Chapter 14. Basic sills: The Great Group

Among the intrusive rocks occurring outside the mountain district, by far the most important are those which form the very numerous sills of generally basic composition (dolerite, basalt, etc.) intercalated among the basaltic lavas and subjacent strata.

The intrusive nature of the sheets of "trap" intercalated among the Secondary strata in the northern part of Skye was clearly recognised by Macculloch. So long ago as 1819 he illustrated by admirable diagrams,<ref>*Description of the Western Islands of Scotland,* vol. iii., Pl. XVII.</ref>which have often been reproduced, how these sheets, while preserving for long distances a close parallelism with the bedding and a very uniform thickness, sometimes break abruptly across to a new horizon, or divide into two or three thinner sheets separated by sedimentary beds; how in places the sheets thicken out, and irregularly cut out and truncate the strata, portions of which, bent and broken, have become entangled in the igneous rock; and how veins or small offshoots are sometimes given off from the sheets, traversing the overlying as well as the underlying strata. It is remarkable that, notwithstanding these decisive proofs of intrusion, the sheets of basic rock continued to be generally regarded as true lava-flows and therefore of the same Oolitic age as the strata with which they are associated. Even after the true age of the great series of basalts above had been determined by botanical evidence, eminent geologists held that in this district of Trotternish occur volcanic rocks of two distinct ages, Jurassic and Tertiary.

The intrusive nature and Tertiary age of the basic sills in the Jurassic are now generally conceded, and indeed admit of no dispute. What geologists have not yet fully recognised is that such sills occur in enormous profusion, and attain individually and collectively a great thickness, among the overlying bedded lavas; that throughout the basaltic plateaux, which make up two-thirds of the area of Skye, these intrusive sills determine almost all the salient features, and indeed are the cause of the plateau form itself (*see* (Figure 79), below). The proofs of the intrusive habit of a basic sill are, in the nature of the case, less obvious when it occurs among basalts than when it is intercalated in a group of shales and sandstones, but upon examination the evidence is equally convincing. Notwithstanding the surprisingly regular disposition of the sills along defined horizons in the series, occasional transgressions are to be verified; and, what is an even more striking proof of intrusion, the sills are observed here and there to intersect some of the earlier basic dykes. Petrographically the resemblance of the sills in the basalt group to those among the Jurassic strata is as evident as their difference from the undoubted lava-flows among which they occur; while a study of their micro-structure shows that they have almost invariably something of that ophitic character which is much less common in the lavas. The existence of numerous intrusive sills in the basaltic group having once been recognised, it is found that they have, as a group, definite characteristics, which enable us to identify and map them with perfect confidence even when, as is usually the case, the field-observations afford no ocular demonstration of their intrusive nature.

It is not to be understood that all the sill-formed basic intrusions in Skye belong to a single group referable to one epoch. We shall indeed make some remarks in the next chapter on certain smaller groups of sills, in addition to those, closely associated with acid rocks, which we have already described; and it is also worthy of mention in passing that some of the basic dykes occasionally assume for some distance the habit of sills. We are at present concerned, however, with the vast majority of basic sills in the island, which do in fact constitute one natural group of intrusions, and will be spoken of for the sake of clearness as the "*great group of basic sills*" or of dolerite sills. It is these rocks that play so important a part in the constitution of the basaltic plateaux, besides occurring in force, as noted above, in the underlying Jurassic strata as exposed along some portions of the coast.

The *epoch of intrusion* of these sills is quite determinate. They are later than any volcanic or plutonic rocks in the island, but earlier than the great majority of the minor intrusions. Their injection constitutes therefore the earliest episode of the last of the three phases of igneous activity which we have pointed out as recognisable in our area. The intrusion of so many distinct sills, often individually of great volume, was a process which doubtless occupied a prolonged lapse of time. If we could assign to this group any of the basic sills which, near Suishnish and elsewhere, are closely associated with acid intrusions, it would appear that the earliest of the great group of sills were, at certain points, overlapped in time by the latest of the intrusions belonging to the granite and granophyre group of the Red Hills. We have described, however, remarkable circumstances characterising the basic members of the composite sills, which lead us to infer for them a common origin with the acid rocks with which they are associated. We therefore separate them from the rocks now under consideration, and refer them to a somewhat earlier date. Considering the composite intrusions as a peculiar group belonging to the interval between the plutonic phase and that of the minor intrusions, we must regard the latter phase as beginning with the intrusion of the great group of sills.

As regards the *distribution in space* of the sills, it is in the first place very noticeable that in Skye they are developed in greatest force, both individually and as a group, in the northern part of the island. Over all the plateau country, lying to the north and west of the central mountains, the sills form every prominent feature; but, approaching nearer to the gabbro and granite of the mountain tract itself, we find that they thin out and finally disappear (Figure 52). This is certainly not due to the dying out of the group as a whole, for beyond the mountain tract the sills reappear in the Strathaird peninsula and elsewhere. They never attain, however, to the south and east of the mountains the massive dimensions which they display in the northern and western parts of the island, but become rarer as well as smaller, and do not extend into the south-eastern part of Skye. It is not easy to assign exactly the limits in this direction of the area affected by the sills; partly because the lava-group, in which the sills are elsewhere principally developed, has here been removed by erosion; partly because other groups of sills come in, which cannot always be readily separated in the field from the great group. A comparison of the Jurassic series of Strath with that of Trotternish, as regards the occurrence of intercalated basic sills, is, however, sufficiently conclusive, and the greatly diminished thickness as well as the increasing rarity of the occurrences leaves no doubt as to the dying out of the group.

It is clear from the distribution thus indicated that the sills have no close connection with the plutonic focus of central Skye. So far as our information goes, they are probably related to some quite distinct focus, either in the north of the island or beyond its limits. We might place it conjecturally in the neighbourhood of the Shiant Isles, 12 to 14 miles north of Skye, where Professor Judd<ref>*Quart. Journ. Geol. Soc.,* vol. xxxiv., pp. 676, 677: 1878</ref> and Sir A. Geikie<ref>Ibid.vol. lii., pp. 373, 376: 1896.</ref> have described what appears to be a single sill 500 feet thick.

The failure of the sills in the neighbourhood of the mountains is beyond doubt due to the obstacle presented to their spread by the ring of metamorphosed basalt lavas. The sill-magma, which easily found a way along the divisional planes of the lava-flows outside the metamorphosed belt, was arrested when it encountered the tougher and more stubborn rocks, devoid of apparent bedding, which fringe the plutonic intrusions; and sills are accordingly absent in this belt, as well as in the gabbro and granite themselves. This, of course, would be sufficient to prove the posteriority of the sills to the plutonic intrusions, even were no other evidence available. The total absence of the sill rocks among the patches of basalt entangled in the gabbro and granite is equally significant. The belt of metamorphosed basalts free from sills has usually a width of nearly a mile from the main boundary of the gabbro or granite (*see* (Figure52)).

With reference to the *thickness* of the individual sills, we have observed none in Skye comparable in magnitude with that mentioned above in the Shiant Isles, supposing the 500 feet there seen to belong really to a single sill. Many of the sills in the northern and north-western parts of Skye, however, attain a thickness of 100 feet, and there are some which exceed 200 feet. Still greater thicknesses of sill-rocks are found where two or more large sills come together without any intervening "country" rock. This is, among the basaltic plateaux, a very frequent occurrence, and in this way arise what we shall style for convenience *double, triple, and multiple sills.* The thickest multiple sill verified in the area mapped is that with fine columnar jointing which forms Preshal More, near Talisker: here the total thickness shown is about 500 feet.

The accompanying section (Figure 53) will illustrate the important part which the sills play in the structure of the basaltic moorlands. It is taken in a north-easterly direction from the high-road a little west of Inver Meadale farm-house, near Struan, and traverses Monadh Meadale, one of the hills to the north-east of Loch Harport. Here a total thickness of about 2000 feet is distributed approximately as follows:

Feet		Feet
325	Four-fold sill	
	Lavas	55
200	Four-fold sill	
	(Lavas to S.E.)	—

	35	Sill	
		Lavas	50
	115	Double sill	
		Lavas	65
	140	Double sill	
		Lavas	65
	165	Double sill	
		Lavas	60
	55	Sill	
		Lavas	100
	40	Sill	
		Lavas	120
	30	Sill	
		Lavas	105
	50	Sill	
		Lavas	175
	50	Sill	
Twenty sills,	1,205 ft.		795 ft, Lavas.

It is seen that the sills become more numerous as we ascend in the succession, and collectively make up three-fifths of the whole thickness. Of the upper half of the section the sills make about five-sixths, of the lower half about three-eighths. It is also seen in the section that the tendency of the sills to run together as double or multiple sills becomes more pronounced as we pass upward, and this too seems to be very generally true throughout the basalt tract. A section taken farther northward, *e.g.* at the Quiraing, would probably bring out even more strikingly the importance of the intrusive sills intercalated among the basaltic lavas, but our detailed survey has not extended into that part of the island.

The *persistence and regularity* of the sills are very remarkable. Whether in the basaltic lavas or in the Jurassic strata, they may often be traced for long distances, maintaining accurately a defined horizon. Among the basalts it is not uncommon to find two sills which have been separated coming together; but this is susceptible of two alternative explanations: one of the sills may have broken obliquely across the basalt lavas intervening, or a lava-flow dividing the two sills may have died out. Since the several flows of lava are as a rule not distinguishable, except in so far as they are separated by sills, no simple criterion is available; but the latter alternative is probably the usual explanation, and the indications go to show that the individual sills have in general a much greater lateral extension than the individual lava-flows.

We shall have to point out in another chapter that the basic dykes of our area do not traverse different kinds of rock with equal facility, but exhibit very marked preferences. In the nature of the case a sill does not usually, like a dyke, encounter different country rocks in its progress; but when such a case occurs we find the same reluctance to enter certain kinds of rock. Thus the sills have not without difficulty penetrated a mass of volcanic agglomerate lying in their path, and may sometimes be seen to die out rapidly in such a mass. A good illustration of this is seen at the southwestern corner of Camas Bàn, near Portree (*see* (Figure 6), p. 23). We have already seen that the sills are completely stopped, not only by the peridotites, gabbros, and granites, but also by the basaltic lavas metamorphosed in the vicinity of those rocks.

As regards the manner of intrusion of the sills, it cannot be doubted that they were fed through dyke-fissures. The difficulty of identifying with certainty any of the dykes representing these feeders is one to which it is not necessary to attach much importance. Apart from an ocular demonstration of the continuity of a sill with its dyke-feeder, which could only be expected as a rare accident, there seems to be no means of discriminating the feeders of the sills from the feeders of the basalt lava-flows. It may be therefore that some of the basic dykes, earlier than the majority of those in the area, belong to the great group of sills. It is probable, however, that the fissures through which rose the material to form these sills are for the most part situated in that portion of Skye lying to the north of the ground as yet surveyed in detail. That basic sills may spread laterally to great distances from their source is evident from their extent as actually seen in Skye, and is still more clear in areas where the confusing element of a great number of sills is not present. The Great Whin Sill of Teesdale, for example, can be traced over an extent of 80 or 90 miles; and, if its origin be at Cauldron Snout, the magma must have forced its way laterally for a distance of at least 70 miles.

We shall have to notice later that the more massive sills have presented an obstacle to the passage of dykes subsequently injected. This would lead us to anticipate that *the higher sills of the great group were in general those earlier intruded.* That this was the case appears from several circumstances, and especially from the fact that multiple sills become more frequent towards the upper part of the group. A dyke-fissure propagated upward would often be arrested at the lower surface of a sill, and the magma forced up through the fissure would then spread laterally, forming a new sill immediately below the earlier one. In this way the new sill would at most have to traverse the dyke-feeder or feeders of the earlier sill, a much easier matter than penetrating the sill itself. It is also probable that a given fissure has often served for more than one intrusion, so that the feeders would sometimes be multiple dykes.

The basic sills of this great group, presenting a very general community of petrographical characters, show also considerable uniformity as regards habit and appearance in the field. In thickness there is great variation, the single sills ranging from a few inches to 200 feet or more. Apart from this, the chief difference observable among the sills in the field depends upon the degree of development of columnar jointing in the rocks. This character may be wholly wanting, or may occur with varying development and regularity. Where it is absent, the sills, and especially those of moderately large dimensions, very often show a certain platy or rudely laminated structure parallel to the upper and lower surfaces and most marked in the neighbourhood of those surfaces. This is often found also in association with the columnar jointing. It imparts a certain quality of fissility to the sill, but is not related to anything in the intimate structure of the rock, and must be regarded as an effect of contraction.

Conspicuous *columnar jointing* in the sills seems to have a well-defined geographical distribution in the island. It is very prevalent and often very perfectly developed in the north, but gives place, as we pass southward towards the central tract, to a rude division into blocks, frequently showing the quasi-horizontal platy structure already mentioned. When most clearly marked, the columns are as a rule at right angles, or nearly so, to the surfaces of the sills, and therefore make only a small angle with the vertical, depending on the dip of the sills themselves. Irregularities are, however, found in some places (Plate 9). The columns extend from top to bottom of even the thickest sills, though they may be broken at intervals by cross-joints.

Some of the finest examples of columnar jointing are seen in the two hills named on the Ordnance map Preshal More and Preshal Beg,<ref> They have attracted the notice of several of the earlier writers, the name appearing under various disguises: Briis-mhawl (Pennant), Breeze-hill (Jameson), and Brishmeal (Macculloch).</ref> near Talisker. They are two outliers of the same multiple sill, which is columnar throughout. The most regular development is seen in the lowest member, which forms the steep sides of each hill. As seen on the south-east side of Preshal Beg, this is from 70 or 80 to 100 feet thick, the columns often ranging unbroken through this distance. They are perpendicular to the surfaces of the sill, and at the west end, where the sill itself is rather sharply tilted up, the columns are inclined so as to preserve their approximate perpendicularity. On the north side, however, their inclination is less according to rule. The cross-section of any column is an irregular polygon of from 4 to 7 sides, with diameter usually between 1 and 2 feet; and the same form and dimensions are preserved throughout the length of the column. Resting upon this regularly jointed sill, and forming the upper part of the bold hill, are two or more other sills, in which the columns are smaller and less perfectly formed, and tend to form rather divergent bunches. These upper sills have a thickness (left after erosion) of 180 to 200 feet, the thickness of the whole multiple sill being not less than 275 feet. Preshal More shows a like arrangement (Figure 54), and here, in the precipitous northern face of the hill, the total thickness of columnar rock shown is scarcely less than 500 feet. There are in places irregularities in the disposition of the columns, which are sometimes curved (Plate 9). The arrangement shown in these hills, of a lower sheet with very regular columns overlain by one or more sheets with a more confused prismatic structure, seems to be not uncommon in other parts of the Inner Hebrides, Fingal's Cave in Staffa being a well-known example.

Perhaps the most striking exhibitions of columnar jointing in Skye, however, are to be seen on the east coast. As we proceed northward, the first example is met with at Rudha Buidhe, between Loch Sligachan and Portree Harbour (Plate 10). Beyond Portree, the thick sills intruded in the Jurassic strata display, as exposed in the sea-cliffs, a highly developed and very regular columnar structure, which reaches its climax in the Kilt Rock<ref>See sketch by Sir A. Geikie, *Quart. Journ. Geol. Soc.,* vol. lii., p. 374: 1896.</ref> and along the coast of Loch Staffin.<ref>The name Staffin, like that of the island Staffs (from the Norse *stay,* staff) is doubtless in allusion to this feature.</ref>

Very striking are the *magnetic phenomena* connected with the sill-rocks<ref>Harker, Magnetic Disturbances in the Isle of Skye, *Proc. Camb. Phil. Soc.,* vol. x., pp. 268–278, Pl. XI., XII.: 1900.</ref>. In the moorland country these rocks, as we have remarked, usually form all the salient features. In the neighbourhood of any prominent ridge or knoll, which stands out above the surrounding ground, the compass shows a very sensible deflection from the normal magnetic meridian. Projecting knobs of rock are found to be places of violent magnetic disturbance, particular points in the rock attracting either the north or the south pole of the needle, and giving evidence of strong permanent magnetism distributed in an irregular fashion, as already noticed in the gabbro of the mountains. Again, areas sometimes hundreds of yards in extent often show disturbances of a lower order, but still easily verified with the pocket-compass. Such an area embraces one or more centres of violent local disturbance, and the effects become gradually less noticeable with increasing distance. There appear to be evident relations between the two orders of phenomena, and it is possible that much more wide-spread but feebler disturbances, only to be detected by a systematic magnetic survey, may also be connected with permanent rock-magnetism. The localisation of the more strongly marked phenomena in exposed summits and ridges decidedly suggests atmospheric electricity as the cause of the magnetisation.

The *metamorphism produced by the sills* in older rocks adjacent to them is never comparable in degree and extent with the effects set up in the neighbourhood of the gabbro and granite masses. The basaltic lavas in contact with the sills of the plateaux often show no perceptible change from this cause. Even in the Jurassic rocks invaded by the thick sills of the Trotternish coast, as Sir A. Geikie<ref>*Quart. Journ. Geol. Soc.,* vol. lii., p. 376: 1896; and *Ancient Volcanoes of Great Britain,* vol. ii., p. 310: 1897.</ref> has noted, the alteration "seldom goes beyond a mere induration of the strata for a few yards, often only for a few inches from the surface of junction". In their being attended as a rule by little or no conspicuous thermal metamorphism the sills resemble the ordinary dykes of the district.

Of reciprocal modification of a mineralogical kind in the sills themselves at their contact with sedimentary rocks we have not found any indication. Bryce<ref>Quart. *Journ. Geol. Soc.,* vol. xxix., p. 328: 1873.</ref> recorded dipyre as occurring in a thick sill on the shore of Loch Staffin. This sill is intruded among Jurassic strata, partly calcareous, and forms the base of the well-known Loch Staffin section.

One place only calls for special notice as illustrating an advanced degree of metamorphism produced by the basic sills. This is in the Isle of Soay, where the relations of the rocks have been studied and specimens collected by Mr Clough. The country-rock here is a coarse-grained grit of Torridonian age, consisting of quartz with a considerable amount of alkali-felspars, these latter being turbid and iron-stained (S9984) [NG 444 122]. At certain localities the grit has been in great part vitrified in contact with basic sills, which are in no case more than 10 feet thick. A series of specimens has been examined from a little bay near the extreme south point of the island (S9981) [NG 444 122], (S9982) [NG 444 122], (S9983). In its most altered condition the rock has the black vitreous appearance of a pitchstone, but in this as a matrix are enclosed little pale spots which represent undestroyed grains of quartz. Mr Clough found the specific gravities of two specimens to be 2.42 and 2.47. Thin slices present under the microscope a very beautiful appearance. In one variety relics of quartz-grains are preserved in a matrix consisting principally of colourless glass. The grains are evidently corroded, and a large part of the quartz of the grit, with the whole of the felspar and iron-oxide, has been fused to make the matrix. This latter is a clear colourless glass crowded with little crystals (*see* (Plate 21)., Fig. 3). Three minerals are to be recognised among these crystals. First there is magnetite in sharp octahedra, usually not more than 0.0005 inch in diameter. Secondly, and of later formation than the magnetite, which it sometimes encloses, is cordierite, in well-shaped crystals averaging about 0.001 inch. These are perfectly clear and colourless. They have the crystal habit usual in this mode of occurrence,<ref>The forms present are the prism, brachypinacoid, and basal, and the habit is such as to simulate very closely a hexagonal prism. The vertical length is not much greater than the transverse diameter. For such microscopic cordierite crystals see especially Prohaska, *Sitz. Wien Akad., math.-naturw. Classe, vol.* xcii., pp. 20–32: 1885; and Zirkel, *Neu. fahrb.,* 1891, vol. i., pp. 109–112; also, for figures, Hussak, *Sitz. Wien Akad.,* mats.-*naturw. Classe,* vol. *lxxxvii ,* pp. 332–360: 1883.</ref> giving rectangular and hexagonal sections, but we have not detected polysynthetic twinning. The third mineral builds slender rods with a fibrous structure longitudinally, and has a faint greenish-yellow tint. It seems to be pleochroic, and the extinction, when it can be verified, is nearly parallel to the length of the rods. The mineral is perhaps aegirine.

In another specimen (S9981) [NG 444 122] the same three minerals occur in the colourless glass, magnetite being specially abundant, but there are in addition little rods of clear new-built felspar. These seem to be connected in a very intimate manner with the corrosion of the quartz-grains, being densely massed in embayments of these. This slice shows the junction with the dolerite sill. Approaching this, the cordierite-crystals disappear, while the pale-tinted fibrous rods become very plentiful. They are here of stouter shape than before, and their pleochroism and low extinction-angle can be verified, but it is not certain whether they belong to an amphibole or a soda-pyroxene. Towards the dolerite the glassy matrix encloses felspars from that rock and little grains of augite resembling, except in their granular form, that of the dolerite. The quartz-grains are not found in this part. Immediately contiguous to the dolerite, the glassy matrix assumes a brown colour. It seems that there has been a certain degree of commingling between the dolerite magma and the fused grit. This is evident at the actual junction, and even in other places the formation of cordierite seems to imply an accession of magnesia. The dolerite itself, beyond the narrow zone characterised by brown glass, is, however, of quite normal character. In another specimen sliced (S9983) [NG 444 122] the relations are more complicated, the actual junction between the vitrified grit and the dolerite being of highly irregular form. The matrix enclosing the relics of quartz-grains is here pale brown and turbid, and is found to depolarise, being apparently in great part felspathic. There has evidently been considerable later decomposition, the yellowish-green rods, abundant in places, being quite destroyed. Cordierite is not recognised here.

It is by no means certain that the sills which produce these very striking changes in the Torridonian grits belong to what we have styled the "great group". Of the basic sills of Soay in general, which are rather numerous though individually of no great magnitude, it appears that some at least are to be referred to a much later epoch. Mr Clough has observed three clear instances of the vitrification of grits in Soay, besides others in which the effects seem to be obscured by subsequent alteration. Some of these are in connection, not with basic, but with ultrabasic sills, which belong to a very late stage, and will be discussed in a later chapter. The vitrification is only locally produced in the case of any given sill.

We pass on to the *petrographical characters* of the great group of sills. They appear in the field as dark rocks usually of moderately fine texture, but evidently crystalline: only exceptionally, in some of the thinner sills, do we find a compact appearance comparable with what is seen in the basalt lavas. The rocks are typically non-porphyritic, and in general not amygdaloidal, though in some cases amygdules occur sparingly. There is as a rule little appearance of decomposition, excepting a rusty surface due to oxidation. The specific gravity is high. Forty examples gave figures varying from 2.82 to 3.07, with a mean of 2.94. It is clear that the rocks are all of basic composition, and are not varied, as in the volcanic group, by sub-basic types.

A striking characteristic of the basic sills as compared with the basic lavas is their much fresher condition. This is partly connected with the general absence of any vesicular structure. When scattered amygdules are present, they consist of calcite or other secondary products, rarely chloritic. Veins of decomposition-products are decidedly rare. In the thick sill which forms the cliff at Rudha Buidhe, between Portree and the Braes, there are irregular veins and knots of yellowish crystalline calcite. This has in part a brecciated structure with clear radiating growths surrounding dull patches, and in the interspaces there is a little chalcedony, also with radiate structure (S9256) [NG 519 367].

The very small amygdules, which occur sparingly in some of the sills, are of regular spherical form. Where scattered amygdules of larger size are present, they have a rather more irregular shape, but still, as a rule, without systematic elongation in any particular direction. This is a point of contrast with the basaltic lavas and also with many of the basic dykes of the region. The infrequency of a conspicuous amygdaloidal structure is a character not only of the great group of sills but also in varying degree of other groups of sill-formed intrusions in our area. Mr Clough notes that in some of the sills in the Isle of Soay amygdules are more abundant near the top than near the bottom, but they always decrease in size close to the margins, as is also the case in the dykes.

To illustrate the *chemical composition* of the sills of the great group two complete analyses have been made by Dr Pollard (I., II.). We have not for comparison with these any other published analyses of rocks from the British Tertiary suite, which are definitely stated to be from sills, and can be assumed to belong to the "great group". It is highly probable, however, that the "trap" rocks from Fingal's Cave and the Giant's Causeway, analysed many years ago by Strong, are to be placed here, and we accordingly quote the figures for these in columns A and B.

It is to be noticed that, while these rocks have about the same silica-percentage as the gabbros, they differ widely in other respects. The sills are poorer in alumina and lime, and richer in iron and alkalies. Two minor constituents also show significant differences: the sills have an exceptionally high percentage of titanic acid, and, unlike the gabbros, they contain phosphoric acid to an amount such as is usual in basic igneous rocks in other regions.

In the photographs of the arc-spectra of these two rocks kindly communicated by Sir J. Norman Lockyer the lines corresponding with Ti, Cr. Va, and Sr are all very clearly shown, those for titanium and strontium being especially prominent in I. and that for chromium in II.<ref> Since the above was written, Dr Pollard has made actual estimations of chromium and vanadium in some of the Skye rocks (*Summary of Progress, Geol. Sur.* for 1902. nu. 60. 611. The figures are here reproduced: (S8185) [NG 42 28] Olivine-Basalt lava (p. 31), Cr_2O_3 0.04 V_2O 0.04; (S8043) [NG 481 232] Olivine-Gabbro (p. 103, I.) Cr_2O_3 0.03 V2O 0.03; (S8194) [NG 449 242] Olivine-Gabbro (p. 103, II.) Cr_2O_3 0.02 V_2O 0.02; (S8057) [NG 434 337] Olivine-Dolerite, sill (p. 248, I.) Cr_2O_3 trace V_2O 0.03; (S8062) [NG 468 256] Dolerite, inclined sheet (Ch. 21) Cr_2O_3 0.01 V_2O 0.06</ref>

	I	II	A	B
SiO_2	46.13	45.24	47.80	52.13
TiO_2	3.60	2.26	not det.	not det.
Al_2O_3	17.07	15.63	14.80	14.87
Cr2O2	trace	trace		
V_2O3	0.03			
Fe_2O_3	6.61	5.56	not det.	not dot.
FeO	8.20	7.19	13.08	11.40
NiO, CoO		trace		
MnO	0.28	0.23	0:09	0.32
MgO	4.38	7.88	6.81	6.46
CaO	7.15	9.38	12.89	10.56
Na_2O	3.58	2.01	2.48	2.60
K_2O	1.19	0.72	0.86	0.69
H_2O above 105°	1.71	2.21	1.41	1.19
H_2O at 105° C.	0.59	1.12		
CO2		0.49		
P_2O_5	0.0 9	0.20	not det.	not det.
	100.61	100.06	100.25	100.22
Specific gravity	2.91	2.85	(2.957)	(2.878)

I. Olivine-dolerite (S8057) [NG 434 337], sill 500 yards N. of tarn, Broc-bheinn, about 4 miles W.N.W. of Sligachan: anal. W. Pollard, *Summary of Progress Geol. Surv.* for 1899, p. 173. Vanadium and strontium were detected spectroscopically by Sir J. Norman Lockyer in this and the next rock.

II. Olivine-dolerite (S7854) [NG 502 336], sill forming summit of Ben Lee, N.W. of Loch Sligachan: anal. W. Pollard, *ibid.,* p. 174.

A. "Trap" [? dolerite sill], Fingal's Cave, Staffa: anal. A. Strong, *Pogg. Ann.,* vol. xc., p. 114; 1853. (Specific gravity by von Dechen, on another specimen.)

B. "Trap" [? dolerite sill], Giant's Causeway, Antrim: anal. A. Streng, *ibid.* (Specific gravity by von Leonhard, on another specimen.)

The *constituent minerals* of the rocks are not many: felspar, augite, olivine, iron-ore, and apatite. The felspar is in general a labradorite, but, judged by extinction-angles in thin slices, often a rather basic variety of labradorite; and sometimes, as in the Ben Lee sill of Analysis II., it is a bytownite. The crystals in rocks of average texture are about 1/50 inch long, but there is considerable difference in this respect in different sills. They show the usual tabular habit parallel to the brachypinacoid, giving rectangular sections, which in the finer-textured rocks are of slender form. Carlsbad and albite twinning are constantly found. Sections parallel to the twin-lamell often show a more rounded outline, and between crossed nicols a zonary banding.

The augite has invariably crystallised after the felspar. It is light brown to nearly colourless in thin slices. In some sills, such as the great one in the Jurassic at Steinscholl, there is a purple tinge with distinct pleochroism (S5336). The mineral is usually quite fresh. If it shows any alteration, this is of the serpentinous, not the chloritic, kind, and the augite is probably of a non-aluminous variety.

The great majority of the rocks contain olivine, which is certainly much more general here than in some other groups of basic rocks in Skye. Sometimes it shows crystal outlines with the usual habit, but more often it has a rounded shape. In most of the rocks it is quite fresh: if altered, it gives rise sometimes to green or yellow serpentine, sometimes to a light yellowish or reddish brown mineral with mica-like cleavage, which seems to be of the iddingsite class.

Magnetite, or at least an iron-ore with octahedral form, is constantly present, and sometimes abundant, *e.g.* in the Broc-bheinn sill of analysis I. Only exceptionally does it form irregular grains, which may then be moulded upon the felspar crystals. The only remaining mineral is apatite, which is generally distributed in small quantity.

The *micro-structure* is almost as uniform as the mineralogical constitution, the great majority of these sill-rocks being typically ophitic. This structure is not only much more general, but also as a rule much better developed than in the basic lavas, and it is common to find the augite building plates sufficiently large to enclose numerous felspar crystals.<ref>The olivine-dolerite, probably a sill, from Portree figured in Teall's *British Petrography,* p1. X., fig. 2, is a good example.</ref> The structure is found on various scales, but is most marked in the finer-textured varieties. A micro-ophitic dolerite of this kind forms, *e.g.,* the lower columnar sill of Preshal Beg (S9249) [NG 326 280], where the interlocking augite-plates are about 1/20 inch in diameter, and each encloses many little felspars about 1/300 inch long. The ophitic structure is, however, not universal. The "granulitic" type is found in some of the rocks, *e.g.* in that from Broc-bheinn analysed above, although neighbouring sills are ophitic. We consider, with Professor Judd, that the "granulitic" structure is a result of movement in the mass prolonged to a late stage in the consolidation: it does not import any difference in the nature of the rock.

The rocks composing the sills of the great group are then for the most part *olivine-dolerites.* Where olivine fails, as in the Preshal Beg rock mentioned above and the Slat Bheinn rock to be described below, this character does not connect itself with any other essential differences, and we are not disposed to regard it as of primary classificatory value. Little difference is observable among the several sills of the group, excepting that the smaller ones, especially when they occur among the Jurassic strata, are of somewhat finer texture, and might be denominated basalts rather than dolerites.

The sills are in general non-porphyritic, presenting an even-grained appearance without any evident crystals of conspicuous dimensions. There are, however, exceptions to this rule, and these are in some parts of the area not uncommon. Mere felspar phenocrysts occur, often ½ inch or 1 inch in length. They are never closely set, and in most cases are scattered so sparingly through the rock that they scarcely attain to the rank of normal porphyritic elements, but suggest rather some special conditions attending the intrusion of these particular sill-rocks. Good examples of these *sporadically porphyritic or quasi porphyritic* rocks are the great columnar sills of Preshal Beg and Preshal More and the strong sills forming the higher parts of Biod Mòr near Loch Eynort. As an occurrence more easily accessible may be mentioned the sill which forms the hills of Dun Merkadale and Cnoc Simid, near Carbost.

Typically *porphyritic* rocks are decidedly rare. We exclude here certain special sills of composite habit, which differ entirely from the ordinary sills of the great group, and will be described separately. As an example of a sill rich in porphyritic elements we take one which forms a strong escarpment on the steep slope overlooking Loch Harport, beyond the mouth of Meadale Burn. This shows abundant felspars, besides little grains of olivine, in a close-textured matrix. The felspars are of irregular shapes, and in a slice (S9806) [NG 374 337] they are seen to be, not single crystals, but aggregates which further include here and there a little patch of augite, unlike the ophitic augite of the matrix. This 'glomeroporphyritic' structure — to adopt a term of Professor Judd — suggests that here also these enclosed elements have not the status of true porphyritically developed crystals. The felspars, ranging up to about ■ inch in length, have rather broad twin-lamellae, and enclose round glass- or stone-cavities of rather large size, concentrated in the interior of the crystals. The rock is rich in round grains of olivine. The ground is micro-ophitic, the felspars being very minute and of slender shape.

It may be inquired whether any law is apparent in the vertical distribution of different petrographical varieties among the sills of the great group, but on this point our observations are very inconclusive. If a sequence of increasing basicity held among the successively intruded magmas, we should expect to find the higher sills somewhat less basic in composition than the lower; and this would also imply that the denser magmas were intruded at lower levels. It is very doubtful, however, whether any such law should be expected in this group of rocks, which, as we have seen, is not one of the groups connected with the Skye focus of eruption; and such observations as have been made do not appear to fall under any defined principle. We may take as an example the sills exposed on Biod Mòr:, near Loch Eynort. Specimens of the sill-rocks taken on the western slope of this hill, at intervals of about 100 feet in altitude, give the following results: in descending order:

Fine-grained, black, with rather sparse glassy felspars to ½ inch	2.96
Fine-grained, dark grey, felspars more sparse	2.92
Dark grey, with platy fracture	2.92
Felspars more abundant than before, but much smaller	2.85
Very fine-grained, with rare scattered felspars to ¼ inch	2.83
With only a few small felspar phenocrysts	2.90
Very fine-grained, black,	2.83
Very fine grained, black	2.82
With abundant slender felspars, up to ■, inch, and scattered round amygdules	2.85
With a tendency to spheroidal weathering	2.91

Here no law is apparent in the arrangement of more and less dense rocks. The occurrence of scattered felspar crystals of relatively large size in the higher sills is, however, a feature noticed in numerous localities, and is possibly of significance.

One feature occasionally observable in the basic sills remains to be noticed, viz. the *inclusion of foreign rock-debris* (*xenoliths),* or of isolated crystals (xenocrysts) coming from the disintegration of these. These foreign elements are found only infrequently and sporadically. Some of them are doubtless of accidental nature, picked up from the rocks traversed by the sills, *e.g.* fragments of basaltic lava. Most of the derived material, however, has probably a somewhat different significance, and is not derived from rocks visibly traversed by the sills. The most common xenoliths are of gabbro, and, as has been remarked above, the sills now under consideration nowhere come into contact with the gabbro actually exposed at the surface. A like remark applies to the granite xenoliths which are of rarer occurrence. These foreign elements are probably derived from a considerable depth, and may have the same source as the gabbro and granite fragments in the volcanic agglomerates, from which we have already been compelled to infer the existence of an older suite of plutonic rocks nowhere brought to light by erosion.

The petrographical characters of xenoliths will be considered more particularly in treating of the basic dykes, where they are of much more frequent occurrence. In this place it will be sufficient to notice a single case, the only one within our knowledge in which the derived elements are found in such profusion as to set their mark on the appearance of the rock as seen on the ground. The locality is in the northern part of the Strathaird peninsula, and the sill forms the flat top of Slat Bheinn or An Dà Bheinn, a hill built essentially of the basaltic lavas.<ref>The rock carrying the xenoliths was at first grouped tentatively with the lavas (Ann. *Rep. Geol. Sur.* for 1896, p. 73, and Sir A. Geikie's *Ancient Volcanoes of Great Britain,* vol. ii., p. 269; 1897). Closer examination, both geological and. petrographical, proves it to be a sill.</ref> In the neighbourhood of the little tarn marked on the map the rock shows abundant crystals of felspar, ■ to ¼ inch long, scattered through the dark grey fine-grained ground. There are also many enclosed pieces of gabbro, and it is easy to see, even in hand-specimens, that the felspar crystals are not normal porphyritic elements of the rock, but arise from the breaking up of the gabbro xenoliths. Some xenolithic dykes on the slopes of Slat Bheinn perhaps represent the channels by which the sill was supplied, but their actual connection with it has not been demonstrated. Four slices were made of the sill-rock with its inclusions (S7466) [NG 538 197], (S7467) [NG 538 197], (S7468) [NG 538 197], (S7469) [NG 538

197]. The rock itself is a rather fine-textured ophitic dolerite with no special peculiarities. The felspar xenocrysts show little sign of change except the production of granular epidote, which is sometimes so plentiful as to impart a yellow colour to the crystals in hand-specimens. The derived augite, from the gabbro, when preserved, is more or less obscured by secondary magnetite dust, and in general the mineral has been totally destroyed, being represented only by clotted patches of ferruginous matter and presumably by some part of the augite of the dolerite. The undoubted gabbro xenoliths often show but little sign of any caustic action of the magma upon them giving rise to chemical reactions; and this might be expected from the resemblance in composition between the enclosed and enclosing rocks. It is different with certain small xenoliths, usually an inch or less in diameter, which seem to represent granite, and are completely transformed. Towards the junction with one of these the dolerite becomes rather richer in augite, and there is some uralitisation. Then, on the border of the xenolith, comes a zone, up to 1/10 inch wide, of light green pleochroic chlorite with fan-like groupings. This encloses little crystals of epidote and occasionally what looks like a bastite pseudomorph after a rhombic pyroxene. The interior of the xenolith is recrystallised as an irregular mosaic, or shows a tendency to a radiate arrangement extending inward from the periphery. It is of clear felspar, usually, without twinning, and some quartz, and these enclose needles of actinolite and little crystals of pale epidote.

It is remarkable that the sills rarely enclose recognisable fragments even of the lavas among which they are intruded. Among the few instances observed may be mentioned one in Allt na Coille, above Drynoch, and another in a burn crossed by the Portree road about 3½ miles from Sligachan. It is possible, however, that in some other cases the true nature of enclosed pieces of basaltic lava is disguised by the metamorphism which they have undergone. Occasionally we find in the sills sharply defined patches with an amygdaloidal structure which is wanting in the surrounding rock. Good examples of this are seen in the Varragill River near where it is crossed by the Portree–Sligachan road.

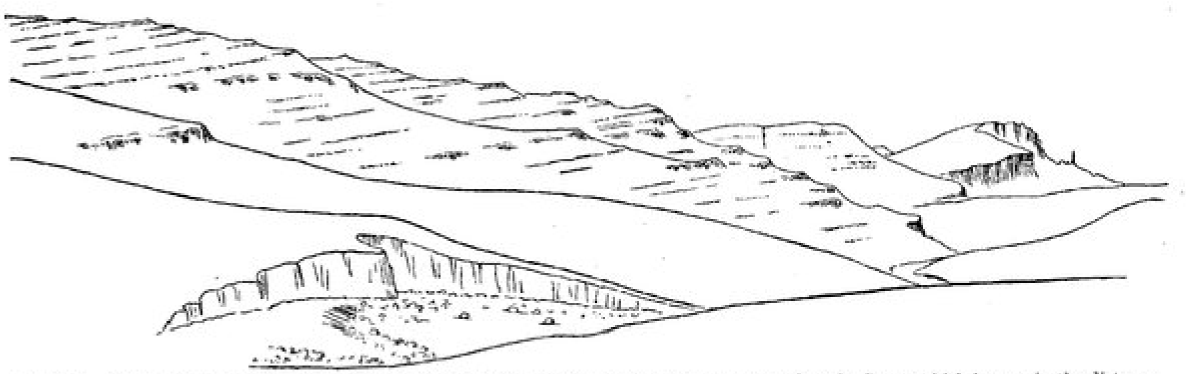


Fig. 79.—Terraced hills on the west side of Glen Varragill; outline view, looking northward to the Storr, which is seen in the distance (right). The terraces are caused by the very numerous intrusive sills intercalated in the basaltic lavas.

(Figure 79) Terraced hills on the west side of GIen Varragill; outline view, looking northward to the Storr which is seen in the distance (right). The terraces are caused by the very numerous intrusive sills intercalated in the dasaltic lavas.

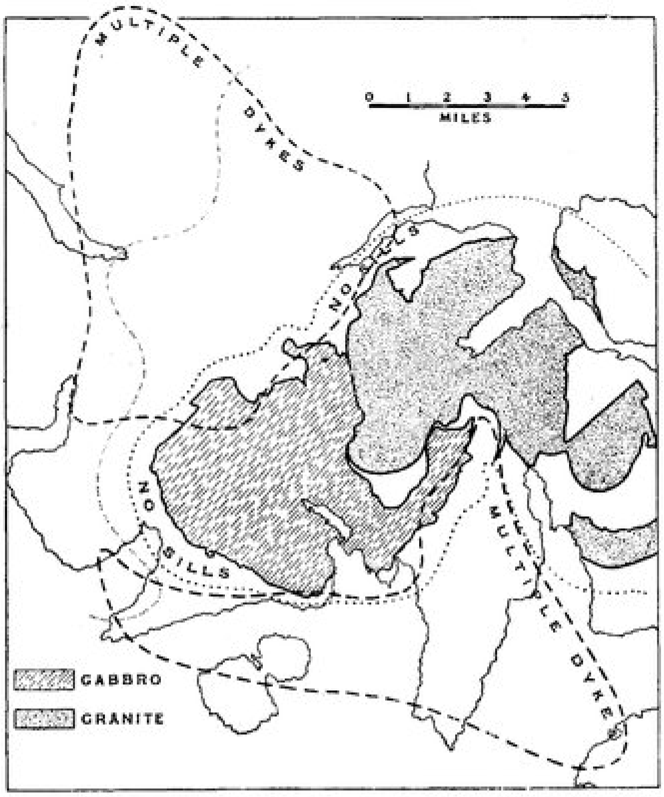


FIG. 52.—Sketch-map illustrating the distribution of the basic sills, and also of the multiple basic dykes, in relation to the large plutonic intrusions. Scale, ¼ inch to a mile.

(a) The heavy dotted line indicates the area (embracing the plutonic intrusions with a narrow surrounding belt) which is free from sills belonging to the great group. The lighter dotted line marks the limit (in this part the eastern limit) of multiple sills. This depends partly upon the general attenuation of the group in this direction, but partly also upon the progress of erosion, since the multiple sills are developed chiefly in the upper portion of the lava group.

(b) The heavy broken line indicates the distribution of the principal multiple basic dykes. They are found within an elongated oval tract, about eleven miles long, centring in the great gabbro laccolite and having its long axis in the general direction of the dykes themselves. This oval tract, however, is divided into two detached areas by the plutonic masses. It is not improbable that better exposures might enable us to join these two areas on the west side of the Cuillins, but on the east side the granite has offered an impenetrable resistance (see Chap. XVII.).

(Figure 52) Sketch-map illustrating the distribution of the basic sills, and also of the multiple basic dykes, in relation to the large plutonic intrusions. Scale, ¼ inch to a mile. (a) The heavy dotted line indicates the area (embracing the plutonic intrusions with a narrow surrounding belt) which is free from sills belonging to the great group. The lighter dotted line marks the limit (in this part the eastern limit) of multiple sills. This depends partly upon the general attenuation of the group in this direction, but partly also upon the progress of erosion, since the multiple sills are developed chiefly in the upper portion of the lava group. (b) The heavy broken line indicates the distribution of the principal multiple basic dykes. They are found within an elongated oval tract, about eleven miles long, centring in the great gabbro laccolite and having its long axis in the general direction of the dykes themselves. This oval tract, however, is divided into two detached areas by the plutonic masses. It is not improbable that better exposures might enable us to join these two areas on the west side of the Cuillins, but on the east side the granite has offered an impenetrable resistance (see Chapter 17).

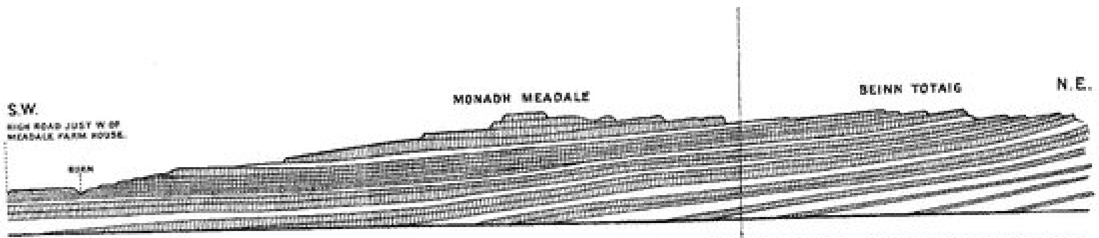


FIG. 53.—Section through Monadh Meadale and Beinn Totaig; showing intrusive sills (indicated by vertical shading) in the basaltic lavas, and showing how these run together to form double and multiple sills. Scale, 4 inches to a mile.

(Figure 53) Section through Monadh Meadale and Beinn Totaig; showing intrusive sills (indicated by vertical hading) in the basaltic lavas, and showing how these run together to form double and multiple sills. Scale, 4 inches a mile.

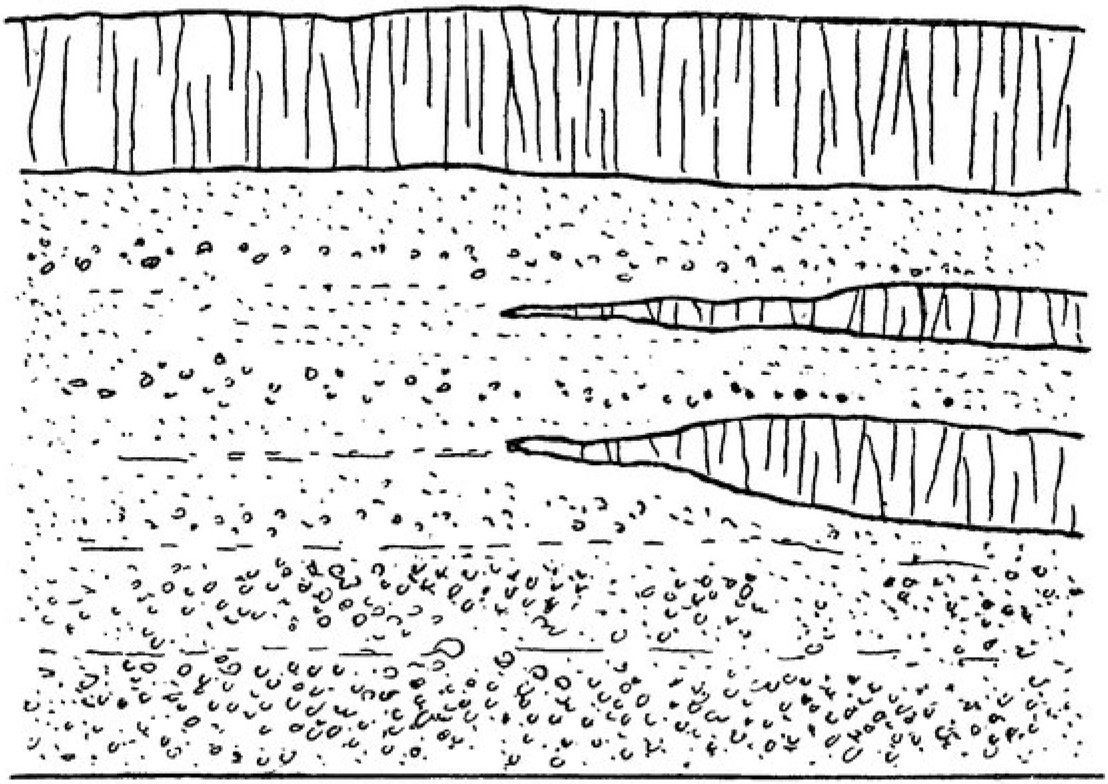
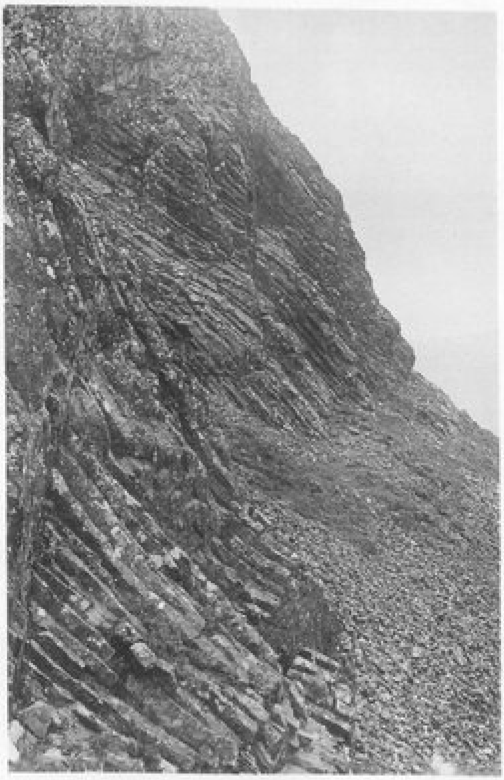


Fig. 6.—Cliff-section at Camas Bàn, on the south side of Portree Harbour; about 60 or 70 feet high. This shows the pyroclastic deposit covered by an intrusive sill of dolerite and invaded by two others.

(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.

PLATE IX.



Part of the northern face of Preshal More, near Talisker, showing curvature of columns.

(Plate 9) Part of the northern face of Preshal More, near Talisker, showing curvature of columns.

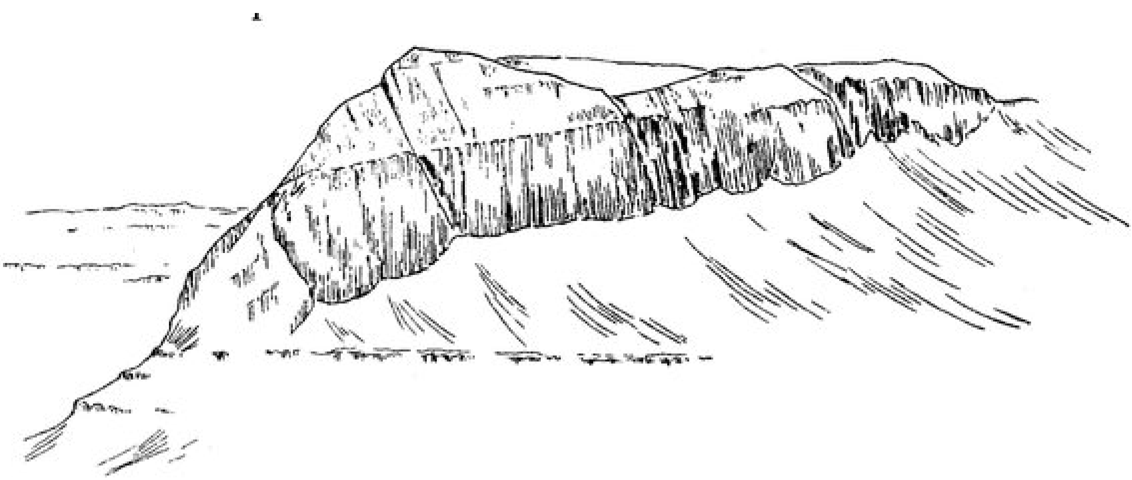


FIG. 54.—Preshal More, near Talisker, seen from the south-west.

(Figure 54) Preshal More, near Talisker, seen from the south-west.

PLATE X.

Columnar sill of dolerite forming the cliff at Rudha Buidhe, near Braes.

(Plate 10) Columnar sill of dolerite forming the cliff at Rudha Buidhe, near Braes.

PLATE XXI.

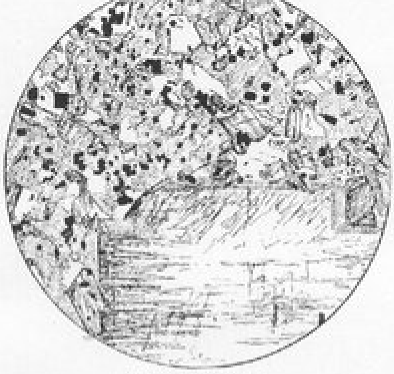


Fig. 1. Marscoite xenolith.

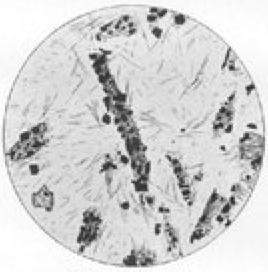


Fig. 2. Fused augites.

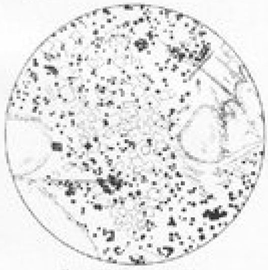


Fig. 3. Vitrified sandstone.

Fig. 4. Corroded xenocryst.

(Plate 21) Fig. 1. (S7551) [NG 508 289] × 30. Xenolith of marscoite from the "spotted" granophyre of Allt Daraich, near Sligachan. The figure shows one of the large labradorite crystals, much fissured, in a ground-mass of hornblende, oligoclase, orthoclase, quartz, magnetite, and apatite. There has been some impregnation by the surrounding acid magma. See p. 195. Fig. 2. (S7858) [NG 505 258] × 100. Augite crystals replaced by fibrous green hornblende and granules of magnetite, in marscoite from the gully on the N.W. face of Marsco. See p. 186. Fig. 3. (S9982) [NG 444 122] × 100. Vitrified Torridonian grit, in contact with a dolerite sill, S. coast of Soay. Some relics of quartz-grains remain in a corroded shape. The rest is a clear colourless glass enclosing minute crystals of cordierite, magnetite, and a pyroxenic mineral. See p. 246. Fig. 4. (S9371) [NG 645 249] × 30. Corroded xenocryst of oligoclase in small sill above the composite sill of Rudh' an Eireannaich, near Broadford. The crystal, except at its centre, is greatly affected by secondary inclusions. In one place corrosion has eaten away the crystal, forming an inlet occupied by the ground-mass with its small felspar crystals. See p. 229.