Chapter 14 Rocks of Lower Old Red Sandstone age Ben Nevis

Introduction

In the present chapter the term "granite" between inverted commas will be employed, once again, in the popular sense to include both granite and quartz-diorite (also trondhjemite), especially in relation to the two big units shown as Outer Granite and Inner Granite in (Figure 31) (see also 1, (Figure 18)). These two titles are convenient in describing field relations, and escape petrographical error if we enclose Granite in each case between inverted commas. The major features of the Ben Nevis story were discovered by Maufe (1910). His field work, however, consisted to a considerable extent in revision of previous incomplete mapping; and he had no time to subdivide the Outer "Granite" beyond recognising in it a prevalent pink porphyritic type (4 of (Figure 31)) merging rapidly outwards into a generally grey non-porphyritic margin (1–3 of (Figure 31)). Since then J. G. C. Anderson has added much of interest in regard to the Outer "Granite" by subdividing its non-porphyritic margin (1935), and his results are incorporated in (Figure 31) and in the text which follows with due acknowledgment. The present writer had the opportunity of checking these results in the field under Anderson's guidance before the 1935 account appeared, and he then accepted them as essentially correct. In recent years, however, J. E. Wright has completed the Geological Survey mapping of the part of Sheet 62 (north of Sheet 53, both Geol.), into which the Ben Nevis Complex extends, and has reached an intermediate position. He agrees that Anderson is justified in recognising a sequence of intrusion in Maufe's non-porphyritic margin, and that in Allt na Caillich what Anderson refers to as Subzone 1 of (Figure 31) is pierced by veins referable to Sub-zone 3; but elsewhere he considers that there is too much variation and too much mingling of type to allow of confidence in the merging junctions drawn by Anderson to separate Subzone 1 from 2, and 2 from 3. Apart from this, Maufe, Anderson and Wright, all agree that the outer boundary of Subzone 4 can be traced with approximate accuracy, though usually of merging type (wherever it makes contact with Subzone 3); and Wright confirms Anderson's claim that this merging type of junction gives place to an abrupt junction on the two sides of Allt Daim [NN 179 740] (where Subzone 4, according to Anderson, makes contact with Subzone 1). All told, the differences between Anderson and Wright are not crucial, but they should be borne in mind in reading the following pages. Also all the new work fits so easily into Maufe's that it has been thought proper to retain the latter's initials at the end of this important chapter. The later contributions are self-evident interpolations. It may be added that exposures have deteriorated somewhat since Maufe and Anderson's days owing to afforestation and to underground diversion of the waters of Allt a' Mhuilinn [NN 161 730] and of its neighbour on the south. E. B. B.

The Ben Nevis massif is geologically divisible into three well-defined concentric zones (Figure 31), which, reckoned from without inwards, are as follows:

1. A discontinuous, complex, outer ring, known as the Outer "Granite", steeply bounded externally against contact-altered schists. This Outer "Granite" has three successively younger non-porphyritic Subzones, numbered 1–3 in (Figure 31); all three are as a rule quartz-diorite and carry augite. Then follows a still younger, porphyritic Subzone 4 which is a medium-grained pink granite with large phenocrysts of perthitic orthoclase.
2. A continuous inner ring, known as the Inner "Granite", with steep intrusive exterior and interior margins. This is of later date than the Outer "Granite". Rather strangely, though more acid and poorer in ferromagnesian minerals than the latter, it is richer in plagioclase, and much of it is now classed as trondhjemite. It is further distinguished by its finer and more even texture. It does not chill at its outer margin against Zone 1, but along its interior margin against Zone 3 it rapidly passes into rhyolite or andesite with vertical, streaky flow-structure. Recent re-examination has shown that this rhyolite is, in some cases at least, separated from the rocks of Zone 3 by a thin layer of flinty crush-rock (p. 162).
3. A central core, consisting of some 2000 ft of volcanic rocks, and an unknown thickness of underlying schists; the volcanic rocks are hornblende-andesite lavas, with a fair proportion of agglomerate; a few thin bands of associated sediment are also found, and the whole mass is disposed in a basin with steeply tilted margins. At two localities along the edge of the basin underlying schists are exposed to view, in one case forming a strip 200 yards long. They are phyllites, presumably belonging to the Leven Schists though their regional metamorphism is of much lower grade than that of the Leven Schists outside the igneous complex (p. 72).

A glance at (Figure 18), p. 129, shows that the Ben Nevis "Granite" has a retinue of dykes comparable with that of the Etive Complex. These dykes are porphyrites, lamprophyres, and allied types. Anderson has found a small group in Sheet 62 (Geol.) to the north of Sheet 53 to be earlier than the earliest Subzone (1) of the Outer "Granite" (1935b, pp. 248, 259, 260); but the great majority cut and chill against the latest Subzone (4) of this intrusion. Here most of them are in turn cut across by the Inner "Granite", though a very few penetrate this latter for a short distance. Thus, as in the case of the Etive Complex, the main dyke phase intervened between the intrusion of the two most important members of a "granite" pluton. We shall return to the Ben Nevis Dyke-Swarm in chapter 16.

The tourist path leading from Achintee [NN 125 730] to the top of Ben Nevis affords an opportunity of verifying many of the foregoing statements. In ascending it one meets with banded green and white calc-silicate-hornfels before reaching grey non-porphyritic quartz-diorite representing Subzone 3 of the Outer "Granite". Subzones 1 and 2 are missing here. Subzone 3 is 400 yards wide, and is cut by a couple of lamprophyric dykes. Beyond, for half a mile, the path traverses pink porphyritic granite, Subzone 4 of the Outer "Granite". This is traversed by many lamprophyric and porphyritic dykes, and also, near the bridges, by a quite distinct basaltic dyke, shown on Sheet 53, which has a general W.N.W. trend and is probably of Tertiary age. Beyond this the path, in its zig-zag course approaching Lochan Meall an t-Suidhe [NN 138 729], thrice crosses the junction of the Outer and the Inner "Granites". The difference of character can easily be recognised. The belt of Inner "Granite" when finally entered upon is found to be about a third of a mile wide, and is fairly well exposed in its more easterly portion. The last 1500 feet of the ascent are accomplished over frost-riven rubble of andesite and agglomerate. On the plateau below the summit, at about the 4000-foot level, a mass of agglomerate is exposed, containing abundant fragments of quartzite and phyllite.

From the number of blocks showing a brecciated structure on their weathered surfaces it might be thought that agglomerates constituted a large part of the volcanic pile. A closer examination reveals the fact that many of the apparent agglomerates are andesites, affected by flow-brecciation. These flow-breccias are particularly common in the upper portions of lavas. They may be conveniently studied in the small crags lying to the right of the path on reaching the summit plateau, and also around the cairn on that Càrn Dearg which lies north-west of the summit.

A more detailed account of the various geological units of the hill will now be given in reverse order.

Volcanic pile

It is perhaps possible to separate two varieties among the hornblende-andesite lavas, one with abundant biotite, in addition to hornblende, the other with pseudomorphs, which probably represent a rhombic pyroxene. For the rest they exhibit only those small variations in composition and texture, which enable one to separate flow from flow but are otherwise of no particular interest.

The unstratified masses of agglomerate, which frequently intervene between the lavas, consist of angular blocks of hornblende-andesite of all sizes up to 4 feet in length. Mixed with these are blocks of red porphyritic felsite and occasional pebbles of quartzite and lumps of phyllite. It is often a matter of great difficulty to separate these compacted agglomerates from the lavas that show brecciform structure, and include xenoliths. Very fine exposures of agglomerate are afforded in the glaciated crags towards the head of Allt a' Mhuilinn [NN 161 730].

The finer-grained parts of the agglomerate may show a certain amount of stratification, and pass gradually into the coarse-grained sediments associated with them. No tuffs with typical ash-structure have been discovered on Ben Nevis. Such rocks are indeed very rare in the related volcanic series of Lorne and Glen Coe.

The sedimentary rocks accompanying the extrusive series include green sandy shales, dark shales with slightly calcareous bands, and a conglomerate composed chiefly of quartzite pebbles. These rocks, which are present in insignificant proportions, closely resemble the sediments intercalated in the volcanic series of Glen Coe, though on Ben Nevis no fossils have as yet been obtained.

It was thought by some early observers that the volcanic pile reposes upon the surrounding "granite". As a matter of fact the Inner "Granite" is bounded by a vertical chilled margin against the volcanic group — a relation especially well seen in the ridge at the head of Allt a' Mhuilinn [NN 161 730], south-east of the summit. The junction is on the whole smooth, although breached here and there by an occasional tongue emanating from the "granite". The lavas undergo changes through contact-metamorphism similar to those exhibited by andesites in other districts, with notable development of new biotite and hornblende, both in the groundmass and in the phenocrysts. The disposition of these altered rocks is quite in accord with what one might expect from the vertical course of the "granite" margin. The altered rocks form a rim round the volcanic massif, and extend up to the level of the summit, some hundreds of feet above the highest point now reached by the "granite". Towards the centre of the massif the alteration dies away, irrespective of level.

We have already anticipated the question: On what foundation does the volcanic series rest, if not upon "granite" ? It is seen at two places resting unconformably upon the Highland schists in just the same manner as do the extrusive rocks of Lorne and Glen Coe. The larger and clearer exposure illustrating this relation is situated in Allt a' Mhuilinn [NN 161 730], a short distance below the foot of the huge precipice north-east of the summit (Plate 10). Here contorted phyllites crop out beside the stream for a distance of 200 yards. Resting against them in unconformable relation is a basement conglomerate, largely made up of quartzite pebbles, and 8 feet in thickness. Following it come about 40 feet of indurated black shales with slightly calcareous layers, and then the lowest lava, a typical hornblende-andesite. Agglomerates and lavas succeed one another up to the summit, with a total thickness of probably not less than 2000 feet, and uninterrupted save for a couple of bands of dark shale. One of these bands has been followed for a short distance in the crags north of the two little lochans close together on the corrie floor, half a mile north-west of the summit.

The basement beds are traceable at intervals for more than half a mile along the eastern side of the central massif, and are then cut out in both directions by the bounding wall of "granite". It is important to note that along the whole line the beds are dipping steeply inwards towards the centre of the volcanic mass. In one section, indeed, there appears to be a slight inversion. In places, too, the shales are contorted, the sharp folds being frequently fractured, and their limbs displaced. In Coire Gamhnean [NN 152 712], on the south-western side of the hill, where phyllites are once more exposed for a short distance between the "granite" and the lavas, the dip of the latter is again inclined inwards at a high angle. Passing from the edge towards the centre of the mass the dip diminishes, sometimes very rapidly, until on the summit ridge the beds are rolling at low angles. Evidently the volcanic massif of Ben Nevis has a basin structure and, surrounded as it is by a "granite" with vertical chilled margins (Figure 31), it presents a close analogy with that of Glen Coe.

Inner "Granite"

The edge, which the Inner "Granite" of Ben Nevis presents to the central volcanic massif, has already been described as "chilled". The result is a marginal zone of fine-grained rhyolite, with small, scattered phenocrysts of felspar and biotite, and with a strong, streaky flow-structure parallel to the vertical junction, along which a seam of flinty crush-rock is developed in (S14044) [NN 1661 7067]; (S14045) [NN 1655 7240]. This flinty crush-rock erodes the rhyolite as has been described in detail at Glen Coe (p. 162). The flow-structure of the rhyolite is even more apparent than that of the neighbouring andesite lavas. The external margin of the same "granite" is not marked by any such evidence of chilling, though it frequently assumes a grey colour in place of the normal pink colour.

The separation of the Inner and Outer "Granites" is perfectly definite. In Allt Daim [NN 179 740] an instructive section of the junction is exposed, in which the Inner "Granite" cuts right across an elongated "basic secretion" in the Outer, so that there can be no doubt that the Inner is the later of the two.

That the interval of time which separated the intrusion of the Inner "Granite" from that of the Outer was considerable is shown by the fact that the main phase of dyke injection intervened. The Outer "Granite" is freely cut by porphyritic and lamprophyric dykes which show no sign of falling off in numbers as one proceeds inwards into the "granitic" complex, until, suddenly, on reaching the Inner "Granite", scarcely a dyke is to be found. As a matter of fact only three such dykes have been detected in the Inner Granite — all of them in or close to Allt Daim [NN 179 740].

Strong as this evidence is, it is not by itself quite conclusive: the three dykes found within the Inner "Granite" all occur close to the margin so that it looks as though the Inner "Granite" may have presented special difficulties to dyke intrusion. Can impenetrability alone account for the absence from the Inner "Granite" of the great swarm of dykes which intersect the Outer ? Fortunately this doubt can be silenced, for in five clear instances the Inner "Granite" is seen cutting right across dykes which traverse the Outer; and in a great number of cases, where bare junctions are not exposed, dykes can be traced so close to the margin that the only feasible interpretation is that they are truncated by it. The five crucial examples are located as follows:

Two in gullies traversing the crags above Allt Daim [NN 179 740], 1100 yards S.S.E. of the point at which the junction of the Inner "Granite" crosses the stream (S14047) [NN 1817 7396] dyke cutting Outer "Granite"; S 14048 same dyke cut by Inner "Granite").

Another, 400 yards farther S.S.E. along the same line of crags (S14048a) [NN 1821 7386] dyke.

Two in Allt Coire Gaimhnean [NN 140 705], the stream at the head of which the more southerly outcrop of the schists underlying the lavas of Ben Nevis is exposed (S14049) [NN 1421 7064] dyke undoubtedly cut by Inner "Granite", (S14050) [NN 1421 7064], although the junction is hidden).

To this we may add that many of the dykes which cut the Outer "Granite" show contact-alteration under the microscope.

The margin between the Inner and Outer "Granites" is inclined very steeply outwards.

Outer "Granite"

Anderson (1935b) has described and illustrated by appropriate maps the distribution and behaviour of the four Subzones of the Outer "Granite". Here we need only briefly summarise his results. The three outer non-porphyritic Subzones, 1–3 of (Figure 31), are generally in the form of rather basic grey quartz-diorite with augite and, in 1 and 2, hypersthene; but in their high eastern outcrops they become more acid and sometimes definitely pink and granitic. The main distinguishing feature in these three Subzones is textural. Subzone 1 is fine, 2 medium, and 3 coarse-grained. The average specific gravity in any one locality increases in the same direction from 1–3, to drop again materially in the porphyritic Subzone 4 (Anderson 1935b, p. 258). The coarse non-porphyritic Subzone 3 becomes pink and acid wherever it approaches Subzone 4, with which it always makes a merging contact. Subzone 4 is throughout a porphyritic granite with large phenocrysts of perthitic orthoclase.

Subzone 4 is continuous except for 3½ miles round the south-east end of the Inner "Granite" which here comes directly against external schists.

Subzone 3 is absent for an additional mile in the south-west, south of where it reaches the River Nevis [NN 200 680]. This is particularly interesting, for the failure of the subzone corresponds with a marked contraction of the Outer "Granite" outcrop. Subzone 3 also fails in the north for about a mile on the two sides of Allt Daim [NN 179 740].

Subzones 2 and 1 are much less continuous, but they are present in many places, almost always external to Subzone 3; and, if both occur together, as is usual, Subzone 1 is almost always external to Subzone 2. The only important exception is in the northernmost protrusion of the piuton where an outcrop of Subzone 1 is, according to Anderson, bisected by an east-west band of Subzone 2 with central patches of Subzone 3.

Again according to Anderson, the full succession of subzones is seen in Allt a' Mhuilinn [NN 161 730], with Subzones 1 and 2 occupying the stream bed, for about 50 yards each, Subzone 3 for a quarter of a mile, and Subzone 4 for more than a mile. Here, as everywhere else where the subzones succeed one another in the numbered order, 1 in contact with 2, 2 with 3, 3 with 4, the junctions are of merging type. On the other hand, where contacts between 1 and 3 and between 1 and 4 occur they are abrupt with associated evidence showing that 1 is earlier than both 3 and 4. Combining the two types of evidence we think Anderson is justified in believing that the Subzones 1, 2, 3, 4 followed one another in the order stated, and sufficiently quickly to anticipate in each case complete consolidation of the immediate predecessor; and also that Subzone 1 had consolidated sufficiently to be veined and to yield xenoliths before it was followed by Subzones 3 and 4. Contacts between Subzones 2 and 4 have not been found.

In (Figure 31) merging contacts are shown by pecklines and sharp intrusive contacts by firm lines. The best exposures of Subzone 1 veined by and included in Subzone 3 are afforded in Allt na Caillich [NN 160 760], and along crags west of the stream that drains the lochan east of Meall an t-Suidhe [NN 138 729] (Anderson 1935b, pp. 235, 237). A well exposed contact of Subzones 1 and 4 occurs in Allt Daim [NN 179 740], but one can say little more of it than that the junction is sharp. On the other hand, in Allt an t-Sneachda [NN 180 763], a little further east, Subzone 1 is cut by numerous granite and aplite veins, and Subzone 4 is full of xenoliths of Subzone 1. The actual contact is seen at a minor hydro-electric dam. Subzone 4 here retains its porphyritic character right up to the margin, though its phenocrysts do not enter into veins. Microscopic evidence confirms that it is the later of the two intrusions (Anderson 1935b, pp. 238, 254).

The steepness of the margin of the Outer "Granite" as a whole against the schists is visible in many sections around the edge of the complex. On a large scale it is patent from an examination of a contoured map showing the "granite" boundary.

General conclusions

It is obvious, from the foregoing descriptions, that the structure of Ben Nevis admits of an interpretation similar to that applied, in the two preceding chapters, to the Glen Coe and Etive igneous centres.

The Outer "Granite" with its steep walls may be conceived as filling the void created by the gravitational sinking of a subterranean block into underlying magma ((Figure 30), p. 176). Then followed a long period during which the uprisen magma, at the level now exposed by erosion, consolidated and cooled. Anderson agrees that this mechanism is probable, and thinks that the subsiding central block had a top that was convex upwards, so that as it descended in a succession of steps it admitted relays of magma responsible for Subzones 1–4 (1935b, p. 264).

The main phase of dyke injection ensued (p. 202), and after it further subsidence, which, confined to the central area, admitted in complementary fashion the uprise of the Inner "Granite".

Then a subaerial cauldron-subsidence developed, for the roof of the subterranean cauldron gave way, and a block of schists, with its burden of lavas, subsided into still liquid Inner "Granite". The motion developed a streaky flow-structure in the magma, which itself became chilled against the cool descending mass. The latter, during its subsidence, buckled into its basin shape by reason of the friction on its walls; and its cracked margin, on coming in contact with the magma, was penetrated to a slight extent by veins of granite. The sinking block in its descent must have dropped over 1500 feet. We are thus led to the conclusion that the lavas of Ben Nevis, in spite of their great altitude, owe their preservation, like those of Glen Coe, to subsidence. Erosion has cut relatively deeper at Ben Nevis than at Glen Coe, and has cleared away the fringe of fault-intrusion, which, analogy leads us to expect, rose from the reservoir of liquid Inner "Granite" more or less completely to surround the sinking mass at higher levels.

The local history seems to have closed with the injection of a few more dykes which pierce the margin of the Inner "Granite".

A point which is not at all clear, is the relative age of the volcanic series and the Outer "Granite". By analogy with other areas we may suppose that the volcanic rocks were extruded first. If this were so, it is perhaps remarkable that not a single dyke has been found cutting the volcanic rocks. At the same time the schists lying beneath the latter are equally free from dykes, though their outcrop runs at right angles to the trend of the dykes, and is sufficiently long to have included several of them if spaced at regular intervals. We can surmise either that the volcanic mass, in its original position, was above the level at which dykes were injected from the subterranean source, or perhaps that it was sheltered by some such mechanism as is discussed later on p. 201.

The interpretation given above of the development of the Ben Nevis Pluton is hypothetical except in regard to the unequivocal subsidence of the central cylinder of schist and lava. There is indeed a suggestion that outward magmatic push may have been a co-operating factor in making room for the pluton. The Glen Nevis outcrop of Ballachulish Limestone is cut out for a short space by the "granite" margin, but it soon reappears in Sheet 62 (*cf.* (Figure 17) and Bailey 1934a, pl. 15) well to the north-west of the position in which it might be expected. Traced north-eastwards away from the "granite" it swings back into its normal course. The deflection is undoubtedly linked with the emplacement of the "granite", but it has not been found possible to decide whether it betokens:

1. a downward sag of the surrounding schists connected with subsidence of a central block,
2. an outward magmatic push, or possibly
3. a combination of these two causes.

Quite another point is made by Anderson who points out that the coarse non-porphyritic Subzone 3 of the Outer "Granite" is seen through a vertical range of 3900 feet from where it is washed by the River Nevis [NN 200 680] on the west to where it forms the summit of Aonach Mòr [NN 193 730] in the east, "the greatest exposed vertical thickness of any igneous intrusion in the British Isles" (1935b, pp. 243, 264). "In the high Eastern Area", he says, "all the Marginal Types [Subzones 1–3] are more acid than the corresponding Types in the outcrops at lower levels elsewhere. This difference may be explained as due to gravitational differentiation, such as has been described from the Mull ring-dykes (Bailey 1924, pp. 320–330)". H. B. M.

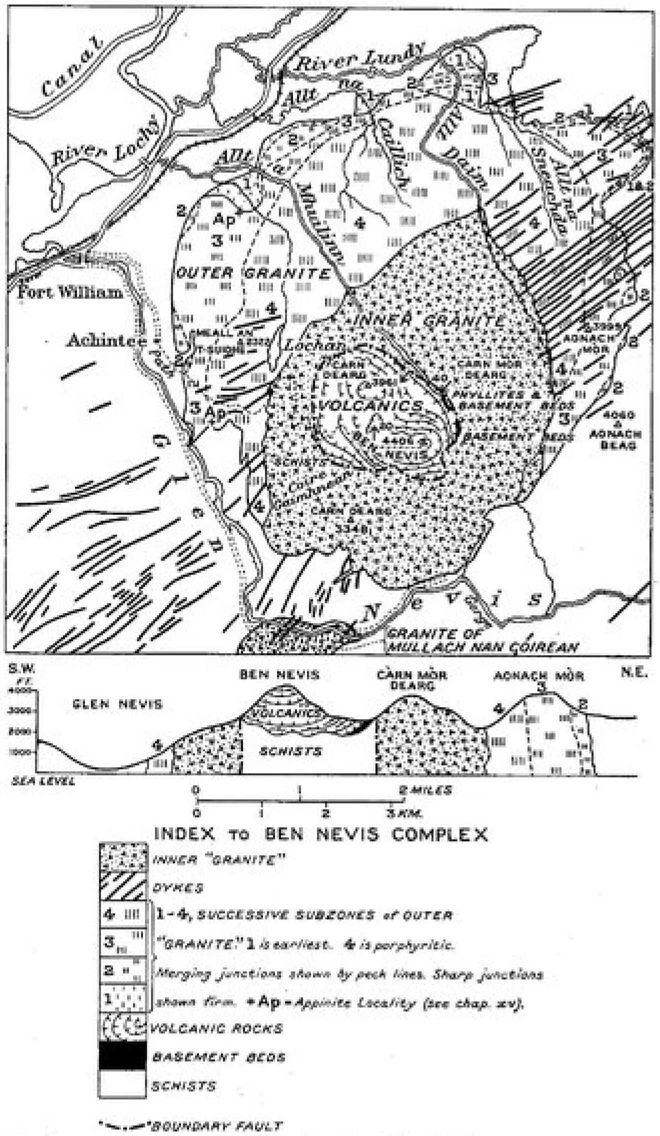


Fig. 31. Map and section of Ben Nevis

(Figure 31) Map and section of Ben Nevis.

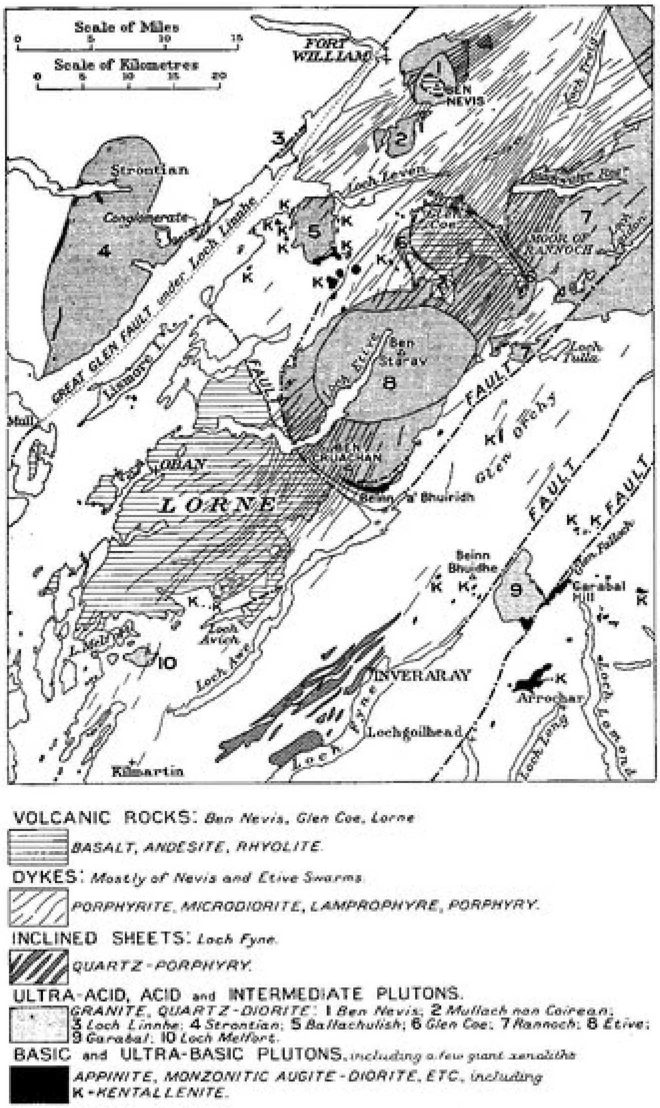
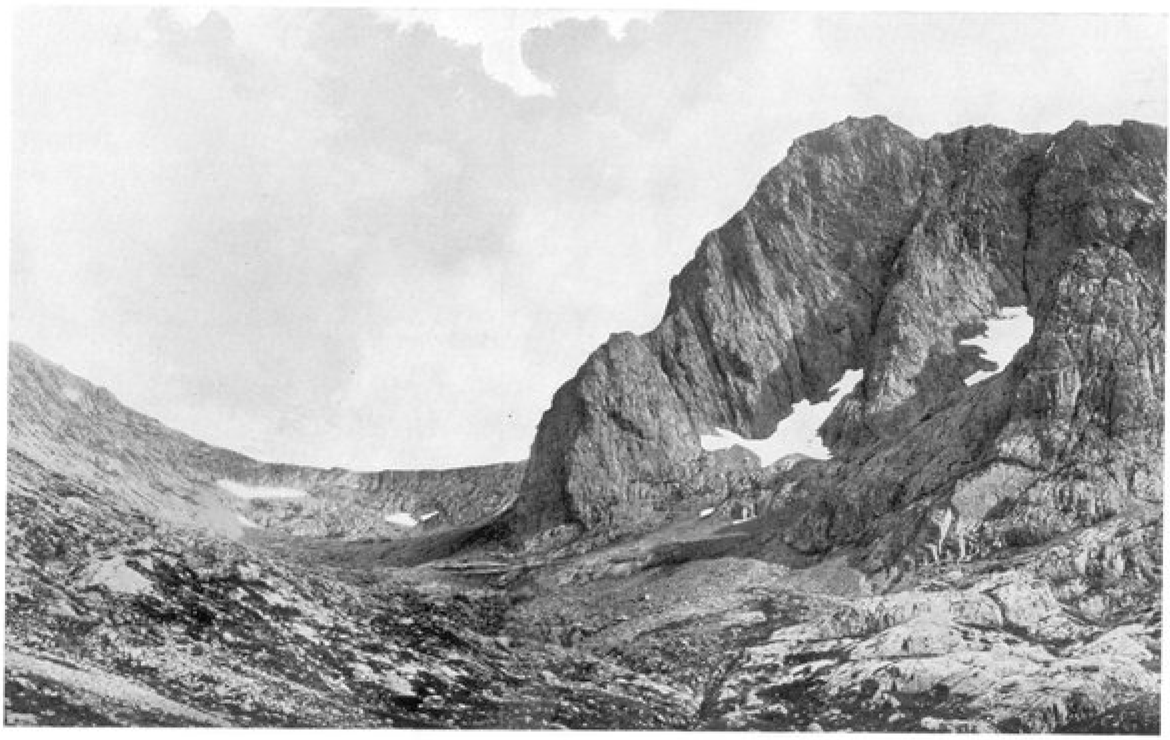


FIG. 18. Map of igneous rocks of South-West Highlands referred to Lower Old Red Sandstone Period

(Figure 18) Map of igneous rocks of South-West Highlands referred to Lower Old Red Sandstone Period.



(Plate 10) Allt a' Mhuilinn [NN 161 730]: Ben Nevis Volcanics on right, and Inner "Granite" on left, meeting in stream.

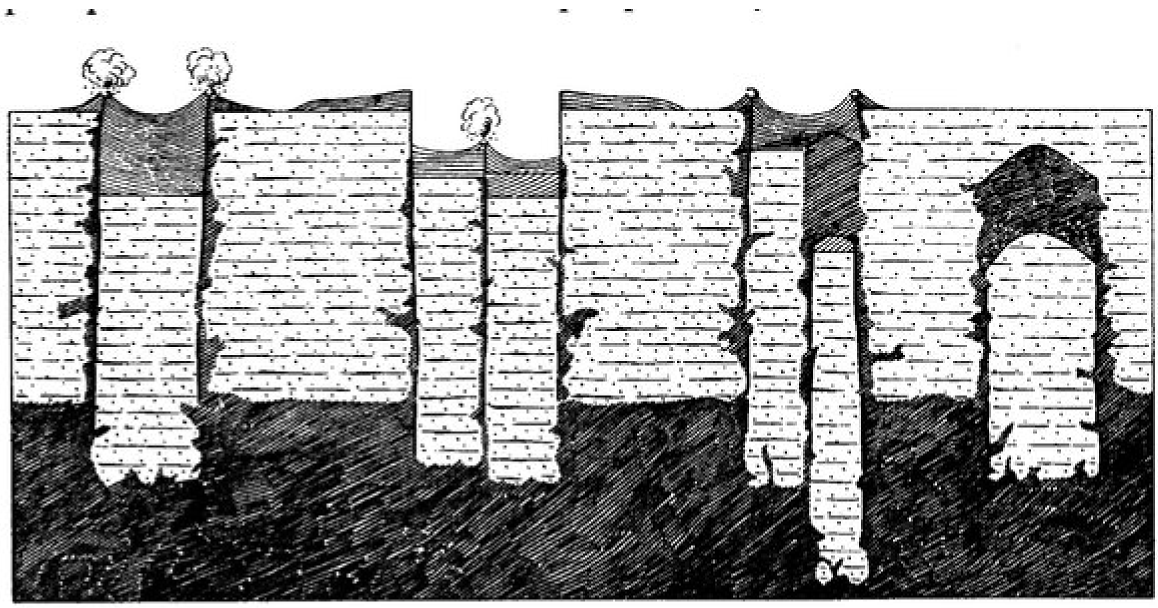


FIG. 30. Diagram of subaerial and subterranean cauldron-subsidences accompanied by volcanic and plutonic accumulations of igneous rocks

(Figure 30) Diagram of subaerial and subterranean cauldron-subsidences accompanied by volcanic and plutonic accumulations of igneous rocks.

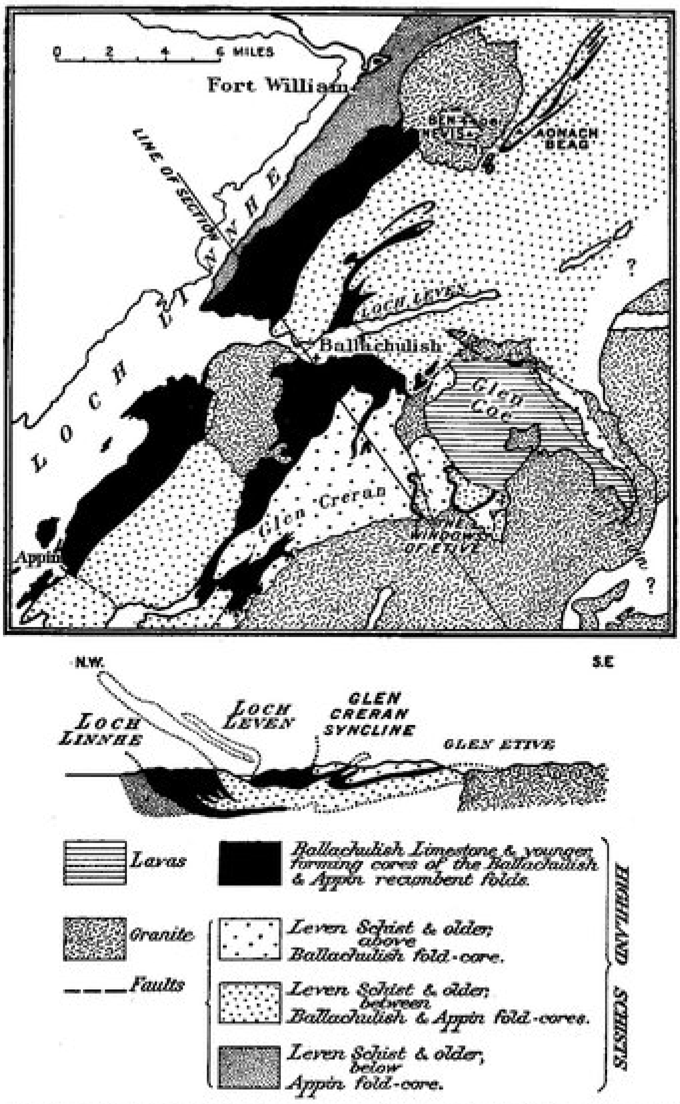


FIG. 17. Map and Section showing the structure of the Highland Schists and the positions of the cauldron-subsidences of Glen Coe and Ben Nevis

(Figure 17) Map and Section showing the structure of the Highland Schists and the positions of the cauldron-subsidences of Glen Coe and Ben Nevis.