Chapter 32 The ring-dykes of Loch Bà, Beinn a' Ghràig, and Knock

Introduction

The subject of ring-dykes has already been introduced in Chapter 29 of this Memoir, and the reader is referred to that Chapter for a definition of terms, and a general statement as to character. It is there pointed out that the ring-dykes of Mull group themselves about two centres, the earlier of which is situated on Beinn Chàisgidle, and the later at the head of Loch Bà (C_1 and C_2 of (Figure 58), p. 338). It has also been shown that the outermost of the earlier series, the great Glen More Ring-Dyke, shows indications of a dual control from both centres. The intrusion of the Loch Bà Ring-Dyke, dealt with in the present chapter is entirely controlled by the second centre. The Beinn a' Ghràig and Knock Dykes scarcely show any tendency to circulate, but are included in the category of ring-dykes because of their dyke-like form, and their general parallelism to the north-western segment of the Loch Bà Ring-Dyke.

The Loch Bà, Ring-Dyke, illustrated in (Figure 58), is the most perfect example of a ring-dyke known to science. It is composed of compact porphyritic felsite, and has a fairly continuous outcrop, with a maximum diameter of five miles. The dyke itself ranges up to a quarter of a mile in width, but more often measures about 100 yds. W.B.W., J.E.R.

The Beinn a' Ghràig and Knock Ring-Dykes are composed of pale well-crystallized granophyre. Their main interest attaches to the beautifully developed and well-exposed screen which separates them, and the fact that portions of the roof of the former are preserved and can be easily studied.

The subject-matter of the present chapter will be dealt with under the following headings:

1. Form of Intrusion

2. Age-Relations

3. Late Explosions

4. Petrology

Throughout, the Loch Bà, Felsite is taken in advance of its associates on account of the dominating interest of its ring-form. From the point of view of age-relations, it would bave been preferable to consider the granophyres first, because, at any rate, the Beinn a' Ghràig Granophyre is clearly of earlier date.

Certain special subjects are reserved for separate discussion. Thus the contact-alteration produced by the granophyres is described in Chapters 8 and 10, and the question of the assimilation of early basic plutonic rocks will be dealt with in Chapter 33.

W.B,W.

Intrusion-form

Loch Bà Felsite

The Loch Bà intrusion may be described as an almost complete ring-dyke about the centre C_2, of (Figure 58). Considered with reference to the centre of the whole plutonic complex, the ring-dyke assumes a sectorial aspect: the north-west segment of the sector, crossing Loch Bà, is nearly parallel to the circumference of the plutonic complex, though somewhat less curved; the apex near Beinn Chàisgidle is greatly blunted; and the radii crossing Glen Forsa and Glen Clachaig, are characterized by a curious sigmoidal curvature. The dyke as a whole displays, more strikingly than any of the Mull intrusions, the symmetry about a north-west axis which is an outstanding feature of Mull geology. Even small details, such as the curvature of the radii, have been found repeated on either side of the line of symmetry.

A glance at (Plate 5) and (Plate 6) will convince the reader that this ring-dyke, apart from its beautiful development, marks a line of structural importance, for it forms the boundary of various rock-divisions. As a matter of fact, there is considerable evidence that it follows a line of faulting, and approximately, at any rate, outlines an area of central subsidence, the north-west caldera of Mull.

W.B.W., J.E.R.

In what follows, attention will be given more particularly to the following points:

1. Exposures upon which the mapping of the almost continuous ring-outcrop is based.

2. Suggestions of a general outward inclination of the dyke.

3. Evidence that the dyke has followed, or accompanied, powerful faulting.

(1) Track of the ring-dyke

In its course from Beinn non Gabhar, north-east to Loch Bà, and again from Loch Bà to the 500 ft. contour on the west face of Glen Forsa, the Loch Bà Felsite is almost continuously exposed, and often gives rise to conspicuous crags. It is to this five miles of outcrop that anyone should go who wishes to realize the dyke-form of the intrusion. The hills flanking Loch Bà, from which the dyke takes its name, show it in strong relief, ascending from lake-level to a height of 1500 ft. On the upland, its northern face generally stands out boldly above the granophyre with which it comes in contact, but its southerly margin against the lavas and agglomerate is everywhere much less marked Its scenic importance in this area is partly attributable to its frequent juxtaposition with granophyre free from minor basic intrusions, and therefore readily denuded. A number of north-west dykes cut across the felsite in this north-west sector, and erosion along certain of these makes possible a close study of its contacts. W.B.W.

For half-a mile, just where the dyke is mapped as taking a rather abrupt turn in the bottom of Glen Forsa, there are no exposures. East of the River Forsa, however, the dyke is seen in four small streams, of which the first is Allt an Eas Dhuibh and the last Allt Mòr. There is also an exposure at the south end of the Còrrachadh ruins. Moreover, from a little north of Allt an Eas Dhuibh to beyond Còrrachadh, a distance of three-quarters of a mile, there is an almost continuous low escarpment of basalt-lava, etc., which defines the eastern boundary of the ring-dyke in agreement with the evidence derived from the exposures which have just been cited. The felsite, there, and in the rest of the ground to be described, shows no tendency to yield crags. In this it differs from its behaviour in the Loch Bà exposures. There is reason to believe that its local weakness as a scenic element is partly determined by its degree of crystallization. Where it forms crags, the rock is often rhyolitic in texture, and elsewhere felsitic.

It should be put on record that, though it is convenient to conform with the general clock-wise plan of the Memoir, and describe the Glen Forsa exposures after those extending either side of Loch Bà, this does not correspond with the development of our knowledge. It was Mr. Richey's completion of the circuit elsewhere that showed that the Glen Forsa outcrop belongs to the Loch Bà Ring-Dyke. E.B.B.

For a mile south of Allt Mòr, superficial deposits cover the mapped course of the Loch Bà Ring-Dyke. Felsite of the characteristic type is seen in the most northerly of the little streams draining Liath Dhoire, and again, less than half a mile farther south, in the main stream at the foot of the slope. In the next mile, there are six stream-exposures, and, following a gap of half a mile, there is a capital section in Allt a' Choire Bhàin. In the mile and a half separating the last-mentioned stream from Breapadail, the felsite is so often seen that there is no need for a detailed statement.

The Breapadail exposure of the Loch Bà Felsite is succeeded, three-quarters of a mile farther west, by another in Allt na h-Eiligeir. The outcrop, however, can be shown to be discontinuous in the interval. Another break in the outcrop is also demonstrable, west of Allt na h-Eiligeir, on the ridge connecting Cruachan Dearg with Maol Buidhe.

In the River Claehaig, the dyke reappears, and can be traced north-westwards for a mile, before it dies out within half a mile of the Beinn nan Gabhar exposures, which served as starting point in this description.

Thus, in the whole circuit of some fourteen miles, three gaps have been found, all situated on the south-west side, and these amount in aggregate to about a mile and a half. If exposures were available at every point, this figure might be slightly increased, but at most it would remain a small fraction of the whole.

In identifying the Loch Bà Felsite in its more isolated exposures, one is guided by several considerations, notably: The character of the rock; its late date—as shown by the absence of cutting intrusions other than dykes its tendency to occur along a line of crush, which may be traceable even where the felsite is absent; and finally, the position of the exposures themselves relative to one another. It is to this last point that attention has been directed in the preceding paragraphs.

(2) Inclination

The Felsite Ring-Dyke has a steep north-north-westerly inclination along the whole of its well-exposed outcrop, either side Of the Loch Bà. This feature is emphasized by the contrary inclination of a fairly well defined set of columnar joints that cross the dyke at right angles. Indeed, on this basis, the dyke appears to be, inclined north-westwards at about 70°–80° on the two sides of Loch Bà, and at about 45° in Beinn nan Lus.

Elsewhere along its course, the Loch Bà Felsite is obviously steep, but the direction and degree of its inclination have generally defied detection. In the little stream mid-way between the summit of Beiun Talaidh and Beinn na Duatharach, there is, however, a clear exposure of the dyke's fluxion-edge (or top) inclined eastwards at a comparatively low angle.

There is thus a slight suggestion of a general outward inclination in the case of the Loch Bà Ring-Dyke, but far more evidence is required upon the point. E.B.B.

(3) Ring-fault

There is abundant evidence for the existence of a ring-fault, along the course of which the Loch Bà Felsite has forced its way upward; and it is substantially proved that the downthrow is towards the centre. The central subsidence may at one time have produced at the surface a caldera comparable with that which occupied the central area around Beinn Chàisigidle at the period of the extrusion of the Central Type of Lavas: It should, however, be noted that here we have no actual indication of a surface-basin, such as is so beautifully demonstrated by pillow-lavas in the case of the south-eastern caldera (Chapter 5) The evidence for cauldron-subsidence is as follows:

1. There are several fine sections of the north-west segment of the Loch Bà Ring-Dyke, where this dyke is clearly intruded along a line of crush. The best of these lie north of Sròn nam Boc, and exhibit the granophyre, sheared into a breccia, cut across by the felsite. A thin slice (S14766) [NM 5543 3745], from the junction of the felsite with the mixed basic-acid intrusion lettered eD on Coille na Sròine, shows fine granophyric and ophitie debris invaded by beautifully epherulitic rhyolite constituting the edge of the Loch Bà Ring-Dyke.

2. Poor exposures prevent our determining whether a similar crush-line continued along the eastern limb of the ring-dyke; but, coming to the southeastern and southern portion of the ring-dyke, we find everywhere, in the numerous streams which descend into the headwaters of Glen Cannel on both sides of Beinn Chàisgdle, evidence of crushing in the rocks along the inner and outer edges of the felsite. North-westwards the crush-zone continues across Maol Buidhe, where felsite is missing. In Glen Clachaig, the outer margin of the Loch Bà Felsite makes a sharp junction against crushed granophyre. The crushing extends a few yards upstream from the felsite and involves cone sheets which cut the granophyre. The belt of crush continues northwards, and serves to bridge the gap in the felsite-ring between An Cruachan and Beinn nan Gabhar. W.B.W., J.E.R.

3. Only small interrupted outcrops of basalt-lava have been preserved in the area ringed about by the Loch Bà Felsite. All the specimens collected and sliced have proved to be of Central Types (Chapter 9). One of these specimens is the analysed rock (pp. 131, 149) from Na Bachdanan, north-east of Loch Bà. Here Central Type of Basalt reaches down to the 700 ft. level just inside the ring-dyke (the basalt-lavas at Coille na Sròine, south-west of Loch Bà, are better placed for our purpose, but have not been critically examined). Outside the Loch Bà Ring-Dyke, in this part of its course, the country consists of Plateau Basalts. The evidence can be followed on the one-inch Map: in Ben More (Area 8, Chapter VIII), the Plateau Group reaches to 3169 ft. above O.D., with the base of the Ben More Mugearite at about 2100 ft., and the base

of the Pale Group at about 1700 ft.; in Beinn Fhada, the base of the Mugearite, near the Loch Bà Ring-Fault, is at about 2000 ft; in Beinn a' Ghràig, the Mugearite has not been distinguished, but the base of the Pale Group is still about 1250. The lavas of Beinn Bhuidhe, north-east of Loch Bà have not been very critically examined, but Maol Buidhe, across Glen Forsa (Area 9, Chapter 8), belongs to the- Plateau Group with a mugearite-position—perhaps the Ben More Mugearite—toward its summit. It is certain that nothing but a marked subsidence could lead to the preservation of Central Types of lava in Na Bachdanan. It is possible that sonic proportion of the rhyolites and agglomerates of the region may belong to cones, rather than vents (p. 197); if this be the case, their preservation also requires subsidence to account for it, but this is more speculative.

4. Near Gaodhail, in Glen Forsa, there is strong suggestive evidence of faulting of Early Basic Cone-Sheets at the line of the Loch Bà Ring-Dyke ((Figure 36), p. 238). The throw indicated is again one of central subsidence.

5. Both sides of Beinn Chàisgidle, there is good reason to believe that the Glen Cannel Granophyre stands considerably higher outside the Loch Bà. Ring-Dyke than it does inside (p. 332).

6. There is also the contrast of gneiss-free vent-agglomerate, inside the ring-dyke, and gneiss-laden vent-agglomerate, outside ((Figure 29), p. 201). This contrast, like the rest of the evidence, suggests central subsidence, but quite possibly of a different type. The main constituent of the agglomerate within the ring is granophyre, obviously a much earlier granophyre than any exposed in the immediate vicinity, though quite possibly of the same age as the Glas Bheinn Granophyre of Chapter 12. In the intrusion of this hidden granophyre, the floor of gneiss must have either foundered piecemeal by sloping, or been let down *en bloc*in the manner suggested by the cauldron subsidence of Glencoe.<ref>See C. T. Clough, H. B. Maufe, and E. B. Bailey: The Cauldron-Subsidence of Glencoe, Quart. Journ. Geol. Soc., vol. lxv., 1909, p. 869.</ref> We cannot, of course, decide which of these two modes of intrusion actually operated; but if the latter, the absence of gneiss-fragments in the agglomerate suggests subterranean cauldron-subsidence in this area at a date prior to that of the formation of the agglomerates.

W.B.W. E.B.B.

Knock and Beinn A' Ghràig ring-dykes

These, the most north-westerly of the plutonic masses of Mull, are classed as ring-dykes mainly on account of their elongated form, the fact that they are separated by an exceedingly well-preserved screen, and their parallelism with the neighbouring portion of the Loch Bt, Felsite. Their curvature is that of the periphery of the Mull plutonic complex as a whole, and, as such, is a very inconspicuous feature. The belt of country occupied by their outcrops is characterized by marked relief, the result, to a large extent, of the contrast between the easily eroded character of the granophyre and the resistant nature of the baked lavas and intrusions which form the walls and roof. The highest summit is Beinn a' Ghràig, 1939 ft. O.D., while the two principal valleys, those of Loch Bà, and Glen Forsa, cross the granophyre-outcrops at levels lower than the 50 ft. contour. The steep hill-slopes towards the west afford admirable exposures, and, on the whole, the conditions are very favourable for the investigation of intrusion-form. The subject will be dealt with under the following heads:

1. The form of the walls, screen, and roof.

2. The ring-like intrusions of the north-eastern extremity.

3. The general absence of disturbance outside the intrusions.

(1) Form of the walls, screen, and roof

The Knock Granophyre, in a course of one and three-quarter miles, has a minimum width of 250 ft. and a maximum of 1000 ft. Its form is therefore distinctly dyke-like.

The Beinn Ghràig mass is much wider, ranging from about half a mile to a mile, but at the same time it is much longer, having a total length of seven miles from Beinn Fhada to Glen Forsa; on either flank, it extends a little beyond the gently

curved north-western segment of the Loch Ring-Dyke. The outer margin of its outcrop can be seen in places to be a nearly vertical wall, but in others shows a marked irregularity, due no doubt in part to the preservation of portions of the roof. Its inner or south-eastern margin is to a large extent defined by the fault accompanying the Loch Bà Dyke, but there are preserved, at this side also, segments of the roof, the form of which suggest that there is a gradual passage from roof to wall—although it is an open question whether the boundary on this side, previous to faulting, approached verticality in depth. The downward tendency of the roof towards the south-east is especially noticeable on Beinn Fhada and Beinn nan Gabhar, where the ring-fault swings south and leaves the granophyre.

It is impossible to say whether the Beinn a' Ghràig Granophyre extends beyond the fault within the area of central subsidence. Certain masses of hybrid basic rock outside the fault on Sròn nam Boc and Coille na Sròine suggest a limit to it in this direction, but the evidence on this point is very weak. A possible exposed extension of the granophyre lies just within the circuit of the Loch Bà Ring-Dyke on the slopes above Glen Forsa, between the 400 and 900 ft. contours, where its freedom from cone-sheets attracts attention.

The outer margin of thr Knock Granophyre is approximately vertical, and so is the screen of baked lava which separates it from the Beinn a' Ghràig Mass. This screen can be traced over hill and valley from near sea-level up to the 1750 ft. contour. It is apparently absolutely continuous for a mile and three-quarters, but varies considerably in thickness, being as little as 10 ft. in one place, and reaching 300 ft. in others. At both ends of the Knock Granophyre, the screen connects with the general mass of the lavas outside. At the south end, the connection is not quite clear on mere inspection of (Plate 6) (p. 307), for the screen, as exposed on the west slope of Beinn a' Ghràig, locally consists of intrusive felsite instead of the usual basalt-lavas. In the field, however, it is obvious that the felsite concerned has this much in common with the basalt-lavas, that it is of earlier date than the two granophyres which it separates, for it is cut by many late Basic Cone-Sheets that are entirely absent from neighbouring exposures of the granophyres.

The course of the screen up the hill-face south of Knock can be readily traced by the eye even for a considerable distance. The caps on Beinn a' Ghràig and Beinn nan Gabhar, which can easily be recognized on the one-inch Map, are also scenic features obvious to the most casual observer. One of the caps on Beinn Ghràig joins up with the screen, forming with it an inverted letter L. At the south-western end of the Beinn a' Ghràig Mass, there is thus a marked contrast between the two sides: on the north-west, the arched roof joins up almost at a right angle with the vertical screen, whereas on the south-east it inclines rapidly downwards as far as erosion has brought it to light. North-east of Loch Bà, however, the asymmetry does not persist, and there seem to be two sides to the arch. Still farther in this direction, the conditions become so complex as to preclude any profitable speculation as to the general form of the roof.

The condition at the north-east end of the Beinn a' Ghràig granophyre, though comparatively speaking obscure, are sufficiently interesting to merit further discussion. It is a noteworthy feature of many of the cappings of the Beinn a' Ghràig interior that they frequently show steep-sided or vertical contacts with the granophyre, being apparently more of the nature of half-submerged blocks than true cappings. In this, they contrast with the remarkably evenly developed roof of the Glen Cannel Granophyre; and there arises a suggestion that the difference is fundamental, and connected with a clearly marked distinction between the ring-dyke and batholithic modes of intrusion. The form of the roof at the north-eastern end of the Beinn a' Ghràig Dyke indicates that subsidiary dykes, often with a ring-like character, may arise from the top of the main mass. The most remarkable of these is that to which the name Killbeg Ring-Dyke may be applied. It has an internal diameter of just over a mile; and is apparently a parasitic outgrowth of the Beinn a' Ghràig Dyke, of which it forms the north-eastern extremity.

(2) Ring-like intrusions of north-eastern extremity

(2a) A well-marked sector of the Killbeg Ring-Dyke, introduced in the previous paragraph, crosses Maol Bhuidhe in a straight course, three-quarters of a mile long; its horizontal thickness here is 500 ft., and its exposed vertical depth 700 ft. In Allt nan Leòthdean, its south-east margin, as seen, is both vertical and chilled.

From Callachally to Pennygown, superficial deposits obscure the outcrop of the Killbeg Ring-Dyke; but south-eastwards from Pennygown, its arcuate track through An Carnais is a conspicuous feature of the landscape. The outer margin of the granophyre is here well-exposed in contact with the truncated basalt-sears of Coire nam Muc. The inner margin is

covered by alluvium, but a low ridge of baked lava, constituting Ceann an Tùir, clearly marks its approximate position.

At the south-east angle of the Killbeg Ring-Dyke, there are granophyre-exposures in two westward-flowing tributary burns, a little above their junction with the alluvium of Glen Forsa. In the River Forsa, no rock of any sort is seen in this neighbourhood. West of the river, however, as soon as the 50 ft contour is crossed, it is possible to draw a fairly well-defined southern limit for local exposures of basalt-lava;, probably this limit corresponds closely with the northern edge of the granophyre, for between the 500 ft. and 1000 ft. contours a continuation of the same line separates basalt from exposed granophyre. The mapping of the granophyre above the 500 ft. contour towards the summit of Beinn nan Lus, and thence round the head of Coire an Ùruisge to Maol Bhuidhe, presents no difficulties.

(2b) (Plate 3), (Plate 5), and (Plate 6) all show the irregular nature of the Beinn a Ghràig Granophyre at its north-eastern extremity, north of Salen, which we have just pointed out to be probably due to the extensive preservation of the uneven and fissured roof. They bring out very clearly, not only the parasitic ring of Killbeg, but also an extension westward from it, which takes a course in rough continuation of the Knock Dyke and of the general outer margin of the Beinn Ghràig mass farther west. This rather irregular outer dyke, known as the Toll Doire Dyke, seems, in Cnoe Maol Mhucaig, to be partially double, suggesting contemporaneous employment of two parallel fissures. Although shown as granophyre throughout in (Plate 6), this intrusion includes subordinate outcrops of dioritic composition either side of Glac a' Chlaonain, and these are picked out by colour and lettered H on the one-inch Map.

A question naturally arises whether the Toll Doire Dyke is an offshoot of the Beinn a' Ghràig mass, an interrupted continuation of the Knock Granophyre, or an independent entity. Unfortunately, no positive answer can be given. This is the more to be regretted, since, as will be shown later (p. 345), it has a distinct bearing upon the interpretation of the age as well as the form of the Beinn a' Ghràig intrusion. As regards form, it may be pointed out that the width of the Beinn a' Ghràig Dyke, south of Loch Bà, suggests that the intrusion has there filled a vacancy left by subterranean foundering of a mass of country-rock bounded at the sides by parrallel fissures. If the Toll Doire Dyke is part of the Beinn a' Ghràig Granophyre, it may be taken as marking the continuation of one of the fissures concerned. W.B.W.

(3) Absence of disturbance outside the intrusions

The intense folding, which characterizes much of the periphery of the southeastern caldera of (Plate 5) (p. 165), is unrepresented about the Loch Bà centre.

As Sir Archibald Geikie has emphasized (p. 48), there is a general lack of disturbance of any kind outside the Knock and Beinn a' Ghràig Granophyres: instead, the featuring of the hill-sides show these great intrusions abruptly truncating gently inclined Plateau Lavas. One gets an impression of an essentially tranquil process during which granophyre has replaced basalt, either by piecemeal stoping, or by contemporaneous infilling of a space prepared by large-scale subsidence *en bloc.*

The phenomenon is particularly clear in Beinn Fhada. On the western termination of the ridge, subdued, but none the less obvious, trap-features indicate that the lavas continue with a gentle and steady inclination until they are clearly terminated at the margin of the granophyre. This scenic evidence is reinforced by close examination. The one-inch Map, and (Plate 3) (p. 91), show a mugearite-lava traced for many miles through the Ben More country. In Beinn Fhada, this mugearite is found on both sides of the granophyre, and its two separated portions have not suffered appreciable vertical displacement relatively to one another.

A local exception to the general undisturbed nature of the country-rock on this side of Mull should, however, not be passed over without notice. It occurs in Glac a' Chlaonain, at the north-west edge of the Toll Doire Dyke. The lavas are here bent suddenly upwards, and the underlying Liassic sediments are exposed to view.

Age-relations

The intrusions dealt with in the present chapter are among the latest of all the igneous rocks of Mull, a circumstance consistent with their position towards the north-western end of the axis of symmetry. Of the three, however, the Loch Bà

Felsite, which is clearly the most recent, does not occupy the most north-westerly position.

The only rocks that cut the Loch Bà, Felsite are a number of north-west dykes (Chapter 34). It is almost certainly later than all categories of cone-sheets, a claim that can be put forward for no other large-scale intrusion. Even the Beinn a' Ghràig Granophyre, which is obviously later than the majority of the Late Basic -Cone-Sheets of Chapter 28, is found on close examination to be intersected by what appear to be a few late stragglers. These, however, are extremely rare in spite of the fact that the granophyre lies right in the track of the main belt of Late Basic Cone-Sheets, which constitute much of its walls and roof.

The Glen Cannel (Chapter 31) and Beinn a' Ghràig Granophyres had been intruded, solidified, and brecciated along the Loch Bà, Ring-Fault before the uprise of the felsite guided by this fracture. The relation is everywhere so obvious as hardly to need further comment. An examination of almost any of the exposures mentioned in connexion with the breceiation along the fault (p. 340) will convince the reader of its truth.

If the conclusion arrived at in Chapter 31 (p.332), to the effect that the Glen Cannel Granophyre extends outside the Loch Bà Felsite to the south and south-east, be correct, then a comparison is made possible between the Glen Cannel and Beinn a' Ghràig Granophyres in respect of their behaviour towards the Late Basic Cone-Sheets; for these extended areas of the great Glen Cannel mass lie in the belt of the main development of these sheets, and are cut freely by a fairly large proportion of them. It is therefore highly probable that the Glen Cannel Granophyre is distinctly earlier than that of Beinn a' Ghràig. W.B.W.,

Good exposures for studying the relations of the Beinn a' Ghràig Granophyre to the Late Basic Cone-Sheets are met with west of Loch Bà. A belt of late Basic Cone-Sheets, crossing the south-east summit of Beinn Fhada, is interrupted for a space by the Beinn a' Ghràig Granophyre, only to reappear in the lava-cappings of Beinn nan Gabhar and Beinn a' Ghràig, and in the country-rock beyond, which consists in part of basalt-lavas (cf. one-inch Map). The Cone-sheets in Beinn Fhada are locally much traversed by granophyre-veins, and in many cases are demonstrably cut off by granophyre in mass. In the Beinn a' Ghràig caps, a felsitic modification of the granophyre occurs as tongues crossing the lavas with the same inclination as characterizes the cone-sheets, and sometimes splits these latter up the middle.

The Knock Granophyre, north of Beinn a' Ghràig, behaves in the same manner to the Late Basic Cone-Sheets as does its bigger companion just described. The two granophyres offer a very marked contrast, in this respect, to the felsite that forms the southern end of the separating screen; for this felsite is cut by numerous Late Basic Cone-Sheets which are entirely absent from the granophyres on either side. Another good exposure showing the Knock Granophyre cutting Late Basic Cone-Sheets is afforded by the hillface above Gruline House. J.E.R.

Only two exposures can be quoted where inclined sheets, apparently indistinguishable in any way from the general group of Late Basic Cone-Sheets, can be seen cutting the Beinn a' Ghràig Granophyre. One of these two exposures is afforded by the stream descending from An Coire, nearly half-a-mile west-south-west of Benmore Lodge, at the lower end of Loch Bà. It shows the granophyre traversed by a pale basaltic sheet, or dyke, with columnar structure: this sheet runs north-east along the stream and dips south-east at 60°. The other exposure is not indicated on the one-inch Map, but occurs in the stream directly above Gruline House, where the granophyre is cut by a sheet of Talaidh Type (S14345) [NM 5528 3956] which dips E. 25° S. In this case the angle of inclination has not been recorded.

Other sheets which probably belong to the Late Basic Cone-Sheets are seen to cut the Toll Doire Dyke (p. 343) in Glac a' Chlaonain. Their dips have not been recorded. There may be one or two other cases east of this, but, where the sheets swing into a direction nearly coincident with that of many of the dykes, it is much harder to pick them out unless they are very well-exposed. W.B.W.

Late explosions

In places along its south-eastern exposures, the Loch Bà Felsite seems to pass into compact tuff containing fragments of granophyre, felsite, etc. Good stream-sections occur in two burns at the foot of Coill' an Aodainn. A specimen from. Allt a' Choire IMAM (S15569) [NM 6104 3449] shows a fine-textured breccia composed of fluxional rhyolite, well-crystallized

granophyre, and some more basic rock, the whole invaded by tongues of spherulitic rhyolite. It certainly looks as though the felsite has locally shattered itself by explosion. W.B.W., E.B.B.

Petrology

Loch Bà Felsite

(Anal III.; (Table 4), p. 20).

The Loch Bà Felsite is for the most part a fine-grained rock that may be termed either rhyolite, or felsite according to the state of its devitrification and the presence or absence of dominant fluxion-structure.

A series of specimens, taken in succession along the dyke from the hill-top west of Loch Bà by way of Glen Forsa and Beinn Chàisgidle to Glen Clachaig, shows that in the more northerly portions of its course it is a beautifully banded rhyolite (S2121) with delicately developed fluxion-structure ((Figure 59)B), while towards the south and east it becomes more definitely felsitic. It contains small phenocrysts of felspar and well-formed little rectangular crystals of yellowish augite (S14322) [NM 5553 3768], in a matrix that exhibits various degrees of banding and devitrification. The felspar-phenocrysts are usually of albite or perthite, and occasionally are edged with turbid orthoclase (S14697) [NM 6100 3546]. There is a general absence of granophyric structure, but it has been noted in some of the more felsitic varieties of the rock where microgranophyric matter fringes turbid phenocrysts of perthite (S14969) [NM 7091 4342]. The augite, for the most part, appears to be an ordinary aluminous species, but, in a few instances, both in the rhyolitic (S14321) [NM 5727 3904] and felsitic varieties, an augite, replaced or partly replaced by serpentine, would appear to be of enstatite-composition (enstatite-augite, Chapter 25). The main differences presented by the various portions of the dyke lie in the state of devitrification and the nature of the resulting crystalline matrix. Frequently, the matrix has either assumed a minutely patchy character, due to the separation of alkali-felspar and quartz into small mutually interfering areas (S2119) [NM 5672 3860], (S14319) [NM 5725 3899], or has become microcrystalline with a definite separation of felspar (oligoclase) microlites (S14362) [NM 6158 3521]. Acicular augite, converted into greenish hornblende and magnetite, is a feature of some varieties (S15570) [NM 6104 3449], and may possibly indicate some slight compositional change in the rock, especially as it seems to be more frequently associated with the occurrence of microporphyritic enstatite-augite (S17104) [NM 5599 3414]. This type of rock connects naturally with the acid varieties of the inninmorites (Chapter 25).

Very occasionally, a still more pronounced type of crystallization is encountered, and then the matrix consists largely of minute short rectangular crystals of orthoclase, free-quartz, and subordinate plagioclase (S17969) [NM 5921 3336]. This type of matrix is most usually present when the rock has a more definitely granophyric character. In the felsitic portions of the mass, the rock frequently shows the results of auto-brecciation and the incorporation of darker and more vitreous angular patches of banded rhyolite. These patches probably represent ribbons of the more quickly cooled rock broken up and carried forward in the course of the intrusion. In one case only, a pyrogenetic hornblende, occurring in small irregular grains, appears to be the dominant ferromagnesian mineral (S17970) [NM 5921 3338]; but the rock, in this instance, seems to have an abnormally basic character, and may owe its unusual character to assimilation of basic material.

The analysed specimen (S14825) [NM 5551 3738] Anal. III., p. 20) is characteristic of the mass. It shows good fluxion-structure, and has small phenocrysts of albite and aluminous augite. The matrix is de-vitrified to a considerable extent, but the degree of devitrification varies greatly from band to band. It is interesting as containing relatively basic glomeroporphyritic groups of oligoclase-albite and serpentinized enstatite -augite

Beinn a' Ghràig Granophyre

(Anal. IV.; (Table 4), p. 20)

The greater part of this rock consists of quartz and orthoclase in granophyric intergrowth of varying coarseness, which furnishes a matrix to, or fringes, small phenocrysts of albite, perthite, orthoclase, or even microgranophyre ((Figure 57)B, p. 334). The chief characteristic of the rock, however, is a green pleochroic augite that occurs in some .abundance as

slightly elongated irregular crystals and grains (S2146) [NM 5738 4046], (S13857) [NM 5838 4082]. It probably has an alkaline composition, and its optical properties would suggest its inclusion in the series of aegerine-augites (p. 350, also Chapters 14, 31, etc). It commonly is of uniform. composition throughout, but occasionally it may form a peripheral coating to an augite of brownish tint and presumably of less alkaline character (S13859) [NM 5911 4195]. It is usually associated closely with magnetite, but without that regularity of arrangement observed in the columnar or acicular augites of such rocks as the augite-diorites, leidleites, and quartz-dolerites of Chapters 18, 25, and 28.

Viewed in section by ordinary light, the alkali-felspar stands out clearly from the quartz by reason of its extreme turbidity (S2094) [NM 5244 3563]. In composition, the rock shows little variation, but in texture it may become more finely granophyric (S2095) [NM 5244 3563] and assume a subspherulitic structure, or its constituent minerals may crystallize as equigranular individuals (S13857) [NM 5838 4082]. In rarer cases, it may assume characters that would indicate affinities with the eraignurites of Chapter 19; the texture being of a finely granophyric nature, with a tendency towards a spherulitic grouping of its microperthitic and microgranophyrie constituents. The augite is mainly acicular in form, and represented by narrow magnetite-charged hornblende-pseudomorphs (S13858) [NM 5883 4121], (S13860) [NM 5897 4152], and, in addition, there are a few well-shaped pseudomorphs (S13860) [NM 5897 4152] that recall the enstatite-augite of the ininmorites (Chapter 25).

Very interesting modifications have been noted in the Beinn a' Ghràig Granophyre at and near its contact with the screen of lavas which separates it from the Knock Granophyre.

A specimen (S14316) [NM 5456 3875], showing the actual junction of the granophyre with the screen, is instructive. The country-rock, much broken up by the invading granophyre, is now an extremely fine-grained granulite composed of recrystallized felspar, and minute granules of greenish augite, pale-brown hornblende, and magnetite. The granophyre, though fmer-grained than usual, continues moderately coarse to its margin, without any sign of rapid chilling. It has resorbed a considerable amount of basic material with a resultant separation of fairly large crystals of zoned labradorite and oligoclase-andesine felspars. The more alkaline portions are strung through with granulitic augite, hornblende, and magnetite, with a crystallization similar to that of the granulitized country-rock. A few feet away from the screen (S14315) [NM 5458 3874], the granulitization and assimilation of basic material are equally well-marked, though the resultant greenish augite and brownish hornblende have coalesced to a greater degree. A little biotite is also present, mainly in the hornblendic areas and in association_ with magnetite.

Knock Granophyre

(Anal. V.; (Table 4), p. 20).

The Knock Granophyre, like the Beinn a' Ghràig rock, has typically a granophyric structure (S14841) [NM 5427 3847], (Figure 59)A). The dominant ferromagnesian mineral, however, is a brownish-green, presumably aluminous, augite that forms sub-idiomorphic to irregularly bounded crystals. Another point of difference is the occurrence of a more obvious quantity of plagioclase. Augite occasionally assumes an acicular habit, but only to a limited extent.

A specimen from Beinn Bheag (S14840) [NM 5428 3850], much more basic than the normal granophyre, has a relative abundance of basic plagioclase, together with a fair quantity of augite that has assumed a columnar habit and is intimately intergrown with magnetite. Indefinite chloritic and magnetite-bearing patches probably represent imperfectly assimilated basic material.

Close to the screen of lavas, which borders the granophyre to the south-east, the rock (S14317) [NM 5454 3876] has a distinctly abnormal facies, more striking than that of the hybrid portions mentioned above. It may be possible that we are here dealing with a normal basic edge of the granophyre, but it appears from the general character of the rock, especially when considered in connexion with the similarly placed portion of the Beinn a' Ghràig Granophyre (see (S14315) [NM 5458 3874], (S14316) [NM 5456 3875], p. 348), that its peculiarities are due to an assimilation of basic material.

Toll Doire Dyke

This mass presents characters, in different parts, that would justify the application of the name either of granophyre or felsite. In the granophyric portions (S13855) [NM 5708 4195], the rock consists of fairly large individuals of microperthite strung with quartz, with which the felspar is in micrographic relation. The perthitic areas, when showing definite crystal-form, are usually fringed with granophyric material, of which the structure becomes increasingly coarse in an outward direction. There are moderately large areas of free quartz, and a fair abundance of bright green pleochroic alkaline augite of sub-ophitic habit and intimately associated with magnetite.

The felsitic types (S13879) [NM 5723 4167], (S13886) [NM 5798 4227] are somewhat poor in ferro-magnesian minerals, but, in addition to small phenocrysts of albite and perthite, a few microporphyritic crystals, replaced by serpentine and magnetite, appear to have been augite.

The phenocrysts of felspar are frequently surrounded by radiating sheaves of fibrous felspathic matter, with which are associated pseudomorphs after a finely acicular augite. With a more pronounced development of this radial growth, the rock may take on a definite spherulitic structure (S13886) [NM 5798 4227], in which small regular round or ovoid patches of quartz occasionally act as nuclei.

Rocks of a somewhat abnormal character, and mapped variously as granophyre and augite-diorite, present features that appear to indicate considerable assimilation of basic material by the acid magma. A specimen (S15590) [NM 5660 4151], from the more easterly outcrop of augite-diorite, as shown on the one-inch Map, is a granophyric rock that contains a large amount of corroded acid-labradorite felspar. Alkali-felspar has penetrated cracks and replaced weak spots, showing that the original felspar was out of sympathy with the magma by which it was ultimately enveloped. Augite is abundant, and occurs mainly in long irregular columnar crystals crossed by a salite-structure. This rock, in its main characters, is extremely like others to which the name augite-diorite has been applied, and which are dealt with in Chapter 18.

Another rock, mapped as granophyre (S13880) [NM 5722 4176], has certainly much in common with the variant described above, but there is a greater proportion of granophyric matter in its constitution, suggesting assimilation of rather a different order. The augite, as in most Mull rocks of intermediate to sub-acid composition, occurs mainly as irregular columnar crystals; but an original ophitic augite can be recognized by its external form, though now completely granulitized by re-heating into a fine mozaic of augite and magnetite. A still more advanced stage in the assimilation of basic material by the Toll Doire Dyke may be seen in a rock (S13877) [NM 5658 4145] which contains irregular aggregates of bright green pleochroic alkaline augite, with granular strings of the same mineral in association with magnetite and a little granular sphene, in a matrix mainly composed of small irregular grains and patches of alkali-felspar.

Discussion of analyses

((Table 4), p. 20).

It will be seen, from the analyses of the rocks described above, that there is considerable uniformity in the percentages of silica and alumina, but a noteworthy variation in the percentages of ferric iron, lime, and the alkalies.

Allowing for such accessory minerals as magnetite and apatite, it is found that, in the case of the Knock Granophyre, orthoclase and albite make up respectively about 14 and 33 per cent. of the total rock, and that sufficient alumina remains available to produce an aluminous augite with the magnesia, ferrous-iron, and lime. In the case of the Beinn a' Ghràig granophyre, however, we note an increase in the percentage of ferric iron and potash, with a decrease in the relative amount of lime. In this case, orthoclase will form about 27 per cent., and albite about 30 per cent. of the rock, and, at the same time, the amount of available alumina and lime is too small to allow the formation of a normal aluminous augite. It is probable, therefore, as is confirmed by the green colour and optical characters of the contained augite, that in this rock we have a pyroxene (aegerine-augite) in which ferric iron partly replaces alumina, and in which soda enters into the composition.

Similarly, the high percentage of alkalies in the Loch Bà Felsite, and the percentages of alumina, lime, magnesia, and iron, when compared with the percentages of the same constituents in the Knock Granophyre, demand a high felspathic content, and the consequent using up of the available alumina in the formation of these minerals. It is natural to expect,

therefore, that the lime and magnesia would tend to separate in the form of a non-aluminous pyroxene, and this to a limited extent has been found to be the case from actual observation. H.H.T.

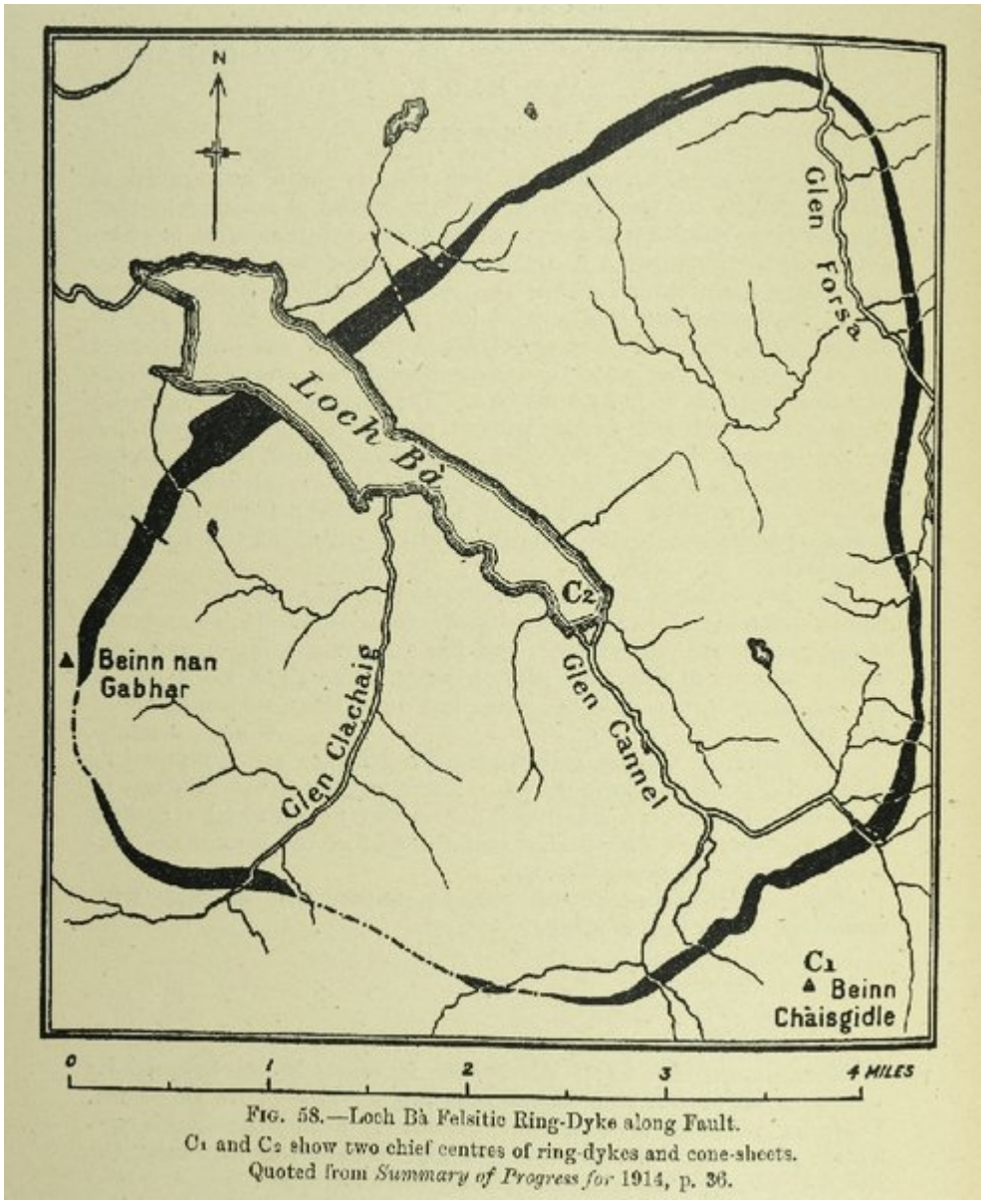


FIG. 58.—Loch Bà Felsitic Ring-Dyke along Fault.
C1 and C2 show two chief centres of ring-dykes and cone-sheets.
Quoted from *Summary of Progress for* 1914, p. 36.

(Figure 58) Loch Bà Felsitic Ring-Dyke along Fault. C1 and C2 show two chief centres of ring-dykes and cone-sheets. Quoted from Summary of Progress for 1914, p. 86.

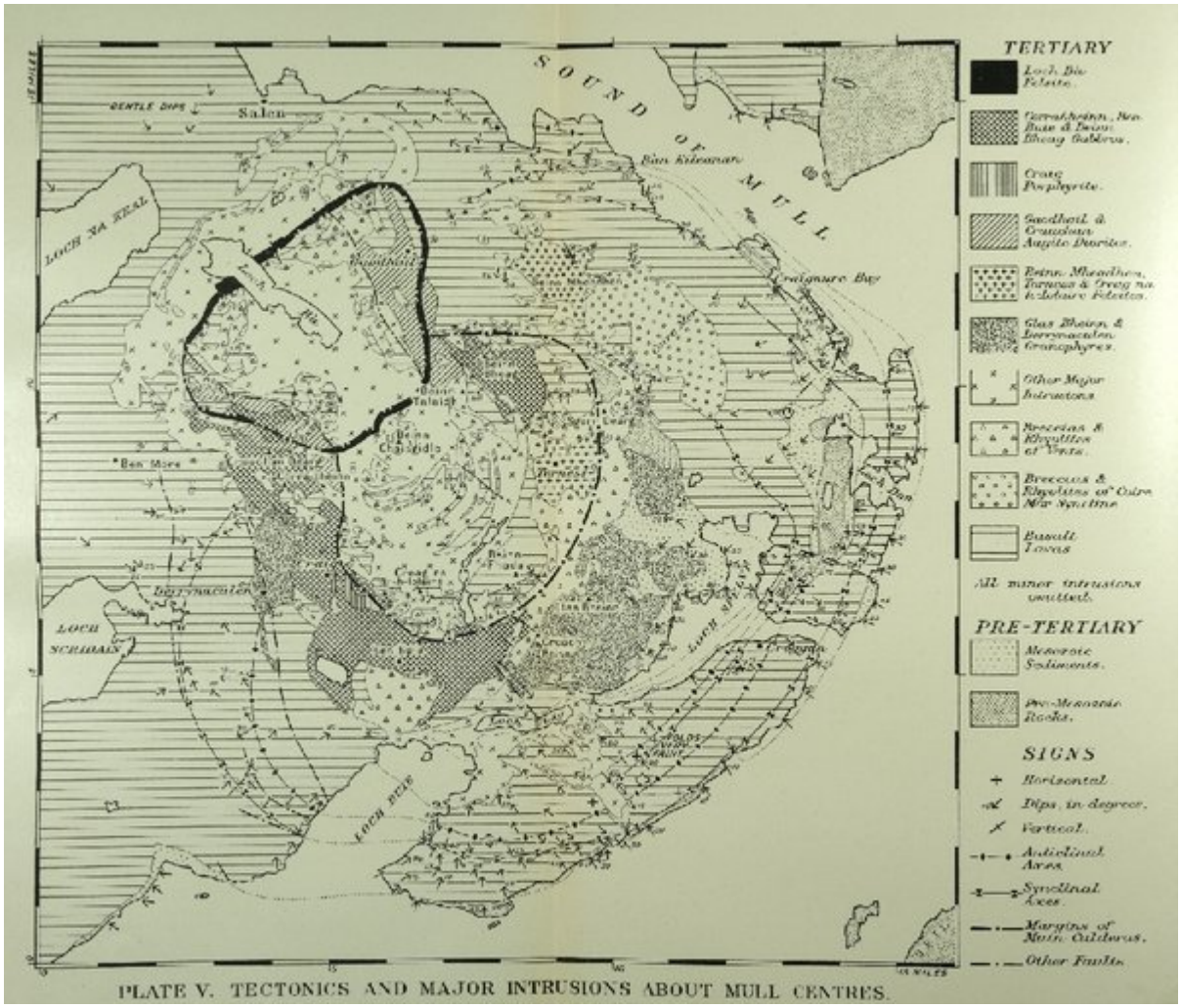
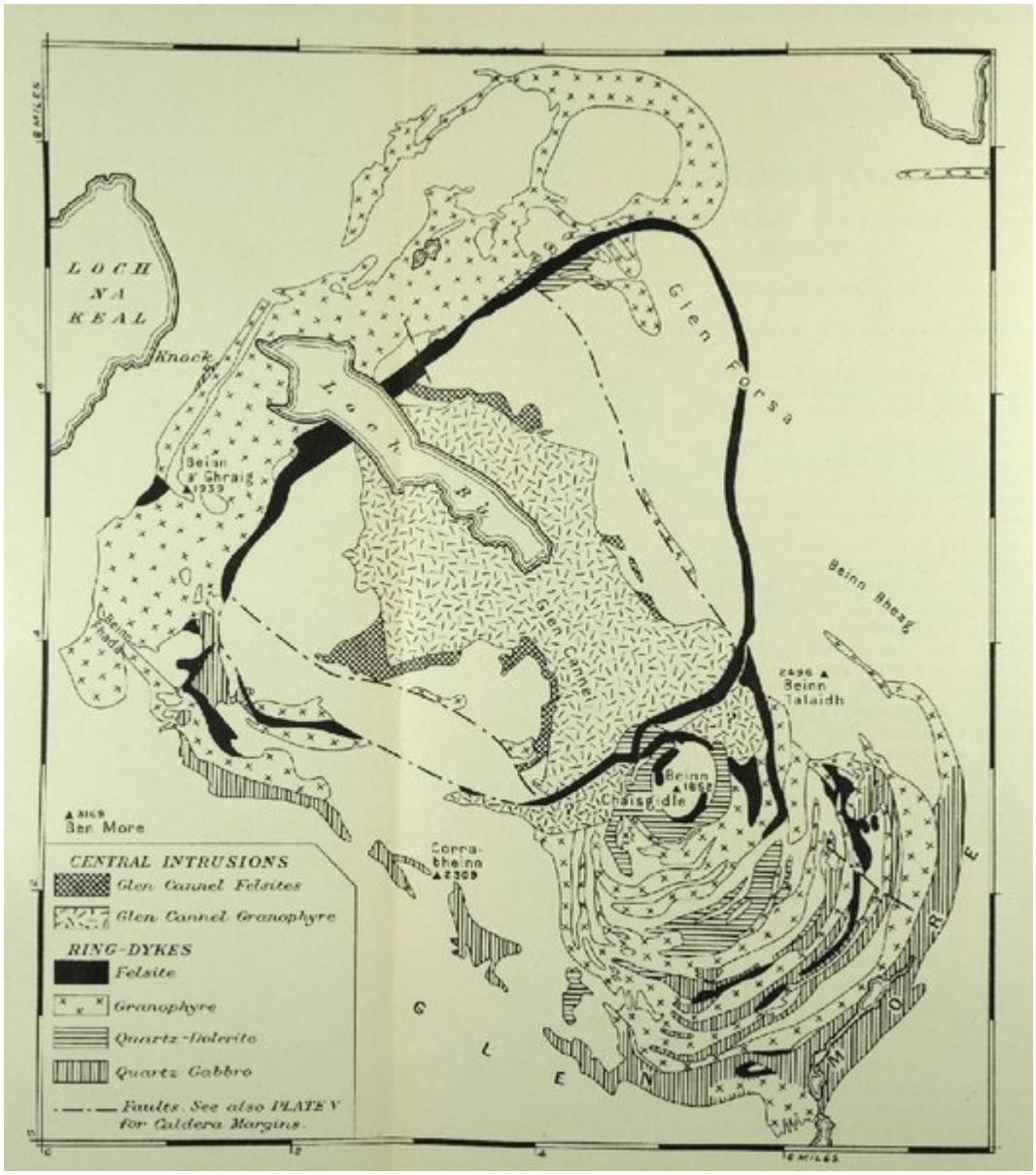


PLATE V. TECTONICS AND MAJOR INTRUSIONS ABOUT MULL CENTRES.

(Plate 5) Map showing calderas, major intrusions, and folds



(Plate 6) Map showing ring-dykes

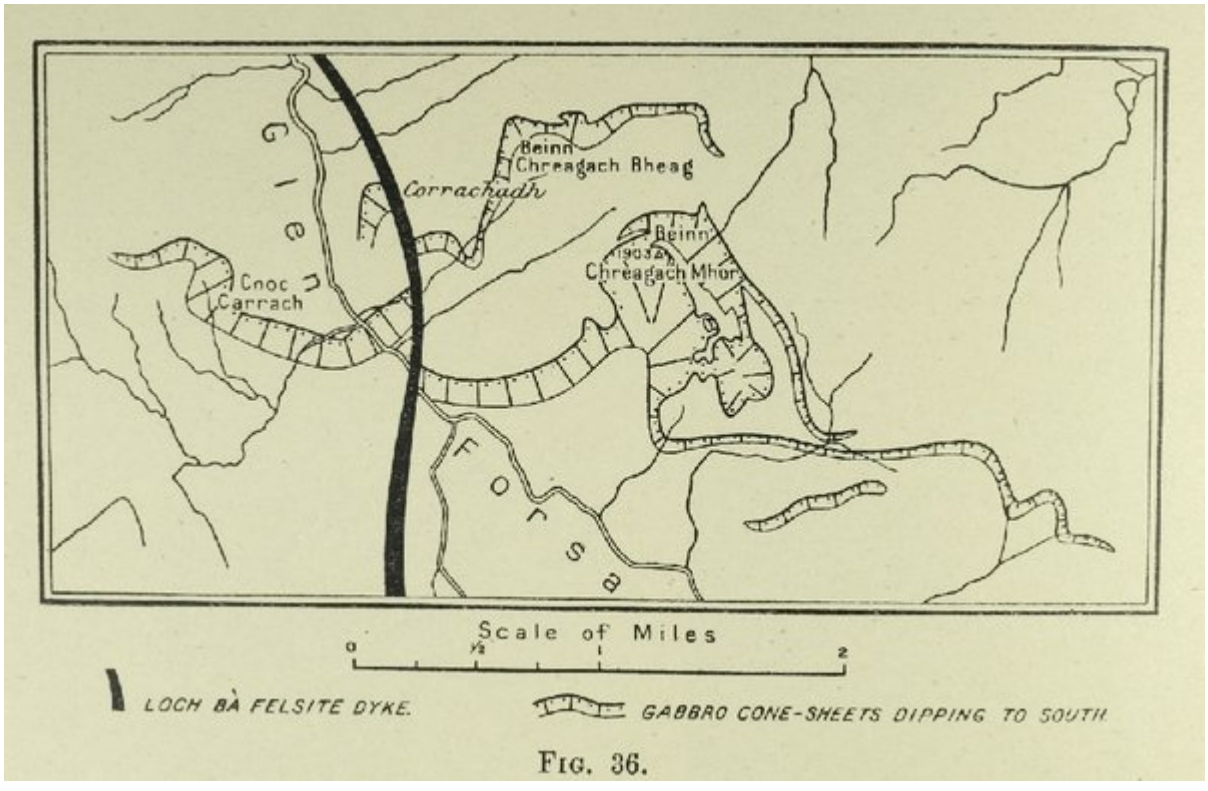


FIG. 36.

(Figure 36) Early Basic Cone-Sheets of Beinn Chreagach Bheag and Beinn Chreagach Mhòr probably displaced at Loch Bà Felsite.

FIG. 29.—Distribution of Gneiss-Fragments in Mull Agglomerates.

(Figure 29) Distribution of gneiss-fragments in Mull Agglomerates.

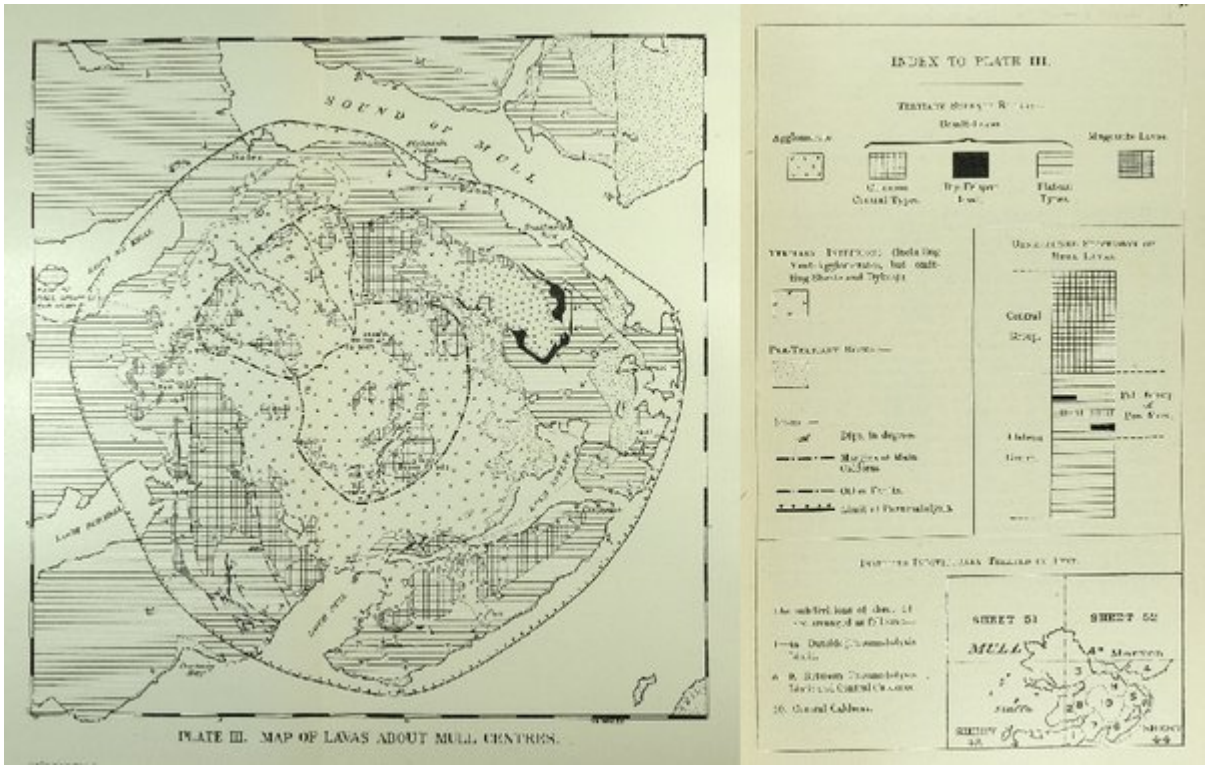


PLATE III. MAP OF LAVAS ABOUT MULL CENTRES.

(Plate 3) Map showing the distribution of lava-types and the limit of pneumatolysis

TABLE IV.—ACID MAGMA-TYPE OF FIG. 2.

	I.	II.	III.	IV.	V.	
SiO_2	70·70	71·30	72·66	73·12	73·32	SiO_2
TiO_2	1·27	0·58	0·34	0·39	0·51	TiO_2
Al_2O_3	11·78	11·24	12·00	12·44	12·25	Al_2O_3
Fe_2O_3	1·32	1·80	2·03	2·09	2·77	Fe_2O_3
FeO	3·45	2·84	2·04	1·65	2·20	FeO
MnO	0·07	0·31	0·18	0·17	0·12	MnO
(Co,Ni)O	...	nt. fd.	nt. fd.	nt. fd.	nt. fd.	(Co,Ni)O
MgO	0·53	0·61	0·07	0·14	0·11	MgO
CaO	1·30	1·56	1·25	0·88	1·65	CaO
BaO	...	0·07	0·12	nt. fd.	0·09	BaO
Na_2O	2·48	3·44	3·26	3·90	3·92	Na_2O
K_2O	4·71	4·66	5·26	4·67	2·34	K_2O
Li_2O	...	? tr.	nt. fd.	nt. fd.	nt. fd.	Li_2O
$H_2O+105°$	1·14	1·04	0·47	0·24	0·35	$H_2O+105°$
H_2O at 105°	0·50	0·39	0·22	0·25	0·35	H_2O at 105°
P_2O_5	0·26	0·22	0·04	0·09	0·10	P_2O_5
CO_2	0·51	...	0·24	0·05	0·06	CO_2
FeS_2	...	nt. fd.	nt. fd.	nt. fd.	nt. fd.	FeS_2
S	0·08	...	...	...	...	S
	100·10	100·06	100·18	100·08	100·14	
Spec. grav.	2·58	2·53	2·61	2·57	2·66	

(Table 4) Acid Magma-type of Figure 2

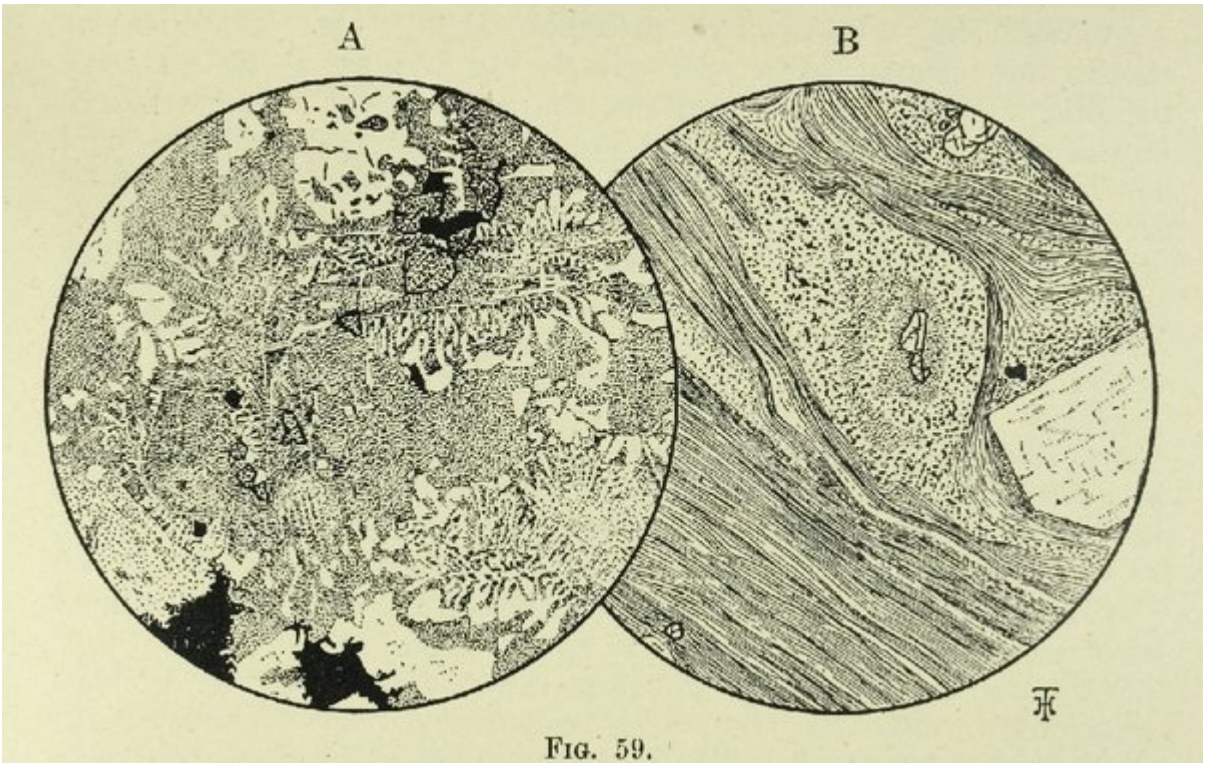


Fig. 59.

(Figure 59) A. [(S14841) [NM 5427 3847]] ×17. Knock Granophyre. Brownish-green augite and crystals of oligoclase edged with perthite, enveloped in a typically granophyric matrix of which the structure is emphasized by the turbidity of the alkali-felspar. B. [(S14825) [NM 5551 3738]]×17. Felsite of Loch Bà. Rhyolitic type with well-developed fluxion-structure. The phenocrysts are of yellowish augite and albite. Areas devoid of banding have suffered a more pronounced devitrification.

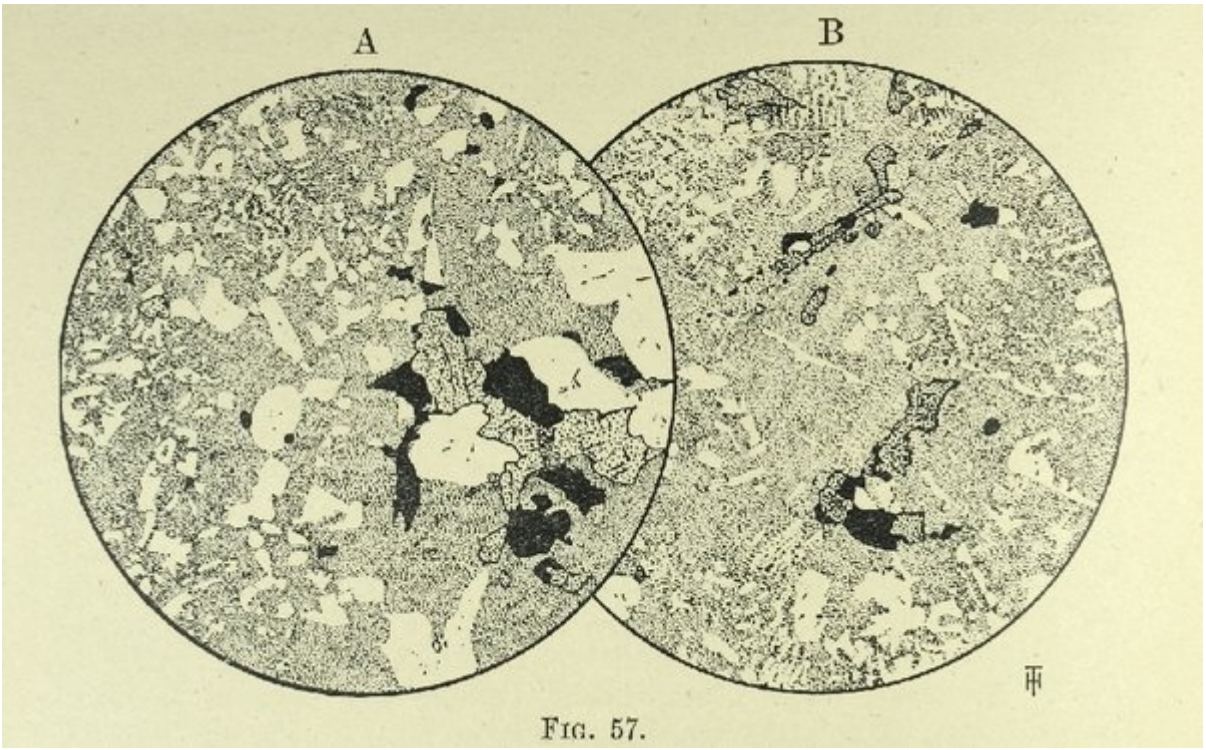


Fig. 57.

(Figure 57) A. [(S14844) [NM 6003 3457]] ×17. Granophyre of Glen Cannel. Green pleochroic augite (aegerine-augite) associated with magnetite, perthitic orthoclase and quartz in a somewhat coarse micrographic matrix. B. [2146] x 17. Granophyre of Beinn a' Ghràig. Green pleochroic aegerine-augite with magnetite, in a moderately coarse matrix of quartz and turbid alkali-felspar in micrographic intergrowth.