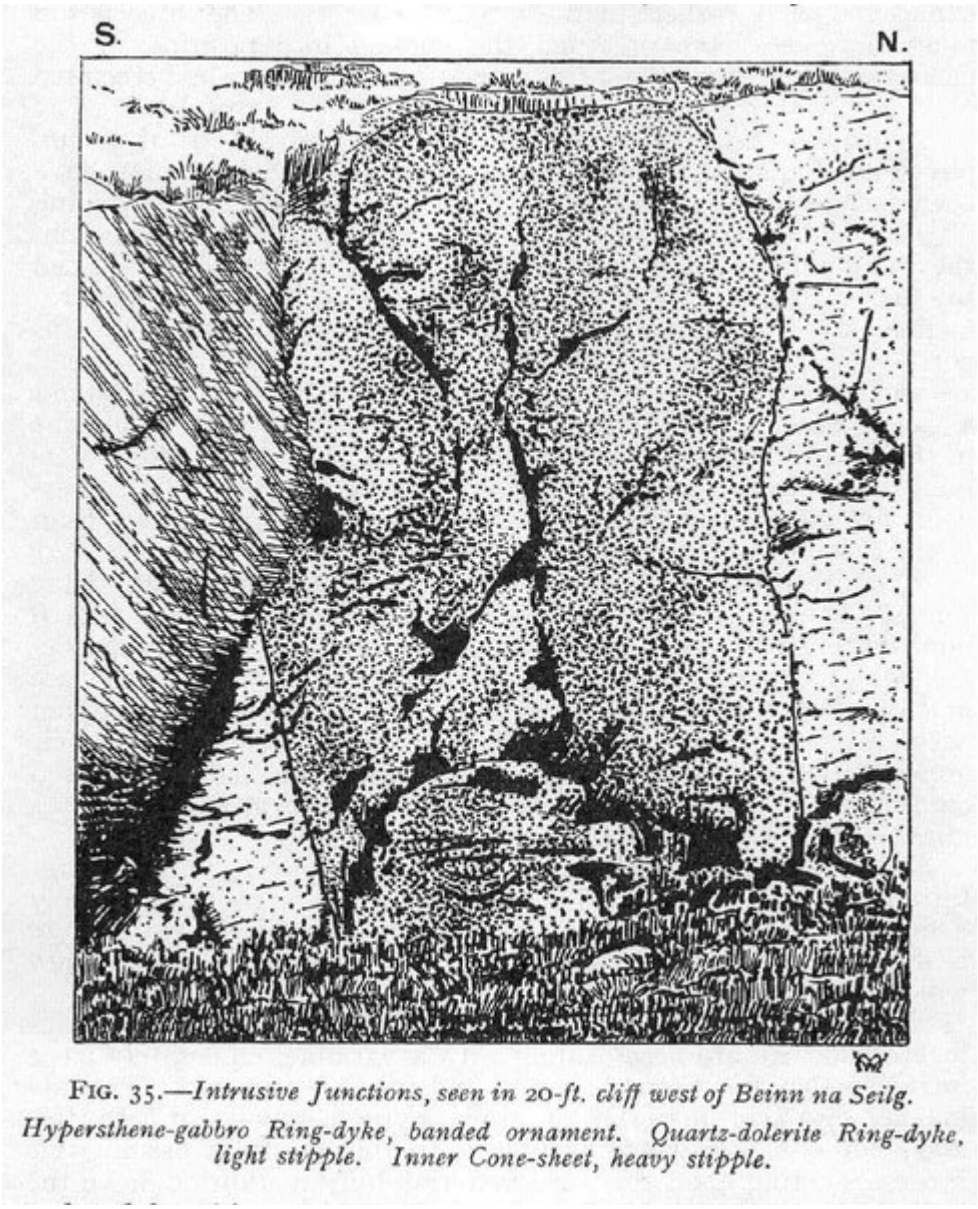


FIG. 35.—*Intrusive Junctions, seen in 20-ft. cliff west of Beinn na Seilg. Hypersthene-gabbro Ring-dyke, banded ornament. Quartz-dolerite Ring-dyke, light stipple. Inner Cone-sheet, heavy stipple.*

(Figure 35) Intrusive Junctions, seen in 20-ft. cliff west of Beinn na Seilg. Hypersthene-gabbro Ring-dyke, banded ornament. Quartz-dolerite Ring-dyke, light stipple. Inner Cone-sheet, heavy stipple.

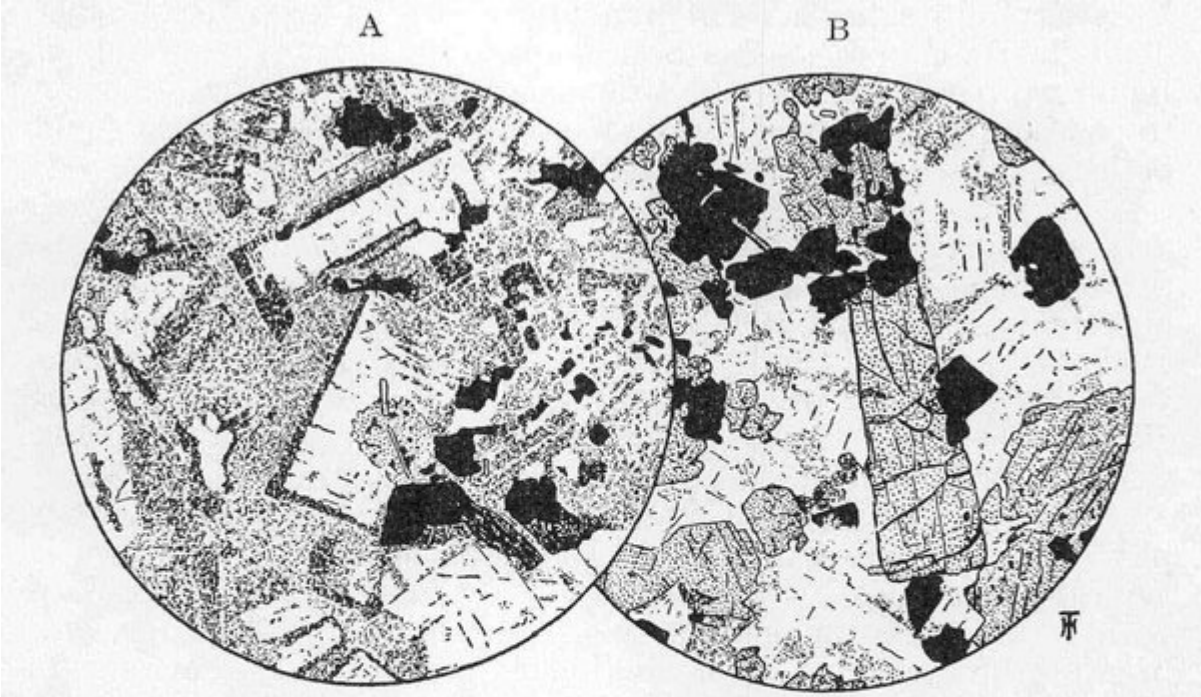


FIG. 33.—*Granophyre of Grigadale and Quartz-dolerite of Sgùrr nam Meann.*

A. (22820) × 20. *Grigadale Granophyre. Crystals of plagioclase edged with turbid alkali-felspar, partially resorbed augites of gabbro origin, and occasional patches of iron-ore, in a granophyric matrix of alkali-felspar and quartz.*

B. (22409) × 20. *Quartz-dolerite of Sgurr nam Meann. The section shows a large crystal of hypersthene, with partially recrystallized augite and iron-ore, in a matrix of plagioclase felspar that has been invaded by acid material and locally albitized.*

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

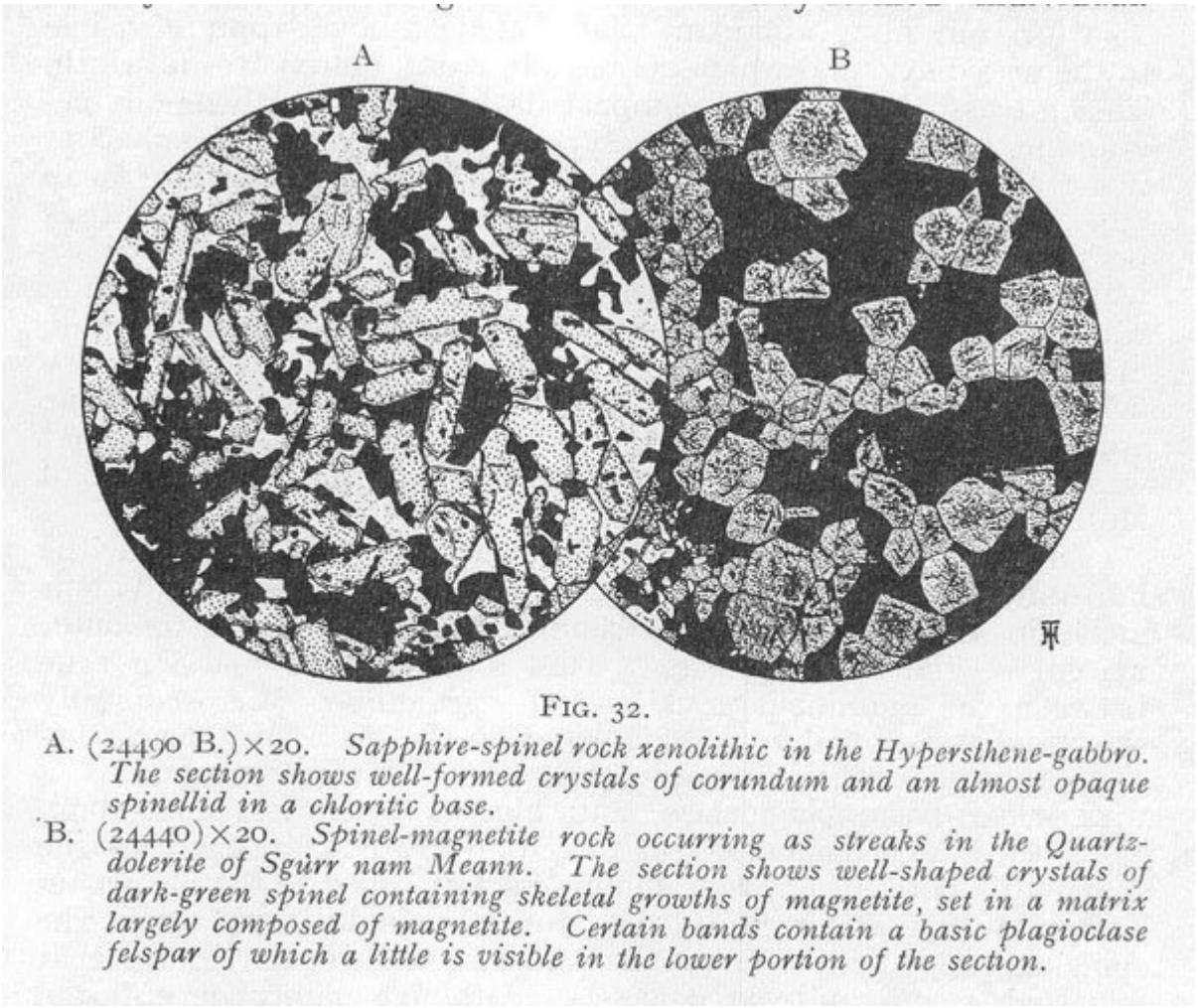


FIG. 32.

A. (24490 B.) × 20. *Sapphire-spinel rock xenolithic in the Hypersthene-gabbro. The section shows well-formed crystals of corundum and an almost opaque spinellid in a chloritic base.*

B. (24440) × 20. *Spinel-magnetite rock occurring as streaks in the Quartz-dolerite of Sgùrr nam Meann. The section shows well-shaped crystals of dark-green spinel containing skeletal growths of magnetite, set in a matrix largely composed of magnetite. Certain bands contain a basic plagioclase felspar of which a little is visible in the lower portion of the section.*

(Figure 32) A (S24490 B) [NM 4805 6478] × 20. Sapphire-spinel rock xenolithic in the Hypersthene-gabbro. The section shows well-formed crystals of corundum and an almost opaque spinellid in a chloritic base. B (S24440) [NM 4283 6815] × 20. Spinel-magnetite rock occurring as streaks in the Quartz-dolerite of Sgùrr nam Meann. The section shows well-shaped crystals of dark-green spinel containing skeletal growths of magnetite, set in a matrix largely composed of magnetite. Certain bands contain a basic plagioclase felspar of which a little is visible in the lower portion of the section.

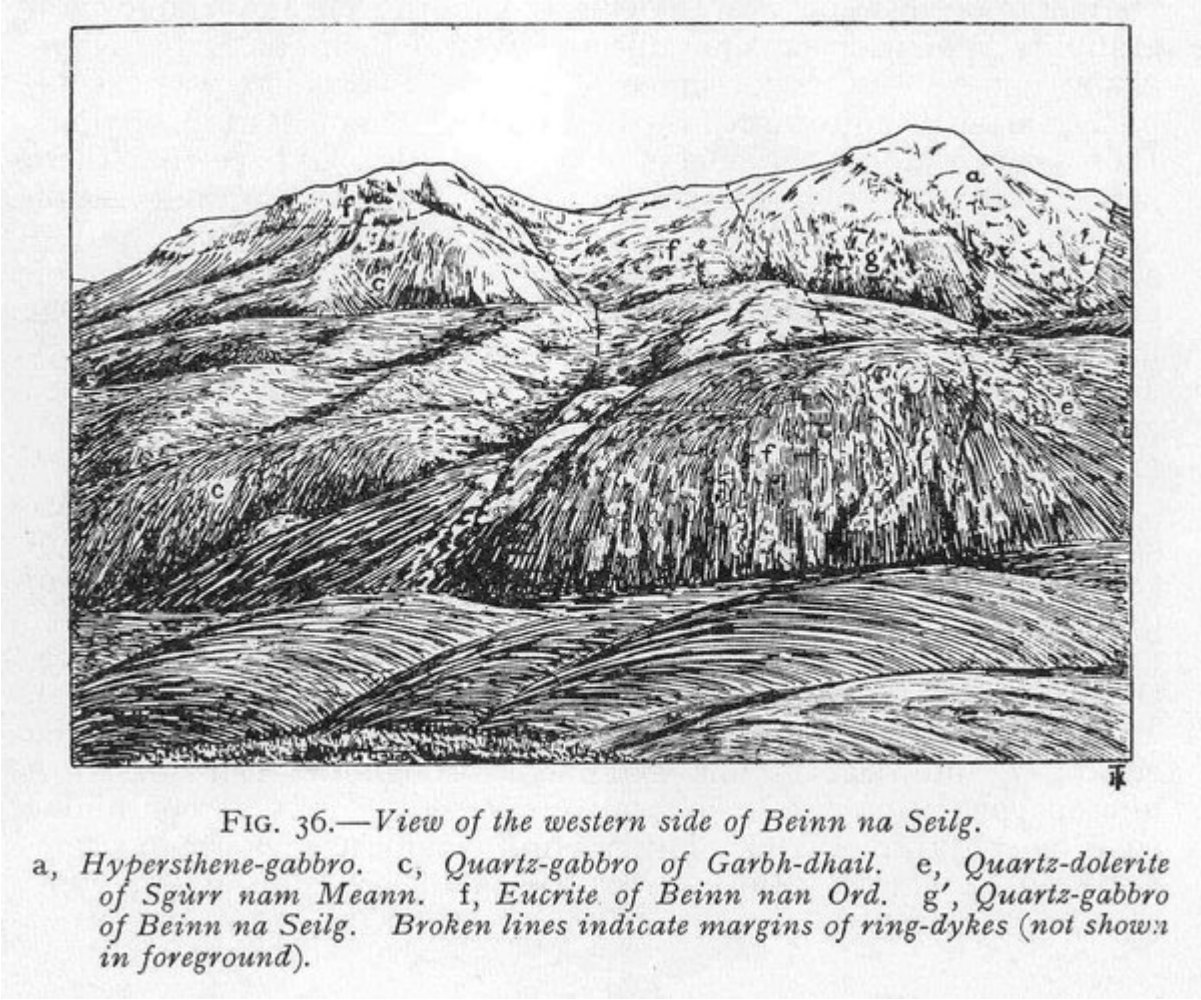


FIG. 36.—*View of the western side of Beinn na Seilg.*

a, *Hypersthene-gabbro.* c, *Quartz-gabbro of Garbh-dhail.* e, *Quartz-dolerite of Sgùrr nam Meann.* f, *Eucrite of Beinn nan Ord.* g′, *Quartz-gabbro of Beinn na Seilg. Broken lines indicate margins of ring-dykes (not shown in foreground).*

(Figure 36) View of the western side of Beinn na Seilg. a, Hypersthene-gabbro. c, Quartz-gabbro of Garbh-dhail. e, Quartz-dolerite of Sgitrr nam Meann. f, Eucrite of Beinn nan Ord. g′, Quartz-gabbro of Beinn na Selig. Broken lines indicate margins of ring-dykes (not shown in foreground).

(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.

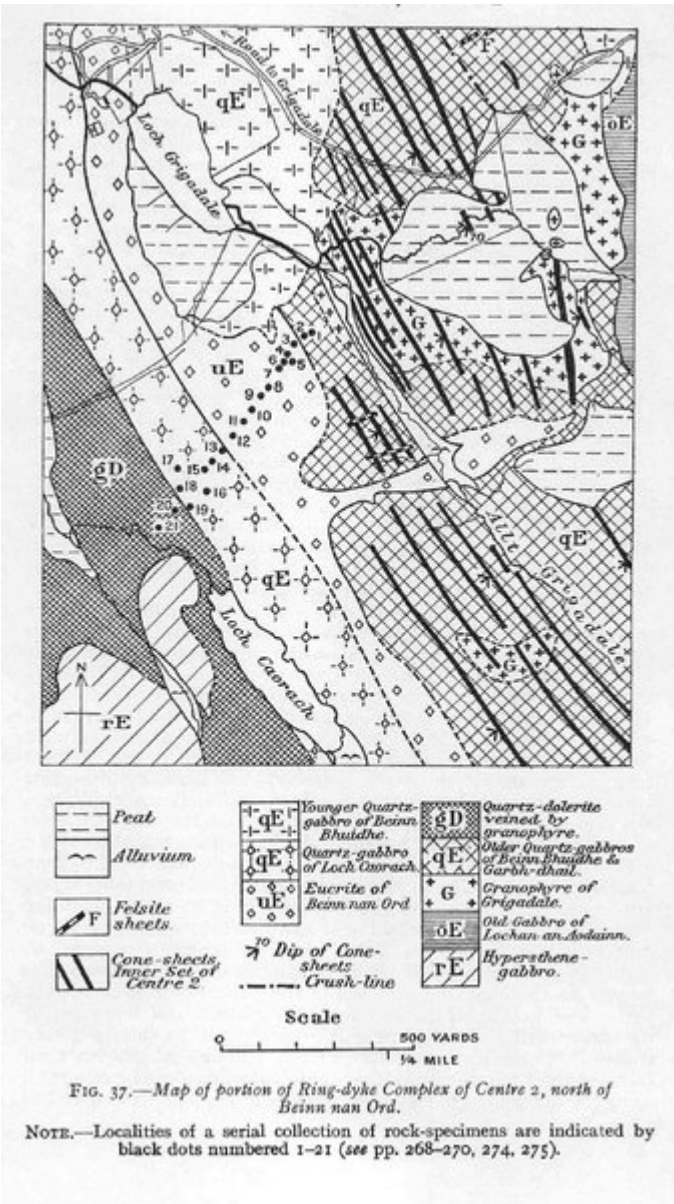


FIG. 37.—*Map of portion of Ring-dyke Complex of Centre 2, north of Beinn nan Ord.*

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

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

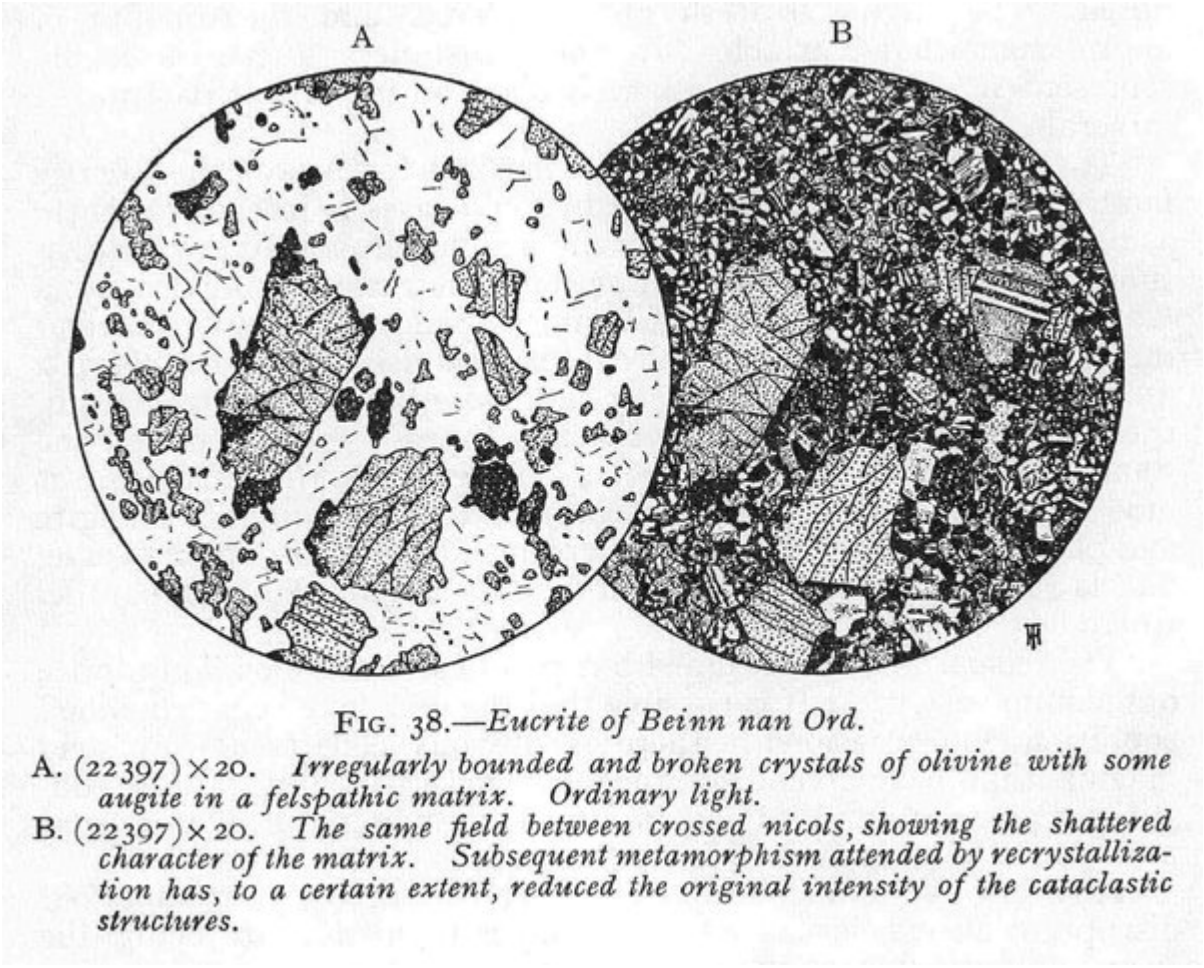


FIG. 38.—*Eucrite of Beinn nan Ord.*

A. (22397) × 20. *Irregularly bounded and broken crystals of olivine with some augite in a felspathic matrix. Ordinary light.*
B. (22397) × 20. *The same field between crossed nicols, showing the shattered character of the matrix. Subsequent metamorphism attended by recrystallization has, to a certain extent, reduced the original intensity of the cataclastic structures.*

(Figure 38) Eucrite of Beinn wan Ord. A. (S22397) [NM 432 662] × 20. Irregularly bounded and broken crystals of olivine with some augite in a felspathic matrix. Ordinary light. B. (S22397) [NM 432 662] × 20. The same field between crossed nicols, showing the shattered character of the matrix. Subsequent metamorphism attended by recrystallization has, to a certain extent, reduced the original intensity of the cataclastic structures.

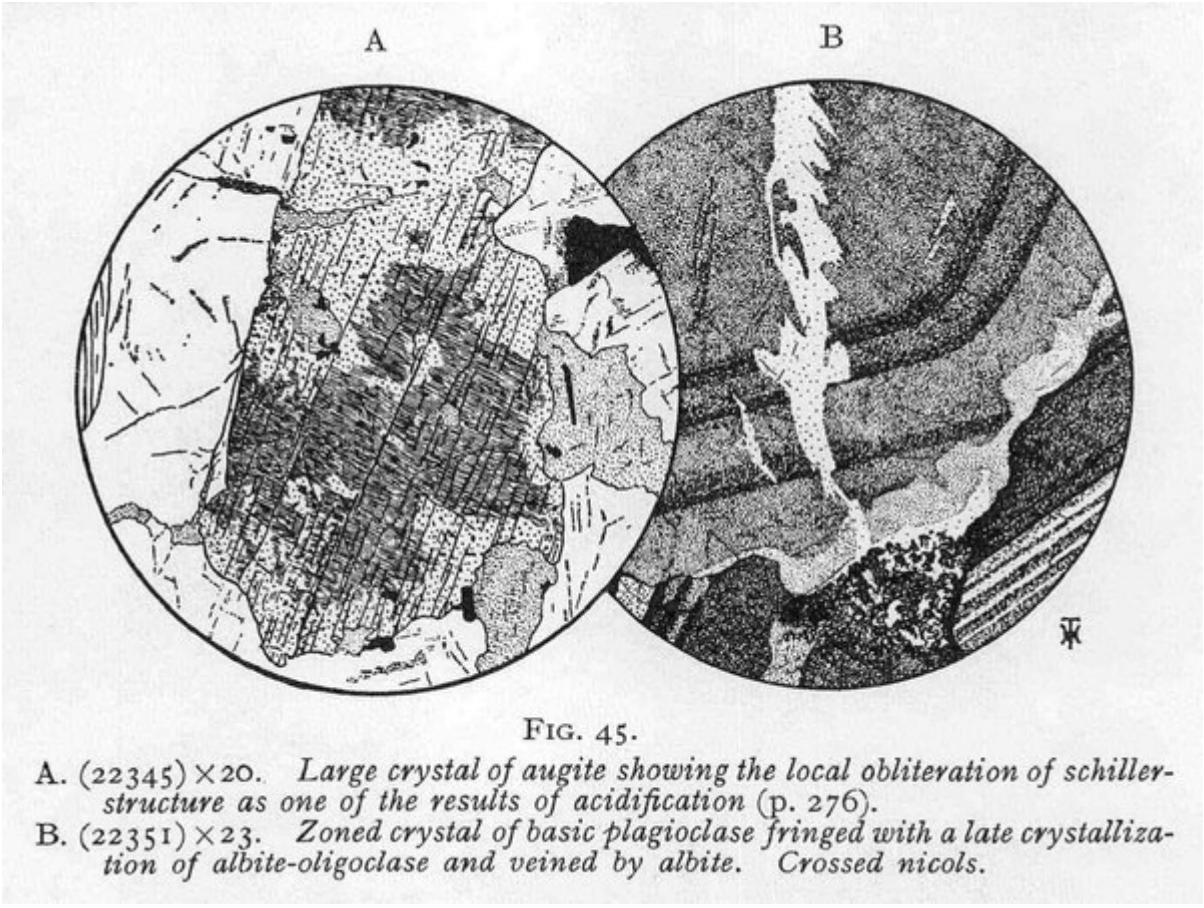


FIG. 45.

A. (22345) × 20. *Large crystal of augite showing the local obliteration of schiller-structure as one of the results of acidification* (p. 276).
B. (22351) × 23. *Zoned crystal of basic plagioclase fringed with a late crystallization of albite-oligoclase and veined by albite. Crossed nicols.*

(Figure 45) A. (S22345) [NM 4373 6780] × 20. Large crystal of augite showing the local obliteration of schillerstructure as one of the results of acidification (p. 276). B. (S22351) [NM 4390 6770] × 23. Zoned crystal of basic plagioclase fringed with a late crystallization of albite-oligoclase and veined by albite. Crossed nicols.