Chapter 9 Granites and granophyres: field-relations.

Granite and granophyre cover in Skye an area which fully equals or exceeds that occupied by the gabbro. The principal development is found in the Red Hills, lying north-east and east of the Cuillins. This collective name for the granite hills seems to have been first used by Macculloch in 1816: it merely renders the Gaelic name Beinn Dearg, which is applied specifically to more than one hill near Glen Sligachan and again near Broadford<ref>In the former neighbourhood there are also Meall Dearg and Ruadh Stac (Red Stack). Colour epithets are used in Gaelic with considerable laxity, but here the reddish tone is, in certain conditions of the weather, very marked.</ref>. The granite hills present much simpler and more rounded outlines than those composed of gabbro, and they are also lower, the granite itself never attaining the altitude of 2500 feet.

From Glen Sligachan a continuous tract of granite (including granophyre), six or seven miles across, extends north-eastward to the shore opposite Scalpay, with a prolongation into that island, and eastward to Glas-bheinn Bheag and Strath Beag. Here it joins for a short distance an otherwise isolated granite area, about three by two miles in extent, comprising the eastern Red Hills–Beinn na Caillich and its neighbours — which lie west of Broadford. Farther south, at Beinn an Dubhaich, occurs a separate mass of granite, and between these two are the Kilchrist granophyres, forming several smaller outcrops of a rock in some respects peculiar. On the eastern side of the Blaven range granite is found, though not continuously, along a line from Strath Mòr to near the headland of Rudha Bàn, beyond Camasunary, these outcrops connecting themselves with the large mass first mentioned. Some intrusions on and near Creag Strollamus are probably related to, though not visibly continuous with, the neighbouring mass of the eastern Red Hills. On Scalpay, besides the area in the southwestern corner of the island, which is evidently an extension of the large mass forming the main Red Hills of Skye, there is a sheet-like mass, or perhaps more than one, the outcrops of which encircle almost continuously the hill Mullach na Càrn at about 1000 feet altitude. Other occurrences have been mapped in Raasay by Mr Woodward, but these are not included in the scope of our detailed study.

Certain sheets of granophyre, large and small, intruded in the Mesozoic strata along a curved belt of country from Beinn Bhuidhe, near Broadford, to Suishnish, between Loch Slapin and Loch Eishort, are reserved for special description. They have much in common with the rocks of the Red Hills, but seem to be of somewhat later date, and moreover exhibit certain peculiarities both geological and petrographical. We also postpone consideration of most of the minor intrusions — dykes and some irregular sheets — of granophyre and quartz-felsite; more particularly those which belong to a distinctly later epoch than the granite group, as opposed to those which are merely apophyses of the large intrusive bodies of the Red Hills.

As in the case of the gabbro, we have to distinguish here *two different habits* as regards the form and relations of the larger intrusive masses; viz. the sheet-like or laccolitic and the disruptive or boss-like. This was recognised by Macculloch in 1819, and again by Sir A. Geikie in 1858. The instances which those writers cite of the former kind of habit are taken only from the smaller intrusions in the Lias, where the sill form is sometimes displayed with considerable regularity. If we view the large mass forming the Red Hills with regard to its general form and position, neglecting irregularities of detail, we find that considerable portions of this too have the form of a thick sheet.. The departures from regularity are, however, greater here than in the gabbro of the Cuillins. They seem to have some relation to the nature of the rocks with which the granite is in contact in different portions of its boundary.

We shall most clearly obtain an idea of the relations of this large mass of granite and granophyre by considering the form and character of its boundary in different parts. On the extreme west the line runs nearly north and south for two miles or more, close to the Sligachan River. The northern part of this boundary (against basaltic lavas) is concealed, but the remainder (against gabbro) is well seen, and seems to be everywhere nearly vertical. Farther south, on Druim an Eidhne, the junction is of a very different kind, the granite passing under the gabbro at a low angle. Where the volcanic agglomerate begins to intervene between the two plutonic rocks, the granite boundary is at an altitude of about 1000 feet; but it runs down eastward into Strath na Creitheach, underlying the much-expanded mass of agglomerate as the latter underlies the gabbro of Sgùrr an Eidhne. On the other side of the valley it ascends again, turning N.E. and N.N.E.; the upper surface of the granite here having an inclination not very different from the north-western slope of Blath-bheinn, as is' shown by the occurrence of an inlier about ¾ mile long. For some distance along the flanks of Blath-bheinn the granite is in contact with gabbro, then a strip of the volcanic rocks again intervenes, as the boundary rises to over 1400 feet on the northerly ridge of Garbh-bheinn. Here begins the large agglomerate mass of Coire na Seilg and Coire Coinnich, and the granite sinks again, passing beneath this mass. It is quite clear that the sinuous southern boundary we are following represents the upper surface — not horizontal indeed but never very steeply inclined — of a mass which terminates upward (Figure 25). Similarly, if we follow the northern boundary from Glen Sligachan towards Loch Ainort, we see that it represents the corresponding lower surface, the granite resting first on basaltic lavas and then on Torridon Sandstone. There are, however, considerable irregularities in this part of the boundary, partly connected perhaps with the dying out of the intrusion. Thus the basaltic lavas forming the summit ridge and much of the upper slopes of Glamaig are almost cut off, and must be in great part underlain, by a tongue of the granite. The boundary rises on the west side to near the main summit, drops by steps to about 1400 feet at the pass on the south side, rises again to the eastern summit, and drops sharply, with something like a vertical junction, along the north-eastern ridge. The tongue which runs along the north-western and northern faces dies out a little before reaching this ridge. The patch of basalt lavas, ½ mile across, to the east of the Tormichaig valley is of the nature of an inlier beneath the granite.

Putting together what is seen at the southern and northern boundaries, we. are able to picture this large mass of granite as presenting the general form of a *large irregular laccolite,* and having in the broadest sense a southerly dip. The varying altitudes and observed inclinations at the boundaries prove, however, that we must; further conceive it as deformed, whether originally or owing to later movements, and that the deformation shows a considerable degree of correspondence with that of the gabbro laccolite. There is an elongated anticlinal dome extending from Marsco to Glamaig, and the Blaven syncline is also in part well marked, but merges northward in a broader one extending in the direction of Loch Ainort. As regards the extent of the laccolite, we can easily trace it dying out towards the south. It passes under the gabbro of the Blaven range, but emerges on the eastern side very much reduced in thickness. It is represented here only by the discontinuous and rather irregular series of strips which extend S. and S.S.W. from was Bheinn Mhòr to Camasunary, the actual dying out being seen above Rudha Bàn. It seems probable too that the laccolite has not extended very far northward of the present limits: indeed it shows signs of dying out in Glamaig, where it is already splitting up and behaving irregularly. Since neither upper nor under surface is exposed in the central part of the area, no estimate of the maximum thickness is possible; but it has probably exceeded 1500 feet, and possibly much more.

Considering the western half of the Red Hills as a whole, we see then that to the south the granite shows an upper surface, to the north an irregular under surface; but westward it terminates abruptly at a nearly straight and vertical boundary. Of this there is only one probable interpretation: the straight line, nearly coinciding with the course of the Sligachan River, must be supposed to mark the position of an important fissure of supply, through which the granite magma rose to spread laterally eastward. The vertical boundary may indeed be regarded as the western face of a large dyke, one of the feeders of the laccolite (*see* (Figure 26). Doubtless other feeders are concealed beneath the granite of the hills further east, and the situation of some at least can be conjectured with some probability. We have already noticed the long curving gabbro dykes, enveloped in the granite, which extend from Glen Sligachan to Coire na Seilg, as some of the feeders of the gabbro laccolite. The relations observed along this line suggest that the fissures which served for the uprise of the gabbro magma were at a later epoch utilised as channels for the magma of the acid rock (Figure 27).

It is certain that the large mass of granite (with granophyre), the limits and relations of which have been partly sketched, was not the result of a single intrusion. It consists of distinct parts, usually having the general form of *quasi-horizontal sheets,* though in places with steeply inclined junctions and disruptive habit. Sometimes this composite structure of the granite mass is even apparent as a feature in the landscape. Looking across Strath na Creitheach from Druim an Eidhne to the slopes of Blath-bheinn, Clach Glas, and Garbh-bheinn, the granite is seen passing under the gabbro, the strongly contrasted colours of the two rocks making the junction very conspicuous. Now turning the eye to Ruadh Stac and Marsco, it can be seen that the granite composing these two hills is itself divided by a gently curved surface roughly parallel with the upper surface of the granite laccolite. The higher parts of the two hills consist of a rock which weathers with a different shape from that of the rock below, having a tendency to a rude columnar jointing, which in the prominent crag named Fiaclan Dearg is especially marked. The apparent relations are represented in the diagrammatic section (Figure 27).

Again, in several places within the granite area we find the rock becoming a fine-textured quartz-felsite, or assuming a spherulitic and sometimes a fluxional structure, along a certain band. Such a band may be in sharp contact with normal granitoid rock, and clearly shows, not only that two distinct intrusions are here seen in juxtaposition, but that there was a sufficient interval of time between them for the later one to experience a relatively rapid chilling at its margin. Such a junction is seen a little to the east of the Glen Sligachan foot-path, where it crosses the watershed E. of Loch Dubh. Another thing which often seems to indicate the junction of distinct intrusions of granite is the inclusion of narrow strips of basaltic lavas, sometimes two or three occurring along the same line. These may, of course, be wholly enveloped by a single intrusion; but their arrangement, and the fact that the acid rock itself sometimes shows fine-textured modifications along the same lines, suggests that, in some cases at least, these relics of the volcanic group are really caught between two distinct intrusions.

We have not found that these various indications afford sufficient data for actually mapping out the several component parts of the large granite mass, and indeed the general uniformity of lithological characters prevailing over considerable areas discourages any such attempt. We are probably justified in stating that, while the granite mass is certainly built up of a number of distinct intrusions, it has not so high a degree of complexity of structure as is met with in some parts of the gabbro laccolite of the Cuillins. This is quite in accord with the general behaviour of the acid and basic magmas respectively, and so also is the greater irregularity of form and habit exhibited by the granite as compared with the gabbro.

Turning to the eastern portion of the main granite area, we find greater difficulty in deciphering the true relations, partly owing to "the fact that in the Loch Ainort district the granite extends below sea-level. Where the boundary runs down to the sea, both at Maol na Gainmhich and at Dunan, the junction seems to be steeply inclined. The granite is in contact in the one place with Torridon Sandstone, in the other with quartzose grits belonging to the Jurassic. That part of the boundary, however, which runs N.–S., obliquely crossing the ridge of Glas Bheinn Bheag, shows an underlying junction, apparently the upper surface of a sill-like mass. The grits here have a well-bedded and laminated character, dipping eastward at about 40°, and the intrusion beneath seems to have followed the bedding. In the lower part of Strath Beag the junction is concealed, and at the south end of Beinn na Cro it again has an abruptly transgressive character.

The granite mass which forms Beinn na Caillich and the other *eastern Red Hills* is almost isolated from the main area, and must be regarded as a distinct intrusion. It has very decidedly *the boss form,* and its unfaulted junctions, *e.g.* with the limestone and gabbro to the east, are nearly vertical. It owes part of its relief, however, to subsequent differential upheaval (Figure 28). The north-western boundary, against the volcanic rocks and the underlying Torridonian, is a straight fault-line which can be traced for 2½ miles. The throw is greatest in the middle. Northeastward it dies out, against a small cross-fault, in the valley of Allt Fearna. About Creagan Dubha the metamorphosed state of the basaltic lavas, and the fact that they are penetrated by little tongues of granite, suggest that the present boundary is not very far from the original one; and the fault does not extend into Strath Beag. The southern, or at least the south-eastern, boundary of the boss is of a less simple kind; but here, too, the junction is probably not merely an intrusive contact. The bordering volcanic rocks are shattered by a number of faults with directions which tend to correspond roughly with that of the boundary, and some of these faults meet the boundary tangentially. The mapping certainly suggests that, while the southern limit of the granite (nearly a semi-circle in ground-plan) represents pretty nearly the original extent of the boss, there has been considerable differential movement along the line of junction, resulting in a relative elevation of the granite.

The *Beinn an Dubhaich granite,* extending 2¾ miles from E. to W., and ¾ mile from N. to S., is a typical example of the boss-like mode of occurrence. It is entirely surrounded by the Cambrian (Durness) limestones, and constitutes the core of an anticline (Figure 30). The elevation along this axis belongs in part to an early time (pre-Liassic at least), but was repeated later, probably in connection with the intrusion of the granite. The mass is, from all appearances, a single one, but its boundary is in ground-plan highly irregular, and isolated patches of limestone, also of highly irregular shapes, are enclosed within the granite, especially in its marginal parts (Figure 29). These enclosed patches range up to a quarter of a mile in extent. The limestone composing them, as well as that bordering the whole intrusion, is in a highly metamorphosed state. In consequence of differential weathering,<ref>The general lowering of the limestone surface by atmospheric weathering is partly a post-Glacial process. This is well illustrated at the "Stone" marked on the six-inch map in the Kilchrist Glebe. It is a large granite boulder standing on a two-feet pedestal of limestone, which it has protected from the general waste. In the central parts of Skye, at least, post-Glacial erosion of the solid rocks has been in general extremely slight (*Geol. Mag.,* 1899, pp. 485–491). The waste of the limestone by solvent action is an interesting exception. It is noteworthy that it is very similar in amount to that indicated by the pedestals of the well-known Norber erratics in Yorkshire,</ref> the limestone surface is depressed, sometimes three or four feet, below that of the granite; so that the actual contact-surface of the latter is exposed; and this is found to be *everywhere vertical* (Figure 30) and (Figure 31). The appearances are, in short, identical with those described for the gabbro boss N.W. of Broadford, which is intrusive in the same group of limestones. There is an additional feature of interest in the presence of a number of basic dykes of pre-granitic age, traversing the limestone and abruptly cut off with it by the granite. Having regard to the strike and dip of the limestone and the courses of the dykes, it does not appear that the granite has occasioned any appreciable disturbance *in detail* of the rocks through which it breaks, or even in the patches of those rocks which it completely surrounds.

This remarkable behaviour of the Beinn an Dubhaich granite presents, as we have already noticed in the corresponding case of the gabbro, a difficult problem in the physics of igneous intrusion. In one respect there is a difference between the two cases; for the dolomitised limestone was doubtless considerably denser than the granitic magma, and if we suppose the rock displaced by the granite to have been removed in the solid state we must therefore suppose it to have sunk through the molten magma. Nevertheless, making all due allowance for this difference in density, it is still not easy on this supposition to account for the complete absence of limestone xenoliths in the granite as now exposed. To suppose that the limestone has been to any important extent dissolved and incorporated in the acid magma raises an even greater difficulty. This would imply an enrichment of the granite in lime, which is quite inconsistent with the facts of the case. A specimen from the eastern end of the granite mass, in contact with the limestone, was found by Dr Pollard to contain only 0.47 per cent. of lime, *i.e.* not more, but less, than is found in the ordinary acid intrusions of the region. Even if we assume the acid magma to have been originally free from lime, it cannot have taken up more than 1/212 of its own mass of that base, or 1/65 of its own mass of dolomitic limestone; and in fact the figure 0.47 represents an unusually low percentage of lime for granitic rocks in general. It seems then that, whatever be the *rationale* of such intrusions as this, with abruptly transgressive relations but no concomitant disturbance at the junctions, the phenomena are not to be explained by any theory which involves appreciable incorporation of the country rock in the invading magma.

The granophyre associated with the large mass of volcanic agglomerate north-west of *Loch Kilchrist,* remarkable for the profusion of gabbro debris which it has enclosed and partially digested, has also an interesting mode of occurrence. There are five isolated areas, within and on the edge of the agglomerate. The two largest are on the eastern and western borders of the agglomerate mass, and form strips ¾ mile and ½ mile long respectively. The granophyre in these places has clearly been intruded along the wall of the old vent, between the agglomerate and the Cambrian limestones. Its boundary towards the limestone is a vertical surface; that towards the agglomerate has a more irregular form. The other three exposures, within the area of the old vent, occur in valleys, and the granophyre has every appearance of underlying the immediately adjacent agglomerate.<ref>A sketch-map showing the several outcrops has been published in Quart. *Journ. Geol. Soc.,* vol. lii., P1. XIII.: 1896.</ref> The most probable interpretation seems to be that which would make these outcrops portions of one irregular sheet, and the diagrammatic section already given is drawn on that hypothesis ((Figure 4), p. 16). What determined the intrusion of the magma in the form of a sheet at this particular horizon is a question not easily answered.

Of the remaining acid intrusions, all of small dimensions, which may be correlated with the granites as regards the epoch of their injection, little need be said in this place. That which forms the upper part of *Creag Strollamus* has a very irregular shape, showing in some places the sheet-like, in others the sharply transgressive kind of boundary. This is partly due to the fact that it is in contact in different places with Torridon Sandstone, basaltic lavas, and gabbro. Within the area occupied by the gabbro boss farther to the S.E. the distinct ganophyre intrusions which occur are chiefly in the form of isolated short dykes, varying in width up to 30 yards, and having no common direction. An unusual mode of occurrence is seen at several places about a mile west of Broadford. Here, in an area of Cambrian limestones, occur a number of small outliers of Torridon Sandstone above the great thrust-plane, and granophyre is seen to have forced its way in the form of a thin sheet along the thrust-plane (Figure 28). The gabbro, which also occurs in the immediate neighbourhood, has not done so. The same thing is seen on the S.E. slope of Creag Strollamus, towards Allt Fearna, where several small inhere of limestone occur in the surrounding Torridonian, and in more than one place granophyre has penetrated along the surface of junction. On the other side of Allt Fearna, where some rather large patches of limestone in the granite are intersected by the tributaries on the right side of the main stream, interesting relations are again seen. For a certain distance the intrusion seems to have been guided by the thrust-plane; but farther south the Torridonian had previously been stripped off (as is proved by relics of the lavas and agglomerate resting on limestone), and the sheet-like habit is at once lost.

A little east of the last locality an enclosed patch of the limestone occurs on the boundary between granite and gabbro. It is divided into a number of strips by vertical dyke-like tongues, which are offshoots from the two intrusive masses, and each of which consists in one half of its length of gabbro and in the other half of granite. The limestone has first been penetrated by offshoots from the gabbro mass, and later, from the opposite side but along the same lines, by offshoots from the granite (*see* map, Fig. 20, p. 98).

Of the numerous enclosed patches of the volcanic group in the large granite tract of the Red Hills the only one requiring special notice in this place is that which forms the northern half of *Beinn na Cro.* Here a portion of the basaltic lavas more than a mile in length, previously penetrated by irregular sheets of gabbro, has become completely involved in the granite. In the northern part the granite distinctly underlies the enclosed mass, though with a very irregular surface of contact and numerous apophyses in the form of felsitic tongues and dykes passing obliquely up through the gabbro and basalt, as is clearly seen on the western slope. Farther south the granite breaks abruptly across, so as obliquely to truncate the enclosed patch; and it thus comes to form the summit (about 1790 feet) and the rest of the mountain (Figure 32). At the southern end of the ridge, however, where the granite terminates at about 800 feet altitude, an outlying patch of lavas is seen resting on Liassic strata and dipping rather sharply to the south. This suggests that the abruptly transgressive behaviour of the granite seen just north of the summit is connected with the existence of a pre-granitic fault throwing the lavas down to the north.

Considering now the *character of the junctions* and the relations in detail of the granite to the rocks in contact with it, we see that the petrographical nature of the latter has had, as in the case of the gabbro intrusions, a very noteworthy influence upon the behaviour of the intruded magma. The junction with the dolomitic limestones of the Cambrian is always a clean-cut surface. No veins from the granite enter the contact-rock, nor are fragments of limestone enclosed by the margin of the intrusion. The junction with Torridon Sandstone, as seen especially about Creag Strollamus, is much more irregular on a small scale. Not infrequently it is impossible in a hand-specimen to draw any sharp line between the two rocks, which are here a fine granophyre and a rather close-grained quartzose grit. A slice (S8053) [NG 606 220] shows that the intruded magma has insinuated itself for a short distance into the interstices between the sand-grains, and clastic grains of quartz are seen embedded in a delicate micropegmatite. In the Isle of Scalpay, and in various other localities, veins traversing the sandstone in the neighbourhood of the junction are visible in the field. This is the case especially in places where the granite sends out tapering sheets, which dovetail into the strata, a type of junction characteristic of the dying out of a large laccolitic body. The northward termination of the large granite mass, as displayed in the Isle of Scalpay, is represented in the accompanying section (Figure 33). At its southerly boundary the granite again runs out into a number of rather irregular sheets, as is well seen on the western slope of the south ridge of Blath-bheinn, above Loch na Creitheach. Here the intrusive rock has picked up abundant clastic grains, and even small pebbles of quartz, from the Torridonian grits with which it is in contact; and the separation of the intrusive rock from the grit is by no means an easy task.

The junction of the granite with the more shaley portion of the Torridonian series is well displayed near Rudha Bàn, a headland on the coast of Loch Scavaig west of Camas Fhionnairidh. Here again we have what may be regarded as the final dying out of the large laccolite of the western Red Hills, and, as often happens in these circumstances, the intrusion takes on a rather irregular character, sending out numerous tongues and showing a very ragged boundary on the map. Essentially, however, it is a sheet, intruded here between the base of the basaltic lavas and the underlying shales, both of which are considerably metamorphosed. The latter are not much penetrated by offshoots from the granite, but their shattered fragments have been enclosed by the intrusive rock in extraordinary number, so that the granite is in places almost crowded with pieces of metamorphosed shales. The basaltic lavas above have not furnished so many xenoliths to the intrusion, but they have been traversed by a network of little veins which run out from the main mass.

Veining on a minute scale is very characteristic of the basaltic lavas in the vicinity of the granite, and sometimes extends to very considerable distances from the contact, arguing a high degree of fluidity in the acid magma. The phenomenon is well seen about Creag Strollamus, Beinn na Cro, Glamaig, Belig, and elsewhere. It is very noteworthy that it affects the compact, not the amygdaloidal, varieties of the lavas, and it seems to have depended upon a certain fissuring of these rocks prior to the intrusion. The volcanic agglomerates and tuffs show veining less commonly and in a more irregular fashion; it is seen in Coire na Seilg.

There remain the junctions of the granite with the gabbro; and, as these afford the most obvious demonstration of the posteriority of the acid ,rock, and have also considerable interest in themselves, they demand a fuller notice.

Along the Sligachan River, where, as has been said, the junction is a vertical or highly inclined one, it seems to be usually of a simple type; but in places the granite sends out veins into the gabbro, as is well seen in the bed of the river N.W. of Loch Dubh. The junction, as it rises from here to Druim an Eidhne, is concealed, and when it becomes clearly exposed, in the little pass between Meall Dearg and the ridge, the granite has assumed the laccolitic habit, passing clearly under the gabbro. Here it sends out a small tongue into the latter rock, which can be followed southward for about 100 yards. From this point a narrow strip of volcanic agglomerate is interposed; but the granite, or rather its felsitic modification, forces its way above this, and sends numerous apophyses in the form of dykes into the gabbro. These are seen at short intervals along the ridge, cutting alike the agglomerate, the main body of gabbro, and the irregular dyke-like intrusions of gabbro which we have pointed out as feeders of the main body. There are other dykes of the same type cutting the gabbro a little farther from the granite exposure and not visibly connected with it: they doubtless originate in the extension of the granite immediately beneath them.

These dykes of spherulitic and other acid rocks which intersect the gabbro of *Druim an Eidhne* present interesting but in no way abnormal characters; and we should not have thought it necessary to offer any evidence of their intrusive nature, had not a very different interpretation of them been put forth in a paper by Professor Judd.<ref>*Quart. Journ. Geol. Soc.,* vol. xlix , pp. 175–195 1893.</ref> That geologist regards them, not as dykes, but as portions of the granite enclosed and partially fused by the gabbro, which is in his view the later rock. Sir A. Geikie<ref>*Ibid.,* vol. 1., pp. 212–229: 1894.</ref> has already given strong reasons for rejecting this idea, and has indeed conclusively proved that the supposed inclusions are dykes; but it will be convenient in this place to state briefly the evidence.

The outcrops of acid rocks in question, within the gabbro area, have the linear form and parallel vertical boundaries characteristic of dykes, and of dykes alone. Owing to their more perishable nature they have given rise to trench-like depressions, which run nearly straight or with occasional deviations, after the fashion of dykes in general. These trenches maintain in each case a nearly uniform width of a few yards, and can be traced through the coarse gabbro for distances of ¼ or ½ or even ¾ mile. In one or two cases they bifurcate. Their direction is that proper to the dykes of the district (N.N.W.–S.S.E.), and is not parallel to the boundary of either gabbro or granite. They are not parallel to the banding of the gabbro, so strongly marked in this place: they correspond roughly with it in strike, but not in dip, and often truncate the banding obliquely. All these facts are incompatible with the hypothesis of inclusions.

The floor of the trenches is in great part concealed by swampy ground, but there are sometimes considerable stretches in which the dyke-rock is perfectly bare, and always sufficiently frequent exposures to leave no doubt of its actual continuity. There is usually a strong fluxion-banding parallel to the walls. One or two of the dykes can be traced with visible continuity from the banded gabbro which they intersect, through the strip of volcanic agglomerate which next intervenes, to the edge of the main body of granite (*i.e.* its marginal modification). Precisely similar dykes cut the wide spread of volcanic agglomerate on the slope down to Loch na Creitheach. Moreover, the margin of the granite assumes in many places characters (such as the spherulitic and other structures) identical with those of the dykes.

Petrographically the dykes which cut the gabbro are perfectly normal igneous rocks, in no wise different from others in the district which intersect the volcanic rocks, and easily matched from other countries. This appears from Professor Judd's description no less than from our own examination. In particular, he has pointed out the close resemblance, extending to minute details, between the spherulites in these rocks and those in certain obsidians and rhyolites from America, which are indubitably normal igneous products. He has indeed likened these supposed inclusions of granite in gabbro to the inclusions of quartz-felsite in a nepheline-basalt at Ascherhübel in Saxony, but his description of the latter does not seem to shown any close resemblance between the two cases. The undoubted inclusions of granite so abundant in many of the basic dykes of Skye exhibit, as we shall see, very different characters. Mons. Lacroix, whose acquaintance with inclusions of all kinds is probably greater than that of any other petrologist, refers briefly to Professor Judd's description in his monograph, but states that he has seen nothing like it in any of the occurrences which he has studied.<ref>*Les enclaves des roches volcaniques,* p. 654: 1893.</ref>

Druim an Eidhne is almost the only place where apophyses of any of the large acid intrusions take the form of typical dykes. It is to be observed that these spring from the *upper surface* of the laccolitic mass. The fringing out of the same at its *edge* takes the form of wedge-like tongues and tapering irregular sheets, as already noted near Rudha Bàn; and where offshoots are found in connection with a *vertical* or steeply inclined granite-contact, they form a plexus of irregular veins.

On the eastern side of Strath na Creitheach, although the laccolitic habit of the granite is still maintained, the rock does not throw off any vertical dykes. It is in most places divided from the gabbro by a narrow strip of basaltic lavas, and in several localities it sends out short tongues either into these rocks or into the gabbro. Several such tongues are seen in connection with the inlying patch of granite on the N.W. slope of Blath-bheinn; and one of them, cutting into the overlying gabbro, is distinctly visible from Loch an Athain. Another tongue, not continuous at the surface with the main body, crosses the much-broken northern ridge of Blath-beinn, giving rise to the principal break between that mountain and the peak known to climbers as Clach Glas. This col (altitude 2310 feet according to Dr Collie's measurements) is about 700 feet above the probable upper surface of the granite laccolite.

The above observations afford indisputable evidence that the granite laccolite of the Western Red Hills is of later intrusion than the gabbro laccolite of the Cuillins. The posteriority of the granite boss of the eastern Red Hills to the neighbouring gabbro boss is equally clear. At many points along their common boundary, to the N.E. of Beinn na Caillich, the granite is seen penetrating the gabbro, and the latter is traversed in the neighbourhood of the contact by innumerable veins of the acid rock. In some places such veins form for a short distance a close network almost equal in bulk to the gabbro which forms the meshes, giving the effect of a breccia of gabbro in a matrix of granite. The veins are not confined to the immediate vicinity of the granite-contact; but they are most numerous there and near the dyke-like intrusions of granite already mentioned, which traverse both gabbro and limestone. These intrusions have rather peculiar characters. They are in the form of stout dykes which run only for short distances in comparison with their size, and then die out with singular abruptness. Closer inspection often shows that when one of these dykes comes to an end in gabbro (not in limestone), the country-rock beyond is traversed by very abundant little veins, which in a sense serve collectively to carry on the intrusion farther. A more curious phenomenon of the same order was observed in one or two places, where a dyke or rib of granite traversing the limestone is interrupted upon meeting a small tongue of gabbro, but continued nearly on the same line in the limestone beyond. The illusion that the granite has been cut by the gabbro is dispelled by a closer scrutiny, which shows that the acid rock has traversed the basic in the form of a plexus of very small veins. Indeed on examination we find that the granite magma has been able to penetrate the gabbro in threads of quite microscopic minuteness. The appearances recall in some respects the injection of gabbro by granite described by Professor Sollas<ref>*Trans. Roy. Irish Acad.,* vol. *xxx.,* pp. 477–519, Pl XXVI., XXVII.: 1894.</ref>at Barnavave, Carlingford, but there are perhaps certain differences between the two cases. It appears from his description that the minute veins noticed by him are generally rectilinear, in one or two parallel sets, and he considers the gabbro to have been not only solid but fissured by contraction-joints before the intrusion of the granite. In Skye the veins form an irregularly reticulated plexus, and there are reasons for believing that no important interval of time elapsed between the solidification of the basic rock and the intrusion of the acid magma.

These phenomena in the Broadford district evince at least a *remarkable permeability of the gabbro by the granitic magma,* and this is no less apparent in the gabbro laccolite of the Cuillins. A striking feature in many parts of the mountain district is the occurrence of veins of granite, or usually granophyre, traversing the gabbro, in no visible connection with any larger body of acid rock. In many places, such as E. and S. of Loch na Creitheach and about the head of Loch Scavaig, the veins occur abundantly in the lower part of the gabbro laccolite, where we have good reason for believing that granite exists not far below; but elsewhere they are absent in a like situation. The difference seems to be related to differences in the nature of the granite-junction below. On Druim an Eidhne, for instance, where the upper surface of the thick acid intrusion is (except for distinct dykes)a smooth one, and the granite passes into felsitic and spherulitic rocks towards its boundary, veins are not found in the gabbro. The other localities mentioned as remarkable for the profusion of veins are where the attenuated granite laccolite has become irregular in its behaviour, with numerous offshoots, and with no marginal modification.

Granophyre veins are found, however, in the mountains far above the base of the gabbro laccolite, and far above any presumable concealed body of acid rock. (*See* map, (Figure 58) A good example of this occurs on the summit ridge of Sgùrr Dearg, near and. to the south of the cairn, where the gabbro is so traversed by veins of granophyre as to present the appearance of a breccia. This must be nearly 3000 feet above the base of the gabbro laccolite, where, if anywhere we should expect the westward extension of the granite from Druim an Eidhne to occur. If any nearer body of granite has been present, it can only have been a sheet intruded along the upper surface of the gabbro laccolite, now totally removed, and of such hypothetical intrusion we have no sort of evidence.<ref>About 700 yards E.S.E. of this spot begins the outlying patch of lavas forming the summit of Sgùrr Mhic Choinnich, which is not improbably the actual roof of the gabbro laccolite.</ref> Other places where granophyre is seen traversing the gabbro of the mountains are the summit ridge of Sgùrr nan Eag and the slopes of Sgùrr a' Mhadaidh towards Coir' an Uaigneis.

The last point to be noted in the field-relations of the large acid intrusions relates to the presence or absence of noteworthy *marginal modifications* in texture and micro-structure towards the bounding surface. In some places the rock near the contact becomes fine-textured and "felsitic", sometimes compact, sometimes porphyritic, sometimes with visible spherulites, sometimes even with fluxion-banding like a rhyolite: in other places the rock maintains the character of a granite or a relatively coarse granophyre up to the actual contact. It is not difficult to see that these differences stand in relation to the varying habits of the intrusions which have been sufficiently distinguished above. Where the magma has been intruded strictly in the form of a sheet or laccolite regularly following bedding or other leading surfaces, as beneath the Jurassic grits of Glas Bheinn Bheag or the gabbro and agglomerate of Druim an Eidhne, there is constantly a marginal modification in the direction of finer texture and special structures. When the sheet-like habit breaks down or becomes very irregular, as in the Camasunary district, there is little or no modification of this kind. With quasi-vertical junctions, as in the bosses of Beinn an Dubhaich and the eastern Red Hills, there is no sign of textural or structural modification near the contact-surface. The Kilchrist granophyres are instructive in this connection. The most easterly exposure on its eastern side, where it presents a smooth, nearly vertical face to the Cambrian limestones, is a coarse granophyre up to the actual contact: on its western side, where the junction seems to be of the underlying kind, though not very regular, little sheet-like apophyses entering the volcanic agglomerate, the rock becomes fine-textured, and contains in places beautiful stellate spherulites. The interior exposures, which we take to represent the upper surface of a sheet-like mass, also show felsitie and even rhyolitic modifications.

Junctions with and without fine-textured marginal modifications differ also as regards the apophyses which the intrusion sends out into the contiguous rocks. When these occur, they are in the former case dykes, in the latter case irregular veins. It is also to be remarked that thermal metamorphism of the adjacent rocks is in the former case often trifling in amount and extent, while in the latter case it may be intense and far-reaching.

The *metamorphism produced by the granites* in the basaltic lavas and in the gabbros has been described under the heads of those rocks. The metamorphism set up by the same cause in the various sedimentary rocks does not come strictly within the scope of our subject, and in general does not present any special features of interest. To this last statement, however, the metamorphism of the *Cambrian dolomitic limestones* makes an exception, and a summary account of this may properly find a place here. For valuable assistance in the examination of the specimens collected, and especially for the true identification of certain of the new-formed minerals, the writer is indebted to Mr Teall, who has found a close resemblance between the phenomena here and those observed at Ledbeg in Sutherland, where rocks of the same series are invaded by a large syenitic intrusion.

The Cambrian limestones, in great part dolomitic, which cover a considerable area in the Strath district were definitely proved to be of this age by Sir A. Geikie in 1887.<ref>*Quart. Journ. Geol. Soc.,* vol. xliv., pp. 62–73: 1888.</ref> Since that time the mapping of Mr Clough and the examination of the fossils by Dr Peach<ref>*Summary of Progress* for 1898, pp. 54, 55.</ref> have enabled these rocks to be more precisely paralleled with the corresponding members of the Durness succession in Sutherland, and it is recognised that the rocks with which we are more particularly concerned are the equivalents of the Balnakiel and Croisaphuill groups. Where they are invaded by the gabbro N.W. of Broadford and by the granite round Beinn an Dubhaich, they become saccharoidal marbles; and in the latter area, not far from Kilchrist, they were formerly quarried. These Skye marbles were well known in the earlier part of the nineteenth century, and Macculloch<ref>*Trans. Geol. Soc..* vol. iii., pp. 101, etc.: 1816. *Description of the Western Islands of Scotland,* vol. *i.,* pp. 418, 419: 1819.</ref> enumerates the several varieties then worked; but operations have been long abandoned, and probably the expense entailed by the short land-carriage would render the reopening of the old quarries unremunerative unless undertaken on a large scale. The largest quarries are on the slope of the hill to the south of Loch Kilchrist, one about 1000 yards south of the lake, and a lower one some 135 yards farther north.<ref> These quarries are incorrectly placed on the Ordnance map, and the others are not given. All the principal openings are marked on the map given above (Figure 29, p. 133).</ref> A smaller one is situated a little west of the Boreraig foot-path and 500 yards south of the Glebe. This and the first-mentioned quarry yield some variety of mottled, veined, and serpentinous rocks, in addition to pure white marble. Another quarry lies just east of the footpath and by the southern angle of the Glebe fence. The rock here, like some others, though in appearance a fine-grained white marble, is in reality an aggregate of the pencatite type, consisting of calcite and brucite. A small quarry about 350 yards S.E. of the old ruined manse is in a white marble which, unlike the generality of the metamorphosed rocks, is still a dolomite-rock. Of the five quarries enumerated, the first three are in patches of limestone surrounded by the granite, and the other two are near the granite boundary, the last one, where the rock shows no very high grade of metamorphism, being situated near the attenuated termination of the intrusive mass.

The Cambrian limestones of Skye are almost free from detrital matter, and contain little original impurity other than silica of organic origin. This is in great part aggregated into distinct nodules and small patches of chert, or in some zones in sponge-forms; but there is usually more or less silica in a disseminated form, as is shown by the accompanying chemical analyses made on material free from visible chert. Outside the areas affected by thermal metamorphism the limestones are usually, though not in every place, dolomitised, and there is abundant evidence that this is the result of metasomatic processes subsequent to the deposition of the rocks. While the limestones not thus altered usually have a compact fine-textured character, and are well bedded, the dolomitic rocks have lost their bedded aspect and acquired a crystalline saccharoid texture often similar in appearance to that of the true marbles within the areas of metamorphism. They have a specific gravity 2.84 to 2.86, and two specimens selected for analysis gave very closely the composition of true dolomite (I. and II.).

The metamorphosed equivalents of these rocks near the gabbro and granite are not dolomite-rocks, though some of them have some dolomite with the calcite: the magnesia that is present is contained in general in various new-formed silicates and other minerals. It results from the relative purity of the original rocks that they do not in general, like impure limestones and dolomites in many districts, become transformed to silicate-rocks, with total expulsion of the carbonic acid. They are converted to crystalline marbles with accessory silicate-minerals in greater or less amount, scattered through the rock or aggregated in various ways. These new-formed minerals are distributed in a manner depending upon the degree of dissemination or the mode of concentration of the original silica which has contributed to the formation of most of them. They may be scattered in the form of granules, crystals, flakes, or fibrous patches, according to their nature, either uniformly or along certain bands following the stratification, in which case most of them (white mica excepted) are not conspicuous in the field. Where, however, the cherty matter has been concentrated in connection with sponge-bodies, chert-nodules, or particular seams of the rock, the new-formed silicate-minerals are richly present in certain parts of the marble, though very rarely to the exclusion of carbonates. At one place in the gabbro area the marbles include a bed of a white rock, with the general appearance of a quartzite but of specific gravity 3.09, which is found to consist wholly of diopside in little grains from -ju inch downward (S6781) [NG 623 240]. A similar rock occurs in contact with the granite at Camas Malaig (S3205) [NG 583 189].

	I	II	A
Part insoluble in dilute hydrochloric acid	2.26	1.72	2.42
SiO_2	0.50		0.11
Al_2O_3, Fe_2O_3, FeO	0.45	0.34	0.62
MnO	0.22	0.19	0.24
MgO	21.19	20.81	20.25

CaO	30.50	30.53	30.05
CO_2	44.54	46.25	46.15
	99.66	99.84	99.84
Specific gravity	2.85	2.86	2.85

I. Dolomite-rock (S8063) [NG 624 217], upper part of Balnakiel group (sponge-bearing zone), 600 yards north of Suardal Farm: anal. W. Pollard, *Summary of Progress* for 1898, p. 198. The analysis gives the molecular ratios:

CaO : MgO : CO2 = 1.03 : 1 : 1.91.

The slice shows merely a crystalline aggregate of dolomite with rare grains of calcite and a few little granules probably of diopside.

II. Dolomite-rock (S8064) [NG 622 196], lower part of Balnakiel group (concentric ring zone), 625 yards N.W. of Loch Lonachan and just east of Boreraig footpath: anal. W. Pollard, *ibid.* The molecular ratios found are:

CaO : MgO : CO2 = 1.05 : 1 : 2.02. Slice identical in appearance with the preceding.

A. Dolomite-rock (S8130) [NC 43 67], Eilean Hoan, 2½ miles east of Durness, Sutherland, for comparison: anal. W. Pollard, *ibid.* Molecular ratios:

CaO : MgO : CO2 1.06 : 1 : 2.07.

Some of the most striking appearances are found in connection with a remarkable structure peculiar to the lower half of the Balnakiel group in this district, the zone or sub-zone which is usually the one in immediate contact with the gabbro and granite, and in which the marble-quarries are situated. The structure consists of a system of numerous concentric rings or shells, building up a spheroidal body several inches or even a foot in diameter. These are most conspicuous on a weathered face of the metamorphosed rock, where some rings stand out more than the intervening parts, owing to their more siliceous composition, and are found to be made up chiefly of serpentine and other silicates. Although this structure is most prominent in the highly metamorphosed rocks, it is probably to be regarded as an original peculiarity further developed and accentuated by metamorphism. While not itself, so far as we can discover, an organic structure, it seems to stand in relation to organic bodies. Towards the top of the strata in question concentric shell structures with less perfect development constantly encircle sponge-forms, thus affording a transition to the upper Balnakiel limestone, characterised by sponges of similar form without the surrounding rings. It may be conjectured that the typical concentric shell structure has originated in connection with a sponge now destroyed, the silica of which has gone to enrich certain shells of the immediately surrounding rock. Some interest attaches to these curious bodies from the closeness with which they reproduce the micro-structures of the so-called Eozoon, a subject sufficiently dealt with by Professors King and Rowney.<ref>*Quart.* Journ. *Geol. Soc.,* vol. xxii., pp. 185–218: 1866. *Rep. Brit. Assoc.* for 1870, Sections p. 78 (abstract only). *An Old Chapter of the Geological Record,* pp. xvi., 11, 41, etc.: 1881.</ref>

The succeeding zone or sub-zone, representing the upper part of the Balnakiel group of Durness and characterised in Skye by its abundance of sponges, only locally comes within the area of most intense metamorphism, but nevertheless shows a noteworthy formation of new minerals even at considerable distances from the granite. The metamorphism of the sponges is here the principal point of interest. The outer crust of each is replaced usually by a matted aggregate of tremolite fibres, mixed with granular calcite, giving a rather silky lustre on a hand-specimen (S6736) [NG 627 194], (S6739) [NG 628 213]. In the interior diopside has usually been formed instead of tremolite, and the granular aggregate of carbonates in which this is embedded is largely dolomite (S6798) [NG 622 219].

The Croisaphuill limestone, characterised by the presence of small black cherts of irregular shape, is farther from the granite, but it too has been in some places considerably metamorphosed. The effects are usually not very evident in the field, but to this there are exceptions. One specimen, for example, shows a weathered face studded with minute light-coloured crystals, about 1/20 inch long, which are found to be diopside (S6745) [NG 628 202]. This mineral seems to be the commonest new-formed silicate in this group.

The metamorphosed dolomitic limestones as a whole afford a considerable number of new minerals, prominent among which are silicates containing lime and magnesia, and especially those rich in magnesia. Tremolite and diopside have already been mentioned. The former occurs usually in little needles, massed or felted together in patches, and is very common in the outer portion of the metamorphic aureole of Beinn an Dubhaich, especially in connection with sponge-forms. Diopside is very widely distributed, both in the less altered and the more altered rocks. It usually forms rather rounded crystal-grains of small size; but is sometimes large enough to be easily visible to the eye, and then often shows good crystal-forms. A rock about ¼ mile S.E. of Suardal contains nodular masses an inch or two in diameter composed wholly of this mineral, the individual crystals ranging up to ■ inch in length (S6738) [NG 625 207]. The diopside is always colourless in thin slices, and visible crystals are white with the lustre and general aspect of a felspar. Another interesting mineral is the magnesian olivine, forsterite, which appears to be very common, and has probably been more so, being now often replaced by serpentine. It has been identified by Mr Teall, and two examples analysed by Dr Pollard (*see* p. 149). In thin slices<ref>See Harker, *Petrology for Students,* 3rd ed., Fig. 73; 1902.</ref> it is often difficult to distinguish from diopside, occurring commonly in the form of rounded grains with the same general characters as the latter mineral. The forsterite is usually more rounded than the diopside, and when they occur together the less perfect cleavage is also a point of distinction (S6739) [NG 628 213] In some cases, however, the forsterite builds well-shaped crystals of characteristic form (S6805) [NG 623 200]. Only exceptionally is it to be identified on a hand-specimen; but some examples show it projecting on a weathered face in the form of abundant little whitish tabular crystals, up to ¼ inch in diameter (S6743) [NG 625 195].

Other minerals are of more local distribution. Little flakes of silvery white mica are scattered through some parts of the highly metamorphosed lower Balnakiel limestone of the granite area. They lie along certain bands, but have no parallel orientation (S6744) [NG 627 197]. In one place there are nests about two inches in diameter consisting of a pale green talcose mineral in large flakes (S6740) [NG 624 206]. At Camas Malaig, not far from the granite-contact, we find small nodular patches composed of idocrase and garnet (S6782) [NG 579 198]. In one specimen only, at about 500 yards W.S.W. of Kilbride, have we observed small octahedra of a violet spine! (S7083) [NG 588 209]. There is also an opaque sulphide, probably pyrrhotite, in the same rock.

The metamorphosed representatives of the Cambrian limestones include not only rocks composed of carbonates and new-formed silicates, but also in places others which consist essentially of calcite and some hydrated magnesian mineral, the latter presumably formed subsequently at the expense of some product of thermal metamorphism. Of these rocks we may distinguish two types; the ophicalcites, composed of calcite and serpentine, and the predazzites and pencatites, composed of calcite and brucite.

	I	II	A	B
SiO_2	42.6	41.5	42.2	41.16
Al_2O_3	1.2	0.9	0.8	1.02
FeO	1.1	1.3	0–5	2.00
MnO				0.26
MgO	51.2	55.6	57.0	54.86
CaO	0.6	0.3	0.3	0.26
Ignition	3.1	1.2	0.3	0.70
	99.8	100.8	101'1	100.26
Specific gravity				3.24

I. Forsterite, forming tabular crystals in pale grey marble (metamorphosed representative of Balnakiel group) (S6743) [NG 625 195], ½ mile W. by N. of outlet of Loch Lonachan: anal. W. Pollard, *Summary of Progress* for 1900, p. 156. In this and the following analyses the iron was estimated as ferric oxide, but is calculated to ferrous. The molecular ratio, MgO: SiO_2 = 1.8 : 1.

II. Forsterite, forming rounded grains in banded serpentinous marble (lower part of Balnakiel group) (S6783) [NG 579 198], near shore north of Camas Malaig, Torran: anal. W. Pollard, *ibid.* This mineral is the source of the serpentine in the rock. Molecular ratio, MgO : SiO_2 = 2.00 : 1.

A. Forsterite from marble of Ledbeg, Sutherland (S3099) [NC 25 12]: anal. W. Pollard, *ibid.* Molecular ratio, MgO: SiO_2 — 2.02: 1.

B. Forsterite, forming grains in the Glenelg Limestone (S7923) [NG 832 187], rather more than ■ mile east of Sgiath Bheinn, Glenelg, Inverness-shire: anal. W. Pollard, *Quart. Journ. Geol. Soc.,* vol. lv., p. 379: 1899. Traces of TiO_2 and F.

The ophicalcite type is found in some parts of the lower Balnakiel limestone, where the rock is a rather coarsely saccharoid marble abundantly streaked and banded on a small scale with sulphur-yellow serpentine. The same thing is seen in the concentric-shell structures in these rocks, already mentioned. Good specimens can be obtained in the more southerly of the two small quarries by the Boreraig foot-path or at Camas Malaig near Torran (S6804) [NG 616 200], (S6783) [NG 579 198]. The serpentine has clearly been formed from grains of a silicate-mineral, portions of which often remain undestroyed. In many cases at least this parent-silicate is forsterite: whether diopside has also contributed is a question which we have not certainly decided.

The predazzite and pencatite type<ref>It is most in accordance with the original usage to employ the name pencatite for an aggregate of calcite and brucite in *equal molecular proportions, i.e.* with the percentage composition of 63.3 calcite to 361 brucite, reserving the name predazzite for varieties richer in calcite. The calculated specific gravity of typical pencatite should then be about 2.57, predazzite being denser.</ref> is found in several localities. Some of the grey or mottled white and grey rocks in the area of extreme metamorphism next the granite belong here; but the purest example comes from the small quarry near the southern angle of the Glebe fence. The rock here is of fine texture and dull white colour, and has the specific gravity 2.574. A slice. (S7082) [NG 617 202] shows a calcite mosaic enclosing abundant grains of a colourless mineral of low refringence and rather high birefringence, which has been identified by Mr Teall as brucite.<ref>A specimen from Ledbeg, in Sutherland, isolated and analysed by Dr Pollard, gave very closely the formula $Mg\ H_2O_2$. see Summary *of Progress of Geol.* Sur. for 1900, p. 155.</ref> Much of it shows a fibrous structure or sometimes a more confused arrangement, and it is doubtless pseudomorphic. In other cases the mineral shows a finely granular structure. In no instance are any relics preserved of the mineral which the brucite replaces, and the outlines are not characteristic, being always more or less rounded; but it may be supposed with much probability that the brucite comes from the hydration of periclase formed in the metamorphism of a magnesian limestone.

Mr Teall's researches on the marbles of Sutherland and Skye bring out a principle of great interest and doubtless of wide application, viz. the *de-dolomitisation* of dolomitic limestones by thermal metamorphism. In the Strath district, outside the metamorphic aureoles, both divisions of the Balnakiel group are found in general, though not everywhere, to be completely dolomitised. In the metamorphosed equivalents of these rocks, the carbonate is as a rule calcite, dolomite being usually absent, or present only in subordinate amount. This results from the fact that the new-formed minerals have taken up magnesia in preference to lime,<ref>We have found no simple lime-silicate. Heddle records wollastonite from "Coire Nuadh" [perhaps Coire Beithe] of Beinn na Caillich, *Mineralogy of Scotland,* vol. ii., p. 29: 1901.</ref> thus reducing the ratio of magnesia to lime in the residual carbonate or, in other words, converting a large part or the whole of the dolomite to calcite. Of the common minerals produced in the metamorphism of these rocks, the forsterite (with its derivative product serpentine) is purely magnesian, and its formation would necessarily set free a corresponding amount of calcite from the destruction of the double carbonate. The same is true of periclase and brucite. Tremolite, containing both bases but magnesia considerably in excess of lime, indicates a selective effect of the same kind but in a less degree. Diopside, if corresponding with Tschermak's formula, contains lime and magnesia in equal molecular proportions; but if there has been to any extent a subsequent alteration of this mineral to serpentine and calcite, de-dolomitisation has in this case been arrived at by two stages. It appears then that the calcite in the marbles is itself to be regarded as a new-formed mineral of metamorphism. That it has at least been recrystallised during the metamorphism might be inferred from its relation to the silicate-minerals as seen in thin slices.

It may be enquired whether de-dolomitisation is adequate to account completely for the comparative scarcity of dolomite in the highly metamorphosed rocks; and a full answer to this question would involve bulk-analyses of the marbles (carbonates, silicates, etc., together) to determine the molecular ratio of lime to magnesia. One such analysis has been made, and gives an affirmative answer to the question. The rock consists apparently of calcite, forsterite, and a colourless mica; and the partial analysis here quoted shows that the molecular ratio CaO : MgO = 1.08 : 1, agreeing with dolomite.

SiO_2	15.96
Al_2O_3	0.74
Fe_2O_3 (total iron)	0.70
MgO	21.43
CaO	32.17
Ignition	29.22
	100.22

Marble (S6744) [NG 627 197], metamorphosed lower Balnakiel Limestone, ½ mile W.N.W. of outlet of Loch Lonachan: anal. W. Pollard, *Summary of Progress* for 1900, p. 157. This analysis gives the molecular ratio CaO: MgO = 1.08: 1.

Another rock which may be recalled in this connection is that of the small quarry near the Glebe fence. As stated above, it is one of the predazzite-pencatite type, and since it is composed merely of calcite and brucite, its specific gravity is sufficient to determine roughly the proportions of the two minerals. The calculation shows that lime and magnesia must be present in about equal molecular proportions, as in dolomite. This rock seems then to be a typical pencatite.

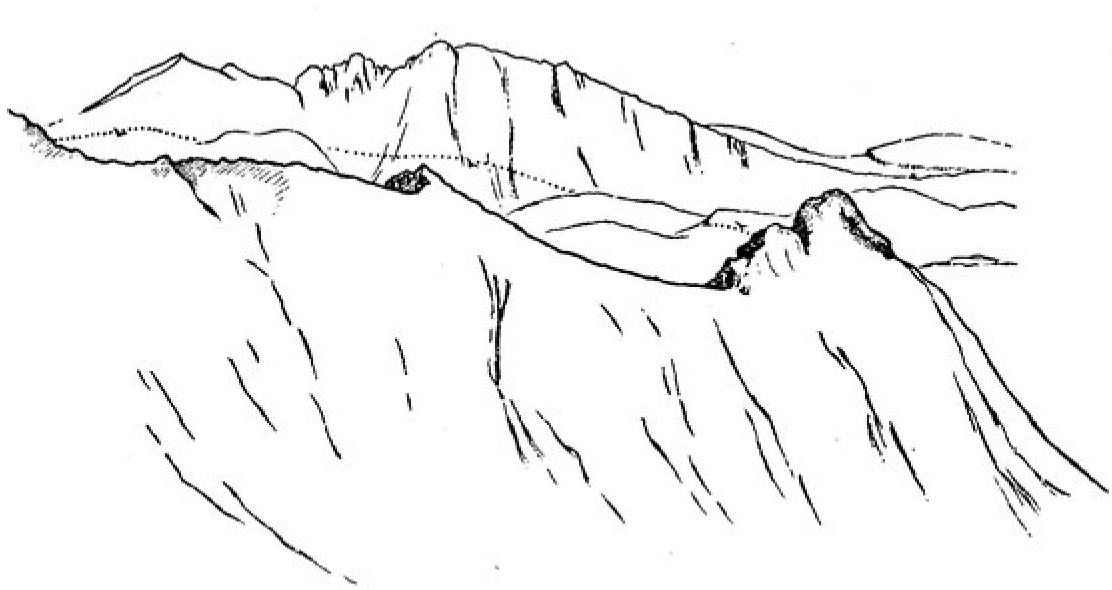

FIG. 25.—View from Bealach a' Leitir, looking east and south-east. In the foreground is the south-easterly spur of Sgùrr nan Gillean, terminating in Sgùrr na h-Uamha; in the distance the Blaven range. Both these are of gabbro, while Strath na Creitheach and the low hills in the middle distance are of granite, underlying the gabbro. The junction is indicated· by the dotted line on the slopes of Garbh-bheinn, Blath-bheinn, and Druim an Eidhne.

(Figure 25) View from Bealach a' Leitir, looking east and south-east. In the foreground is the south-easterly spur of Sgùrr nan Gillean, terminating in Sgùrr na h-Uarnha; in the distance the Blaven range. Both these are of gabbro, while Strath na Creitheach and the low hills in the middle distance are of granite, underlying the gabbro. The junction is indicated. by the dotted line on the slopes of Garbh-bheinn, Blath-bheinn, and Druim an Eidhne.

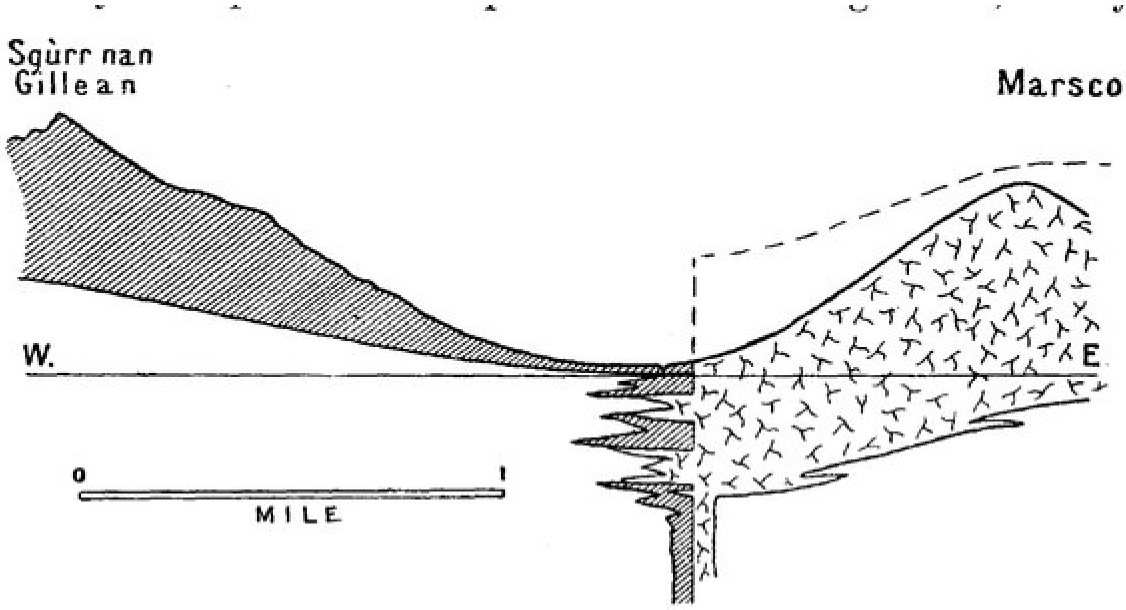

Fig. 26 —Section across Glen Sligachan from Sgùrr nan Gillean (gabbro) to Marsco (granite), to illustrate the supposed nature of the western boundary of the granite in this part.

(Figure 26) Section across Glen Sligachan from Sgùrr nan Gillean (gabbro) to Marsco (granite), to illustrate the supposed nature of the western boundary of the granite in this part.

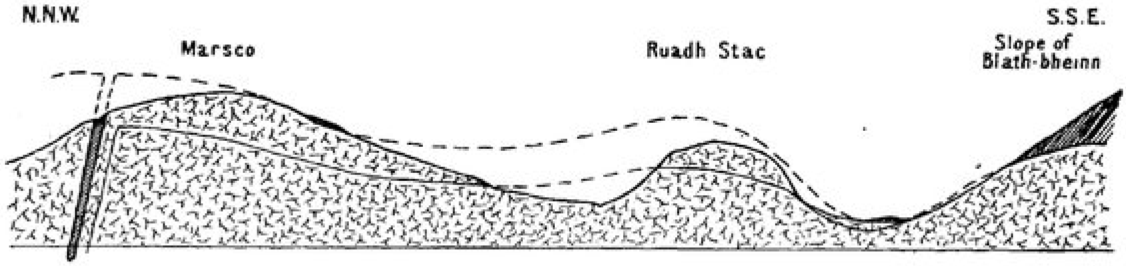

Fig. 27.—Section along a rather sinuous line through Marsco and Ruadh Stac, to illustrate the supposed manner of intrusion of the granite. Scale, 1½ inch to a mile.

(Figure 27) Section along a rather sinuous line through Marsco and Ruadh Stac, to illustrate the supposed manner of intrusion of the granite. Scale, ½ inch to a mile.

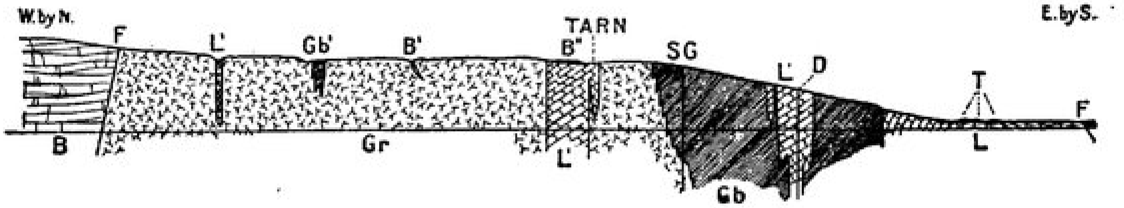

Fig. 28.—Section through Lochain Beinn na Caillich and towards Broadford, crossing the northern part of the granite boss of Beinn na Caillich and the southern part of the gabbro boss; scale, 2 inches to a mile.

F, F are faults, the easterly one bringing on the Lias (Pabbay Shales).

L, Cambrian Limestone (Balnakiel group); B, basaltic lavas; Gb, gabbro; Gr, granite.

L′, B′, Gb′ are enclosed patches of limestone, basalt, and gabbro; B″, an outlier of the basalt resting on an enclosed patch of limestone; T, small outliers of Torridonian upon the limestone, with a thin sheet of granophyre intruded along the dividing "thrust-plane."

S G, dyke of spherulitic granophyre; D, dyke of basalt.

(Figure 28) Section through Lochain Beinn na Caillich and towards Broadford, crossing the northern part of the granite boss of Beinn na Caillich and the southern part of the gabbro boss; scale, 2 inches to a mile. F, F are faults, the easterly one bringing on the Lias (Pabbay Shales). L, Cambrian Limestone (Balnakiel group); B, basaltic lavas; Gb, gabbro; Gr, granite. L′, B′, Gb′ are enclosed patches of limestone, basalt, and gabbro; B″, an outlier of the basalt resting on an enclosed patch of limestone; T, small outliers of Torridonian upon the limestone, with a thin sheet of granophyre intruded along the dividing "thrust-plane". S G, dyke of spherulitic granophyre; D, dyke of basalt.

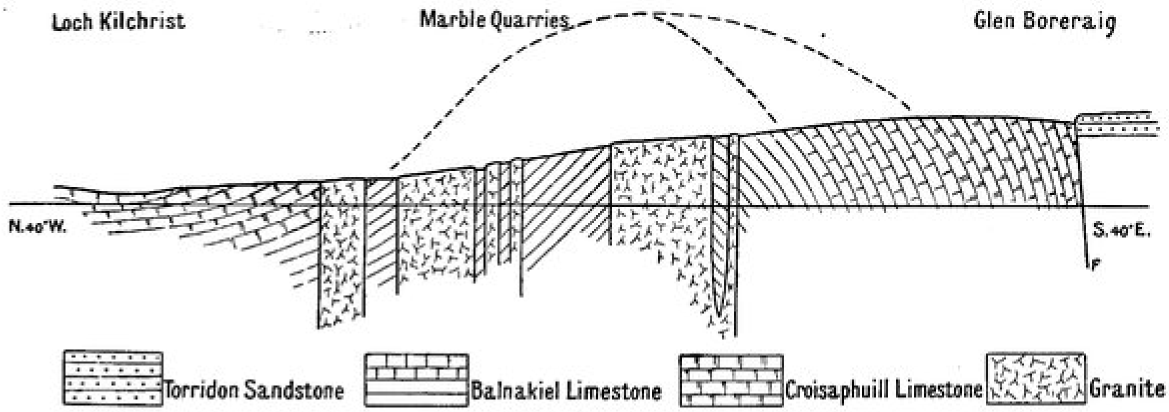

FIG. 30.—Section from Loch Kilchrist to Glen Boreraig, through the old marble quarries. Scale, 4½ inches to a mile. The line of section, passing between Beinn an Dubhaich and Beinn Suardal, does not cross the widest part of the granitic mass. It shows the anticline of the Cambrian limestones with the granite cutting vertically through it.

(Figure 30) Section from Loch Kilchrist to Glen Boreraig, through the old marble quarries. Scale, 4½ inches to a mile. The line of section, passing between Beinn an Dubhaich and Beinn Suardal, does not cross the widest part of the granitic mass. It shows the anticline of the Cambrian limestones with the granite cutting vertically through it.

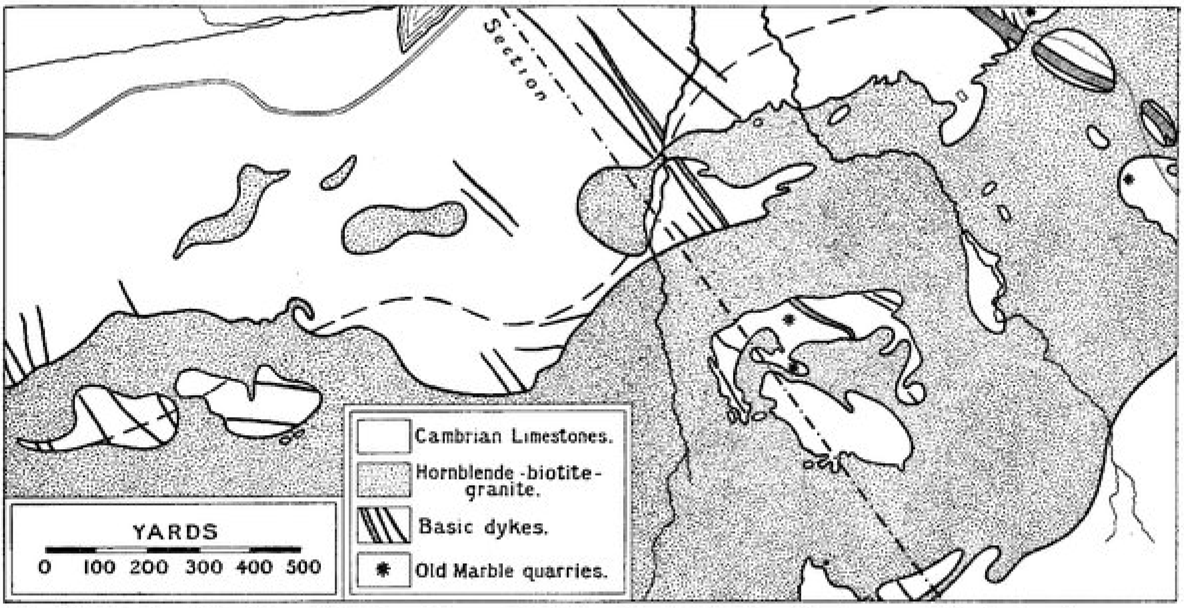

FIG. 29.—Map of part of the Beinn an Dubhaich granite mass, showing its relation to the Cambrian limestones: scale, 6 inches to a mile. The area included lies to the south of the high-road and of Loch Kilchrist, the head of which is shown on the northern border of the map. The ground to the north of the high-road is covered by alluvium, concealing the junction of the Cambrian with the volcanic agglomerate of the Kilchrist vent. The limestones have been both dolomitised and metamorphosed, the metamorphism having to a great extent brought about de-dolomitisation, as described below. The broken line marks the division between the Balnakiel and Croisaphuill groups, the former (lower) being the nearer to the granite axis, with an anticlinal arrangement.

Only a few of the numerous basic dykes are shown. Of those outside the main granite boundary, some are pre-granitic and cut off by the granite, others are post-granitic and stopped by the granite: the dykes in the enclosed patches of limestone all belong to the former category. No dykes intersect the granite.

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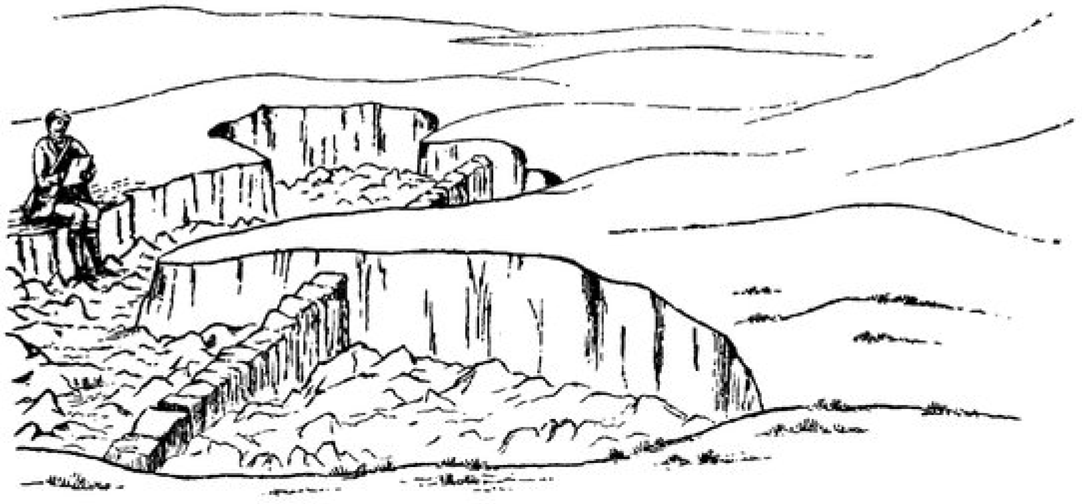

FIG. 31.—Relations of granite and marble (metamorphosed Cambrian limestone) on the lower slopes of Beinn an Dubhaich. This figure represents a typical view of the junction of the two rocks, idealised only to the extent of omitting the heather and bracken which partly conceal the ground. A pre-granitic dolerite dyke is shown intersecting the marble and sharply cut off by the granite.

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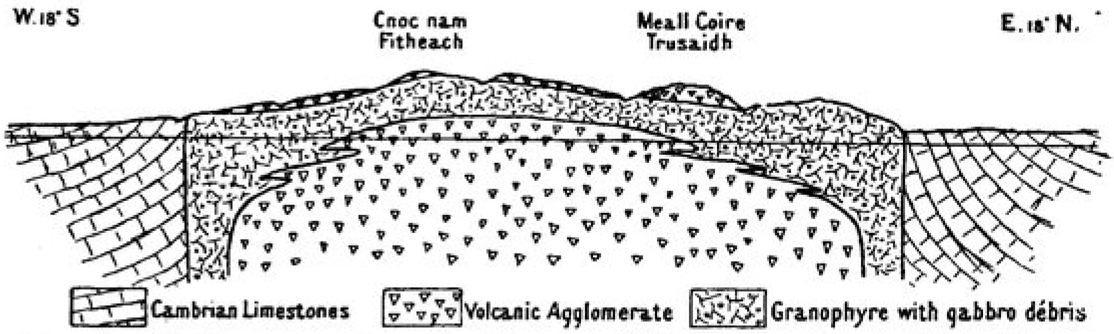

FIG. 4.—Section across the volcanic vent of Kilchrist; showing the volcanic agglomerate breaking through a sharp anticline of Cambrian limestone, and itself invaded by a later intrusion of a peculiar granophyre, full of débris of gabbro, to be described later. Scale, 1½ inch to a mile.

(Figure 4) Section across the volcanic vent of Kilchrist; showing the volcanic agglomerate breaking through a sharp anticline of Cambrian limestone, and itself invaded by a later intrusion of a peculiar granophyre, full of debris of gabbro, to be described later. Scale, 1½ inch to a mile.

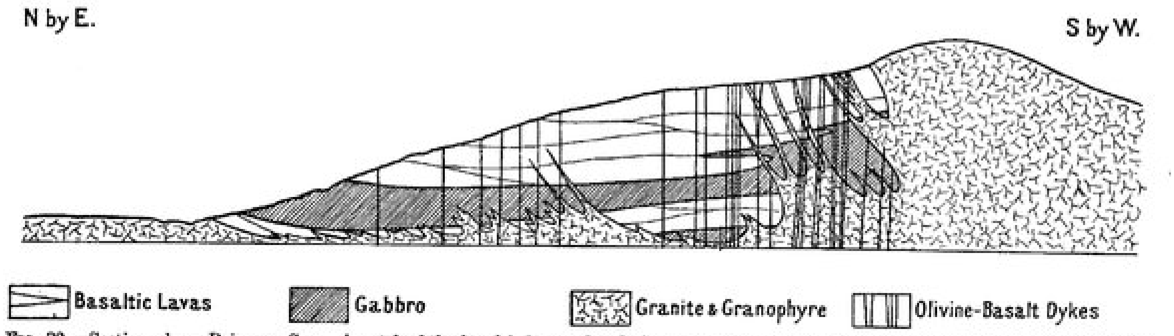

FIG. 32.—Section along Beinn na Cro. A patch of the basaltic lavas, already invaded by sheets of gabbro, has been enveloped in the granite of the Red Hills, which sends numerous offshoots in the form of tongues and dykes through the enclosed mass. The whole is intersected by later dykes of olivine-basalt. Scale, 4 inches to a mile.

(Figure 32) Section along Beinn na Cro. A patch of the basaltic lavas, already invaded by sheets of gabbro, has been enveloped in the granite of the Red Hills, which sends numerous offshoots in the form of tongues and dykes through the enclosed mass. The whole is intersected by later dykes of olivine-basalt. Scale, 4 inches to a mile.

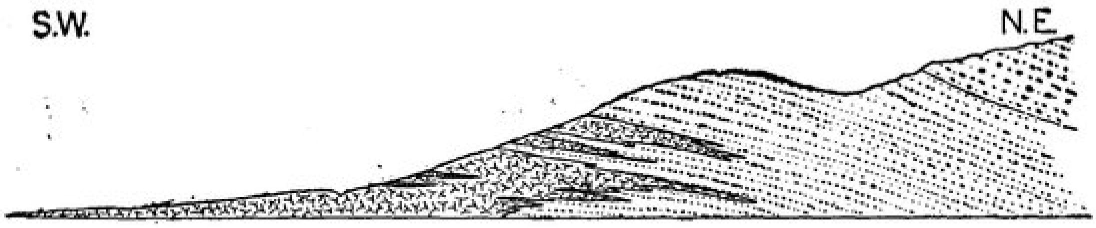

FIG. 33.— Section in the south-western part of Scalpay, from Corran a' Chinn Uachdaraich, showing the relation of the granite to the Torridonian strata. The former is the edge of the large mass building the Red Hills, which here terminates in a number of tapering sheets. Scale, 3 inches to a mile.

(Figure 33) Section in the south-western part of Scalpay, from Corran a' Chinn Ijachclaraich, showing the relation of the granite to the Torridonian strata. The former is the edge of the large mass building the Red Hills, which here terminates in a number of tapering sheets. Scale, 3 inches to a mile.

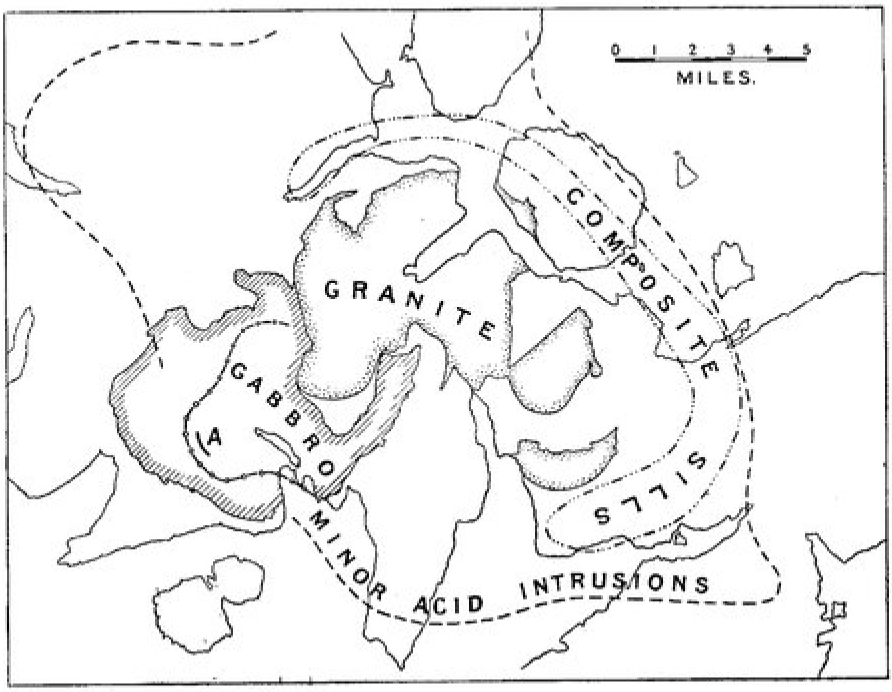

FIG. 58.—Sketch-map illustrating the distribution of certain groups of acid intrusions in relation to the granite of the Red Hills. Scale, ¼ inch to a mile.

(*a.*) The line (of small circles connected by dashes) in the gabbro area indicates the western limit of granite and granophyre veins, in so far at least as they are locally abundant and noticeable, in the gabbro of the Cuillins. It may probably be taken as showing, with rough approximation, the concealed extension of the granite beneath the gabbro laccolite.

(*b.*) The roughly semicircular belt, enclosed by a line of dots and dashes, marks the distribution of the peculiar composite (basic and acid) intrusions of the symmetrical kind, which we have distinguished as the Cnoc Càrnach type.

(*c.*) The heavy broken line indicates the area of distribution of the minor acid intrusions in general. It is an irregular oval, about 24 miles long, centring in the granite of the Red Hills, and having its long axis in a direction nearly agreeing with that of the dykes.

(*d.*) The short heavy line at A marks the position of the peculiar felsite of the Alaisdair Stone-shoot.

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