Chapter 2 Volcanic agglomerates, tuffs, and conglomerates

In this and the three chapters next following we shall describe in detail the volcanic rocks of Skye. Departing to some extent for convenience from strict chronological order, we shall treat these rocks as follows: First, the pyroclastic accumulations, which, though not confined to one horizon, have their principal representatives at the base of the whole series; second, the basic lavas which make up the greater part of the succession; and third, the trachytic and rhyolitic rocks intercalated in the midst of the sequence. While the basic lavas have what may be termed a *regional* distribution, and there is no reason other than the geographical one for treating separately those of the Isle of Skye, the other rocks enumerated represent purely *local* episodes connected with the special focus of igneous activity of Central Skye. This distinction is essential to an understanding of the true relationship of the several groups of rocks, and, as already intimated, we shall apply it also to the various groups of intrusions to be dealt with subsequently.

Disregarding for the present the rhyolitic and trachytic rocks to be treated in Chapter 5., one of the most striking features of the volcanic series of Skye taken as a whole is the *comparative scarcity of fragmental accumulations.* Throughout the greater part of its extent, so far as the detailed survey has gone, the succession of basic lavas is found to be almost unbroken by any intercalation of volcanic tuff, breccia, or agglomerate. Only occasionally, and as a rule at a low horizon, do we meet with a thin and inconstant bed among the lavas which tells of a local outburst of a more energetic kind; and only at or near the actual base of the series do we encounter pyroclastic accumulations of any important magnitude and extent. The general absence of fragmental volcanic rocks is quite in accord with the tranquil welling out of the extravasated material which characterises fissure-eruptions in other countries; and it is also consistent with what is known of like cases that such an extensive and long-continued outpouring of lava should be ushered in by eruptions of a more vigorous and indeed violently explosive nature. The vast fissure-eruptions of Wyoming and Idaho, for example, were preceded by explosive outbursts which gave rise to the breccias of the Absaroka Range. The extreme violence of these early eruptions in Skye is attested by the tumultuous accumulations of shattered blocks and fragments of all sizes, which in two or three places rest on the Jurassic and other strata and attain a thickness of many hundreds of feet. We obtain additional evidence, and also some insight into the nature of these eruptions, from the *actual vents* which are still to be detected in more than one instance. It will be convenient to notice the largest and most important of these vents before proceeding to describe the more or less clearly bedded pyroclastic accumulations.

The largest area of volcanic agglomerate in Skye lies immediately south of the eastern Red Hills of Strath and *north-west of Loch Kilchrist,* about 2½ miles from Broadford. It is bounded on the north side by the subsequently intruded granite of Beinn Dearg Bheag, etc., and its precise relations to the neighbouring stratified rocks, Cambrian limestones and Lias, are in some other places obscured by other intrusions and by faults; but there is sufficient evidence to show that, excluding the narrow strip extending north-westward, the agglomerate cannot be regarded as a bedded or lenticular mass. The main body breaks abruptly through the adjacent strata, and must have a highly inclined or quasi-vertical boundary with a roughly cylindrical form (Figure 4). Its extent, measured north-eastward from the high-road at Kilbride, is more than 2¼ miles, but it is clear that its northern portion has been cut off by the subsequent intrusion of the granite, which sharply truncates the boundary of the agglomerate as shown on the map. The surface of the mass is broken into small irregular hills, rounded, but with a characteristic 'knobby' appearance, contrasting equally with the smooth slope of the granite above and the scar-like spread of the limestones on the opposite side of the strath (Figure 5).

The agglomerate forming the large mass<ref>Its true nature was first recognised by Prof. Judd, *Quart. Journ. Geol. Soc.,* vol. xxx., p. 255: 1874. It has been described by Sir A. Geikie, *Trans. Roy. Soc. Edin.*, vol. xxxv., pp. 108–110: 1888.</ref> consists of material partly volcanic, partly non-volcanic, closely commingled. Of the recognisable elements basic lavas are the most abundant, in pieces ranging in size from small fragments to blocks a foot or more in diameter, and in some places as much as five or six feet. They seem in all cases to be derived from the breaking up of pre-existing masses, true bombs not being recognised. Sandstones also figure largely among the fragments. Most of them are probably from Jurassic rocks, but the Torridonian seems also to be represented, sometimes in the form of quartzite. Jurassic shales are occasionally found. Other rocks occur only sparingly, and it is remarkable that the Cambrian limestones are rarely met with. The few pieces of these latter were found in the western portion of the mass only. All these larger elements, usually constituting a large proportion of the whole, are embedded in a fine-textured matrix of a

dull dark green colour. Nowhere is there any indication of stratification or of any sorting of the coarser and finer materials; although there are places where no conspicuous fragments meet the eye, so that the rock might be described petrographically as becoming a tuff rather than an agglomerate.

Embedded in the mass at various spots are patches of basic lavas 100 or 200 yards in length, which we cannot suppose to have been thrown up in an explosion. They have a lenticular shape, and are sometimes bounded by lines which might be laid down on the map as faults, but are not to be traced farther. In one place, just N.W. of Meall Coire Trusaidh, a patch of Torridonian quartzite nearly 100 yards long is included in the same fashion. These relatively large enclosed patches must be explained by supposing that the vent has been enlarged by successive stages, and that portions of the bounding wall which fell in have sometimes escaped destruction by later outbursts. It is important to notice that the large blocks in the agglomerate and a considerable proportion of the fragments of medium size must have been derived not from below but *from above.* They came from the breaking up of rocks, now removed, which were traversed by the upward prolongation of the funnel. This appears from the large amount of basalt obviously derived from the shattering of some old *coulêe,* and equally from the composition of the non-volcanic element in the agglomerate. As regards the latter, the map shows that the vent, as we now see it, is drilled through the Cambrian limestones almost exclusively, touching the Jurassic only for a short distance at the western edge: still Jurassic rocks are, after basalt, the most important constituent of the agglomerate, while the limestones are practically not represented. It is clear that the Jurassic sandstone of the agglomerate, like much of the basalt, came from overlying strata now removed. The occasional presence of fragments of granite and other acid igneous rocks raises a different question, to be discussed later.

The finely divided material which forms the matrix seems to be in the main of basaltic composition. In part it may have been produced by the mutual concussion and friction of the blocks and fragments, which are now mostly of sub-angular shape; in part it probably represents true volcanic dust thrown up directly by the eruptions. To this later origin also we may ascribe many of the smaller fragments of basalt, and especially those having a highly vesicular or scoriaceous texture.

It is interesting to note the close resemblance between the Kilchrist vent and that, of similar large dimensions and doubtless of the same age, in the central part of the Isle of Arran. <ref>Peach and Gunn, *Quart. Journ. Geol. Soc.,* vol. lvii., pp. 226–219: 1901; Gunn, *The Geology of North Arran (Mem. Geol. Sur. Scot.),* pp. 79–83; and Harker, *ibid.,* pp. 103, 104: 1903.</ref> In the latter, as in the former, the enclosed fragments embrace various sedimentary as well as igneous rocks; and some of them, including patches of large extent, must have fallen into the vent from above. There are also, as in Skye, fragments of plutonic rocks identical in character with those which at a later epoch were intruded in the immediate vicinity. The matrix of the Arran agglomerate contains much more non-igneous material (quartz-grains, etc.) than that of Kilchrist, but there is the same ultimate base of finely-divided basaltic tuff. A curious point of similarity is the fact that the Arran vent is surrounded by a partial ring of later intrusive rocks, chiefly a granite which in places is greatly modified by basic xenoliths. The corresponding phenomena in the case of the Kilchrist vent will be described in their place below (Chapter 11).

Of the material ejected from the great Kilchrist vent over the surrounding country but scanty relics remain, owing to the subsequent invasion of granite and to the extensive erosion which has affected the whole district in later times. A strip of bedded agglomerate, however, runs along the south-western border of the granite, and is continuous on the map with the agglomerate filling the vent. It overlies Jurassic strata with only a small thickness of basalt intervening. Its full thickness is not seen, owing to its being cut off by the granite, but its evident prolongation northward, along the western base of Creagan Dubha, is at first some hundreds of feet thick, rapidly thinning away. It probably did not extend much. farther, and, as Sir A. Geikie has pointed out, at An Carnach, in the Strathaird peninsula, only two miles west of the vent, a thick series of basaltic lavas rests directly on the Jurassic. The relics of volcanic rocks enclosed in the granite on the N.E. side of Beinn na Caillich prove in like manner that the agglomerate has not extended more than 1½ mile from the vent in a northerly direction. This rapid thinning away of very thick accumulations of volcanic agglomerate is quite in accord with what is seen elsewhere in the district; and the outburst thus indicated, the earliest manifestation of volcanic activity in this neighbourhood, may well have been one of important magnitude. That activity was renewed at this vent at a later time is not improbable in itself, and seems necessary to account for the profusion of basalt blocks and fragments in the volcanic pipe; but any direct evidence of such later eruptions in the form of bedded agglomerates has been destroyed by erosion. By analogy we may infer that the chief outbursts were comprised within the earlier part of the volcanic period.

Another locality in Skye where the actual form and relations of a volcanic vent are partially displayed is on the *Sound of Soay.* Along this part of the coast-section the base of the volcanic series rises above sea-level, and for some distance a strip of Mesozoic strata intervenes between the basalts and the underlying Torridonian. It is of special interest as one of the few places in the Western Isles where deposits of Cretaceous age are to be seen. This strip of coast was surveyed by Mr Clough, who has supplied the notes which follow. It will be seen that this vent is of much smaller dimensions than that of Kilchrist. Its position is marked by a small mass of agglomerate about 700 yards west of the mouth of Allt nan Leac, beneath the basalts, which pass over it unbroken. "It is about 40 yards broad, and has nearly vertical boundaries, both on the west and on the east. In all probability it belongs to a small volcanic vent or blowhole, which has broken through the adjacent Cretaceous and Liassic beds… . The materials in this agglomerate comprise blocks of soft red sandstone, some of them broken and angular and several yards long, which are probably of Cretaceous age; also many lumps of chert, containing sponge spicules and foraminifer like those in the Cretaceous cherts found *in situ* near at hand, and a few pieces of quartzite and soft green sandstone. Some of the pieces of chert contain red cores, the nature of which has not been determined. No fragments of igneous rock were noticed; but, besides the basalt which overlies the agglomerate, there were an extensive sheet of basalt at the bottom and a thin basalt dyke at the west side"

On the east side of the mass just described is a bedded agglomerate underlying the basalts and possibly ejected from the same vent, though the occurrence of fragments of igneous rock presents an interesting point of difference. "It is in places 20 feet thick, but in others only two or three feet, or even not represented at all. In it are noticed many pieces of highly vesicular decomposed igneous rock and others of Torridonian grit, red sandstone, and limestone, the two last-mentioned rocks having apparently been derived from Cretaceous and Liassic beds like those which occur below. The agglomerate is injected with various thin irregular squirts of basalt; and in one inaccessible cliff there is a remarkable aggregation of pieces of limestone, some of them six feet long, lying in a matrix which seemed from below as if it might be basalt"

It is clear that the explosive outburst to which these accumulations of coarse agglomerate are to be attributed belongs to the very earliest stage of volcanic activity at this place. The occurrence of fragments of fossiliferous Mesozoic rocks recalls the large volcanic vent of Arran, which has preserved in the same way the only direct evidence of the former existence in that island of Rhmtic, Liassic, and Cretaceous strata.

We pass to those pyroclastic accumulations which, in contradistinction to the contents of the vents, we have called bedded. By this term we do not imply the existence of a visible stratified disposition, but merely that the deposits in question occupy a definite horizon in the volcanic succession, usually at or near the base of the series. They have, as a rule, an evidently lenticular shape, sometimes thinning away rapidly from a central point.

The bedded agglomerate seen on the south-west and west border of the eastern Red Hills of Strath has already been mentioned, and calls for no detailed description. Generally speaking it consists of a dull green matrix of basaltic composition enclosing abundant fragments of lava. Comparing it with the agglomerate of the great vent close by, we miss the large basalt blocks and the profusion of sandstone fragments which characterise the latter; a circumstance which might be anticipated after the remarks made above.

Farther to the north-east, near the high-road which there follows the coast-line, in a strip of country much broken by faults, we find certain agglomerates which are worthy of passing remark. Their relations are obscured by intrusions as well as by faulting; and a further difficulty, experienced also in some other parts of the district, arises from brecciation due to mechanical causes. For instance, a rock on the shore north-east of Creag Strollamus, taken at first as a volcanic agglomerate composed of acid igneous rocks, proved upon closer examination to be merely a crushed and brecciated granite (see (Plate 7)), and specimens from several other localities gave a like result, while others did not permit of any certain conclusion. Nevertheless, the existence of agglomerates containing abundant fragments of acid rocks is easily established, these being in places free from any effects of crushing, especially when they are caught up as patches in the gabbro and granite of the district. One specimen sliced (S6836) [NG 605 266] shows numerous irregularly shaped fragments of pink granophyre, up to an inch or two in diameter, set in a dark greenish grey matrix. The matrix itself is chiefly of acid material also, with abundant chips of felspar and minute rock-fragments; but there is also some admixture of basic tuff-material, besides a few recognisable fragments of basalt. Rocks of this type, containing granite, granophyre, etc., occur at several localities.

An area of volcanic agglomerate and tuff, with an extent of more than one mile and a half, is seen in the upper parts of *Coire Coinnich, and Coire na Selig,* and forms the north-western spur of Belig. Its original relations are nowhere displayed, except to the Plate 1.

Exposed surface of volcanic agglomerate, Druim an Eidhne. north-east of Belig, where it dips under the basaltic lavas. Farther west it is covered by gabbro, and everywhere it is underlain by granite, both of later age. It seems highly probable, however, that the upper and lower surfaces of the lenticular mass have themselves determined in great part the horizons at which the two plutonic rocks were intruded; so that little of the agglomerate is cut off, and the maximum thickness seen, some 1000 or 1200 feet, represents approximately the original total. Where thickest, the material consists of the usual dirty-green matrix enclosing abundant fragments which range in size up to blocks of more than two feet in diameter. In addition to basalt, gabbro is extremely abundant, while in some parts quartz-porphyry and granite are well represented. In places the agglomerate gives way to a grey tuff of acid composition without conspicuous fragments. It is especially noticeable that the large fragments become fewer as the deposit thins out westward and dies away (or is obliquely cut off) on the ridge of Garbh-bheinn.

The other principal mass of volcanic agglomerate and tuff in the district is exposed above Strath na Creitheach in the slope leading up to *Druim an Eidhne.* This also is overlain by gabbro and underlain by granite, but in this case the intrusive rocks have evidently cut into the agglomerate much more than in the former, and what is left probably does not adequately represent the original dimensions. The broad spread occupying the rough slope to the north-west of Loch na Creitheach has a diameter of about a mile and a thickness of probably 300 or 400 feet; in addition, a narrow strip extends for another mile just below the gabbro of Druim an Eidhne. The greater part of the mass may fairly be termed agglomerate, since it contains abundant fragments of various sizes set in a greyish green or dull green matrix of finer material (Plate 1). Among the fragments gabbro figures largely, as well as basalt. In places we find instead of agglomerate a fine-textured tuff, thoroughly compacted, with conspicuous bands of darker and lighter grey. From the irregular distribution of this tuff, and the conflicting dips which it shows, it seems probable that it has been broken up by some outburst from below or by an uneven settling down, suggesting that the actual vent of eruption is concealed below. The agglomerate is not perceptibly less coarse in the narrow strip along Druim an Eidhne than in the broad area below; and the same remark applies to an isolated patch a quarter of a mile wide and more than a mile in length wholly enclosed in the gabbro farther west. Here the pieces of gabbro and basalt are sometimes three or four feet across. These facts may be taken to indicate that the agglomerate actually seen is only the relics of a more extensive mass.

It may be noted, without going further into detail, that numerous small patches of agglomerate, breccia, and tuff occur entangled in the gabbro throughout the Cuillins, often in a highly metamorphosed state. They occur not only near the boundary of the gabbro area, but far in the interior, and at various altitudes. The highest summit of all, for example, is formed by a metamorphosed volcanic breccia.<ref>This point, Sgùrr Alaisdair, 3275 feet, is not named on the Ordnance map: it is 200 yards N.E. by E. from the summit of Sgùrr Sgùmain.</ref> Many of these patches are associated with basaltic lavas, but otherwise their original relations are lost. All these pyroclastic rocks in the mountains seem to be of basic composition; the recognisable fragments are of basalt and often abundant gabbro.

Although the relics of the volcanic rocks in the mountain tract are severed from their original associations, the structure of the great gabbro mass in which they have been entangled, to be described later, permits us to assert that the disturbance caused by its intrusion was restricted within certain limits. We cannot suppose that the small patches of volcanic breccia and agglomerate now seen high up in the northern and western Cuillins have been brought up from the base of the whole volcanic series. These patches must belong to various horizons in that series; and we learn that explosive eruptions, though not equal in magnitude and violence to the earliest ones, *recurred at various epochs* among the fissure-eruptions of basic lavas. These small outbursts were principally confined to what is now *the mountain-district.* Here the earliest paroxysmal eruptions were chiefly concentrated, and attained their greatest violence, and here too minor eruptions of like type were resumed locally and occasionally during the volcanic period. The area which was subsequently to be affected by the great plutonic intrusions was already marked out as a special centre of igneous activity.

It is highly probable from the observed field-relations that the two last-mentioned large masses of volcanic agglomerate, that of Coire Choinnich and Coire na Seilg and that of Druim an Eidhne and Loch na Creitheach, mark the sites of concealed volcanic vents similar to that of Loch Kilchrist and perhaps not inferior in size. This appears from the lenticular

forms of the masses, which reach a great thickness in the centre and rapidly thin away in every direction. It is suggested equally by the large size of many of the enclosed blocks and, we may add, by the occurrence among the other fragments of pieces of plutonic rocks, often in great abundance. There are, however, in Skye fragmental volcanic accumulations, seemingly remote from any large vent, which have a more decidedly bedded habit, and do not thin away so rapidly. These show in many places an evident stratification, though usually of a rude kind. They do not enclose such large blocks as are found in the localities already noticed, and the fragments in them do not present the same variety, gabbro and granite in particular being absent.

The best example of those truly bedded tuffs and agglomerates is that exposed along the coast *between Portree and the Braes.* Sir A. Geikie estimates its maximum thickness at about 200 feet on the south side of Portree Harbour, but it is usually much less. It is probably continuous at the same horizon, at or near the base of the whole volcanic series, to as far as Eilean Tioram at least, four miles S.S.E. from the former locality; but in this neighbourhood it is only a few feet thick. The section at Camas Bàn, Portree Harbour, is shown on (Figure 6). The general mass of the rock is a basic tuff of a dull dirty-green colour or, in the upper part, red and ferruginous, probably from contemporaneous weathering. This deeply weathered rock recalls in its general appearance some of the volcanic clays of Antrim. A specimen from Leac Agamnha, examined by Mr Player, yielded about 30 per cent. of alumina. In the upper part of the Camas Bàn section conspicuous enclosed fragments are scattered only sparingly, but lower down they are more numerous, and include blocks of several inches diameter. Bedding is more or less evident in the finer portion of the accumulation; and even in the coarser, which may be termed agglomerate, a certain stratification is apparent in the distribution of the enclosed blocks. The blocks and smaller fragments consist almost, if not quite, wholly of basaltic rocks, some compact but many scoriaceous, vesicular, amygdaloidal, or pumiceous. Only one specimen was examined microscopically. The slice (S6662) [NG 49 43] shows it to be essentially a brown glass with only occasional microscopic crystals of a basic plagioclase. It has been highly vesicular, and the vesicles are now filled by various secondary products, including a chloritic mineral, nearly colourless and singly refracting in thin section, and "a zeolite"<ref>*Quart. Journ. Geol. Soc.,* vol. lii., p. 348: 1896.</ref> At one locality on the coast of Portree Harbour larger enclosed blocks occur, and Sir A. Geikie places here the vent of eruption. We have not traced the deposit in the northward direction. Large blocks are sometimes found in places where the accumulation is of small thickness: they occur, for instance, up to a foot in diameter on the shore at Eilean Tioram. Here, too, are broken seams of coal, two or three inches thick, in the agglomerate, a feature observed at some other localities.

It is necessary here to make some remark on the occurrence of *gabbro and gramite as fragments in the volcanic agglomerates of the large vents.* All these pyroclastic accumulations are demonstrably much older than any gabbro or granite intrusions seen in Skye. The conclusion is inevitable that there exists, or has existed, in this district *an earlier suite of plutonic rocks, both gabbro and granite, which have nowhere been brought to light by erosion.* Any data concerning these concealed plutonic masses, other than the proofs of their existence, are naturally scanty, but are not entirely lacking. Firstly, we find that they were petrographically the prototypes of the later plutonic masses, which we can observe directly in the same district. The gabbros are not distinguishable from those which build the Cuillins; the acid rocks are hornblende-granites and granophyres identical in characters with those forming the Red Hills, and having similar spherulitic, felsitic, and porphyritic modifications in places. Further, fragments of these rocks are nowhere found, so far as our observations go, in the breccias and agglomerates occurring outside the mountain tract; which suggests that the areal distribution of the earlier concealed plutonic masses has a general correspondence with that of the later and exposed ones. We may even extend this remark to the gabbro and the granite severally, for each is found in the agglomerates only in the neighbourhood of visible intrusions of its own kind: gabbro fragments are never found in the eastern Red Hills, nor granite fragments in the Cuillins; while in the Coire Choinnich and Belig patch, on the border-line between the Red Hills and the gabbro mountains, both rocks are represented. Finally, it is of interest to find in this last-named locality many fragments of gabbro veined by granite; from which we may infer that in the earlier, as in the later, suite of plutonic rocks the basic rock preceded the acid one in order of formation.

Among the basaltic rocks which occupy the extensive tract to the west and north of the Cuillins, pyroclastic accumulations play but a very insignificant part. In the area mapped there are indeed only three or four localities that require notice. One of these is Sgùrr an Duine, on the coast between Loch Brittle and Loch Eynort, where a small patch of volcanic agglomerate is seen. Since it forms the top of a practically vertical cliff of 600 feet, and is covered by drift, its

actual relations are not easily made out; but its lateral extension is not more than about 200 yards, and its maximum thickness perhaps 60 or 80 feet, its form being apparently lenticular. The material is wholly basaltic, including subangular blocks up to a foot or more in diameter. Two other occurrences are to be noted between Loch Eynort and Talisker. One is on Beinn Bhreac, the highest point in this part of the plateau country. The summit is formed by a patch of volcanic agglomerate, some 300 yards long, composed of small basalt fragments, with some up to six inches diameter, often rounded, in an iron-stained matrix. The other locality is the conspicuous hill named Preshal Beg, about a mile and a half south of Talisker. This hill is built of a fine group of columnar dolerite sills, to be noticed in a later chapter, and immediately under these occurs a bed of volcanic agglomerate. Although probably not more than 25 feet thick, it can be traced right round the base of the hill, which is about 800 yards long. The best exposures are on the north side. The fragments are all of basalt, some as much as a foot in diameter, but mostly smaller. They are subangular or sometimes well rounded, especially in the case of the larger blocks. Although this agglomerate seems to have more of the form of a continuous bed than some others, it certainly does not extend far: Preshal More, barely a mile to the north, is made by the same group of columnar sills, but the agglomerate below has disappeared. In all these pyroclastic accumulations outside the mountain tract no single fragment of gabbro or granite has been found: the material consists wholly of volcanic rocks. This is in marked contrast with the agglomerates of the Cuillins and the Red Hills, and also with the deposits, not purely of pyroclastic origin, which we proceed to discuss.

The last fragmental rocks to be noticed in this place are *volcanic conglomerates,* and these, within the area surveyed, have a very restricted occurrence. A good place to study them is about two or three hundred yards north-east of Glen Brittle House, where they occur interbedded among the basaltic lavas a short distance up the two small burns which unite near the sheep-fold. A small cliff-section shows conglomerates with intercalated beds of laminated fine tuff', lyingnearly horizontally. In the upper part the pebbles, with diameters up to two or three inches, are of basaltic lava, sometimes amygdaloidal, sandstone, and exceptionally granite. In the lower part they are sometimes more than six inches in diameter, and are chiefly of fine-grained grey gabbro and grit. All the pebbles have a thoroughly rounded shape, and are undoubtedly waterworn. They are thickly set in a greyish fine-textured matrix, apparently a basic tuff. The whole group has no great thickness, and cannot be followed far along the outcrop; being obliquely cut off both ways by the gabbro, which, as seen in Allt Coire na Banachdich, near the foot-bridge, has greatly metamorphosed the conglomerate. The same rocks, however, are seen in Allt a' Mhuillin, the next burn to the south, with a thickness of over 100 feet, though the top is cut off by the gabbro. They reappear half a mile further, again on the border of the gabbro, the pebbles here being almost wholly of sandstone. These three localities are in a N.N.W.–S.S.E. line, the last and highest being 500 feet above sea-level. This conglomerate has not been certainly detected elsewhere, except as a small patch enclosed in the gabbro of Coire Labain a mile farther east.

The curiously limited distribution of this conglomerate and the well-worn form of the pebbles point to the conclusion that we have here a portion of an old river-channel contemporaneous with the basaltic lavas; and this is in accord with the various facts which lead us to assign a subarial origin to the whole volcanic group. It is also to be remarked that in the Isle of Canna, only 13 miles to the south-west, Sir A. Geikie<ref>*Quart. Journ. Geol. Soc.,* vol. lii., pp. 354–373: 1896. Similar fluviatile conglomerates occur at Fionn-chro in Rum and on the coast W. of Carsaig in Mull.</ref> has found clear evidence of a powerful river which flowed westward over the lava-plains from a source in the mountains of Inverness-shire. The Glen Brittle conglomerate does not, like those of Canna, contain pebbles of rocks foreign to the island; but its pebbles are largely of rocks which, it is almost certain, could not be exposed to erosion in the neighbourhood at the date of the conglomerate; viz, the Jurassic and possibly Torridonian sandstones, which were already buried, and the earlier gabbro and granite, which have never been brought to light. The pebbles then must be derived at second hand, though almost contemporaneously, from a volcanic agglomerate or from more than one such source; a conclusion arrived at also by Sir A. Geikie for the local pebbles in the Canna conglomerates. That the materials reached Glen Brittle from some source to the east is quite in accord with what we have already seen of the petrographical characters of the agglomerates. That there are here no pebbles from still farther east is accounted for by the stream being a small one, possibly a tributary of the river of Canna.

Another equally interesting but less easily accessible occurrence is seen in the cliff a little south of Dùnan Earr an Sgùirr, between Loch Brittle and Loch Eynort. Here the little ravine of Allt Geodh' a' Ghamhna shows a section some 30 feet in height with the following succession, in descending order:

Basaltic lavas, with sills, above	
Coal-seam	0–3 in.
Pale yellowish grey coarse tuff,	1 ft.
Coal-seam,	0–3 in.
Conglomerate with tuff matrix	6–7 ft.
Dull yellowish grey tuff without pebbles, with impure coal-seam (6 to 8 inches) in lower part	5–7 ft.
Conglomerate with tuff matrix	5–6 ft.
Tuff, as before, without pebbles	2½-3 ft.
Conglomerate with tuff matrix	about 9 ft.
Basaltic lavas, with sills, below	

All the pebbles are well rolled. In the highest band of conglomerate they are closely set, and range up to 4 or 6 inches in diameter, consisting in about equal proportions of granite (with felsite) and a reddish quartzose grit (? Torridonian). In the two lower bands of conglomerate the pebbles range up to 10 or 12 inches in diameter, and are almost all of the grit. Here there is a rather larger proportion of matrix, and the conglomerate passes rather irregularly into the tuff devoid of pebbles.

One other locality may be mentioned where conglomerates occur among the lavas. This is in the neighbourhood of Loch Cull na Creig, a little west of Creag Strollamus and about 1½ mile north of Beinn na Caillich. The conglomerates occur at two horizons, but both very near the base of the group, which here rests on Torridon Sandstone. There seems to be no difficulty in supposing that the sandstone pebbles, which form the most conspicuous element of the deposit, were in this case derived from the near vicinity. They range up to as much as a foot in diameter. It is very interesting to find that in this locality, situated to the east of the central mountains, the conglomerates contain no fragments of gabbro, while they do contain abundantly in places fragments of granite and other acid rocks, some porphyritic, similar to those of later date in the immediate vicinity. These are found, together with abundant basalt, in the conglomerate of the higher horizon, exposed in and near Allt an Doire. The lower conglomerate, seen near the tarn, is wholly of Torridon sandstone pebbles with very little matrix.

The various pyroclastic accumulations in the vicinity of the large plutonic intrusions exhibit very marked effects of *thermal metamorphism,* and this is notably the case where patches of these rocks are completely enveloped in the gabbro of the Cuillins or the granite of the Red Hills. A summary account of these metamorphic phenomena will suffice in this place.

The fine-textured basic tuffs and the matrix of the volcanic agglomerates show in the more altered examples a partial recrystallisation. Perhaps the most characterictic change, however, is the production of minute flakes of brown mica, and this is often found in an early stage of the metamorphism.<ref>The phenomena are generally comparable with those described in andesitic and basaltic tuffs of Lower Palaeozoic age near the Shap granite in Westmorland. See Harker and Marr, *Quart. Journ, Geol. Soc.,* vol. xlvii., pp. 299, 300: 1891; and vol. xlix., p. 361, Pl. xvii., Fig. 5: 1893.</ref> A slice (S7463) [NG 518 226] may show little angular red-brown patches, which are chips of lava, and owe their colour to a dense aggregate of minute biotite-flakes of metamorphic origin. Where fragments of felspar-crystals are enclosed in the tuff, they often have a very limpid appearance, as if cleared by the heat from their minute inclusions. The inclusions which they do contain are of relatively large size and of rounded shape.

The metamorphism of the distinct rock-fragments in the agglomerates needs no description in this place, since the alterations produced in the several rocks will be described in succeeding chapters. The pieces of basalt, for instance, show the same metamorphic changes that will be detailed below under the head of the basaltic lavas, including the conversion of zeolites to felspars in the amygdules and the frequent production of hornblende. The gabbro-fragments exhibit uralitisation of the augite and other familiar effects. Fragments of Liassic grits, when highly metamorphosed, are converted into quartzites with various accessory minerals, such as biotite, zoisite, and perhaps sillimanite. These and some other phenomena may be well studied in the metamorphosed volcanic conglomerate seen in Allt Coire Banachdich, about 300 yards above the Glen Brittle road and just below a small foot-bridge.

In consequence of mechanical disturbances of a later date the volcanic agglomerates seem in some places to have suffered a considerable degree of *crushing and brecciation;* but, from the nature of these accumulations, it is not often

possible to obtain very satisfactory evidence. It is very clear in a few places, where considerable strips of basalt and other rocks occur enclosed in the agglomerate. A good instance is seen in the upper part of the Allt Leth-pheiginne glen, to the north of Kilbride. Here an enclosed strip of the basaltic lavas, 70 or 80 yards wide and more than 200 yards in length, is brecciated throughout. Immediately to the south is a similar strip of felsite or fine granophyre, also brecciated and crushed. Other instances might be cited, but there is always some doubt as to how far the shattering of these enclosed patches may be referable to the epoch of the agglomerate itself.

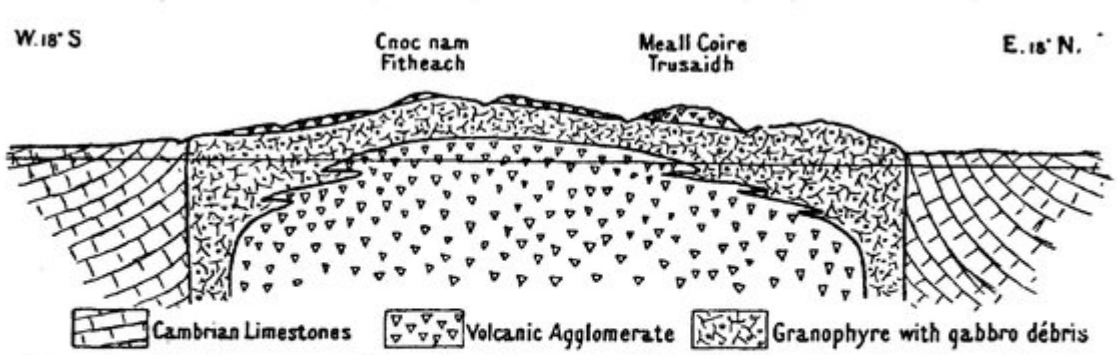

FIG. 4.—Section across the volcanic vent of Kilchrist; showing the volcanic agglomerate breaking through a sharp anticline of Cambrian limestone, and itself invaded by a later intrusion of a peculiar granophyre, full of débris of gabbro, to be described later. Scale, 1½ inch to a mile.

(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.

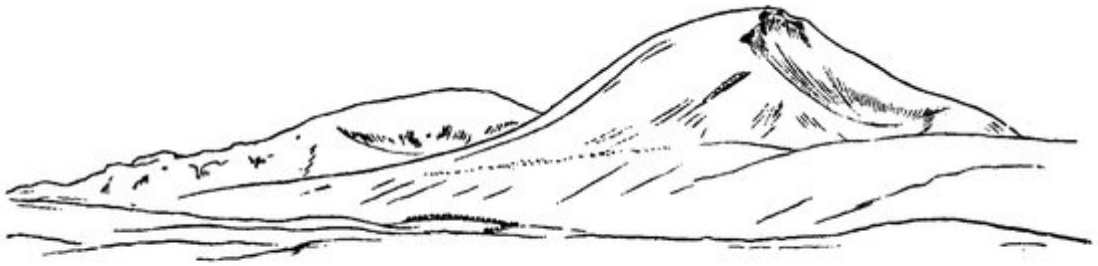

FIG. 5.—Contrasted outlines of volcanic agglomerate and granite, as seen from Broadford.

(Figure 5) Contrasted outlines of volcanic agglomerate and granite, as seen from broadford. The low broken hills to the left mark the situation of the Kilchrist vent, and are composed of volcanic agglomerate. The smooth outline of the granite is seen in Beinn Dearg Bheag and Beinn na Caillich, which form part of the Red Hills. In one place on Beinn na Caillich this smooth outline is broken by the outcrop of a large dyke intersecting the granite.

PLATE VII.

Fig. 1.

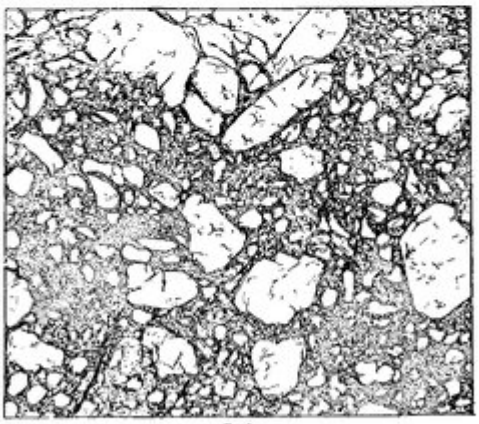

Fig. 2.

Crushed granite, from the shore between Allt Fearna and Strollamus Lodge, 2½ miles N.W. of Broadford. Natural size. The lower figure is from a typical specimen, while the upper one shows an earlier stage in the process of brecciation.

(Plate 7) Crushed granite, from the shore between Allt Fearna and Strollamus Lodge, 2½ miles N.W. of Broadford. Natural size. The lower figure is from a typical specimen, while the upper one shows an earlier stage in the process of brecciation,

Exposed surface of volcanic agglomerate, Druim an Eidhne.

(Plate 1) Exposed surface of volcanic agglomerate, Druim an Eidhne.

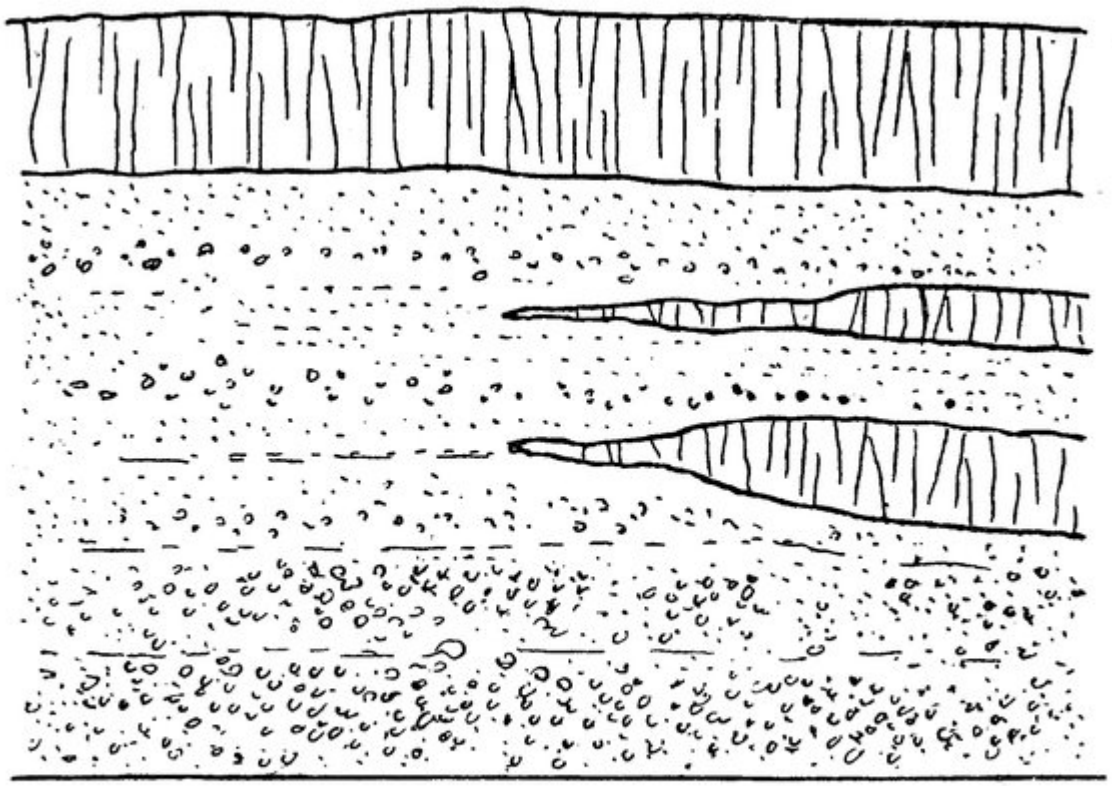

FIG. 6.—Cliff-section at Camas Bàn, on the south side of Portree Harbour; about 60 or 70 feet high. This shows the pyroclastic deposit covered by an intrusive sill of dolerite and invaded by two others.

(Figure 6) Cliff-section at Camas Bàn, on the south side of Portree Harbour; about 60 or 70 feet high. This shows the pyroclastic deposit covered by an intrusive sill of dolerite and invaded by two others.