Chapter 15 Basic sills: Minor groups

While the great majority of the basic sills of Skye are clearly referable to one natural group, the intrusion of which belonged to a defined epoch in the sequence of eruptions, there are in numerous parts of the area examined sills, or sometimes less regular intrusive sheets, which are to be separated from those described in the preceding chapter. They seem to be in general younger than the great group, and they certainly belong to more than one distinct set; but our information concerning their occurrence and their petrographical characters would have to be considerably enlarged to warrant any attempt at discriminating the several groups in a systematic way. The following treatment is therefore confessedly incomplete, and the inclusion in this chapter of rocks by no means contemporaneous involves some departure from chronological order. Some of these minor groups of sills are developed more especially in the south-eastern part of the island; and the basic lavas, which are elsewhere the principal home of the sill-formed intrusions, are there absent. , With the question of recognising distinct minor groups of sills is also connected in some degree that of the precise limit in a south-easterly direction of the great group itself.

We find then that to the east and south of the mountain district of Skye basic sills, or sheets of basic rock having more or less of the habit of sills, are not of infrequent occurrence. They are, however, far less abundant here than to the north and west of the mountains; nor do they individually attain a thickness comparable with what is seen in the great group of sills. Moreover, they do not always adhere with such strictness to a definite bedding-plane; but this is doubtless due mainly to the nature of the country rock in which they are intruded. Mr Clough has supplied the following notes on the basic sills and sheets in the area surveyed by him: "Basaltic sills which keep tolerably well to the bedding are common in the Secondary rocks, but not elsewhere. In the Torridonian rocks there are occasional sheets inclined at rather low angles to the horizon, but these do not generally keep along the bedding: most usually, indeed, they incline in an opposite direction. Thus in Abhuinn Lusa, nearly half a mile above the bridge, there is a sheet of olivine-dolerite which dips S.E., though the Applecross Grits in which the sheet occurs are dipping N.W. Olivine-dolerite sheets which incline S.E. or S. occur also in a tributary of Abhuinn Lusa about half a mile N.N.W. of Loch an Ime, and in a burn about a mile slightly N. of E. of Kinloch.

"In one locality nearly half a mile N.N.E. of Tarskavaig Point a dolerite dyke sends off various thin sheets into Torridonian shales and grits. They keep nearly along the bedding, but they are only about eight inches thick, and do not extend far".

"Basaltic sheets have intruded along some of the Post-Cambrian thrusts. A sheet between four and ten feet thick is seen every here and there along the Moine thrust from near Loch an Uamh almost to Meall Buidhe, — a distance of nearly four miles. About 300 yards W.S.W. of Meall Buidhe a thin sheet, about a foot and a half thick, is seen in the same thrust-line. Sheets are also seen in other thrusts on the S. side of Sgùrr na h-Iolaire, and about a third of a mile N.E. of Gillean".

"Most of the basaltic sheets and sills are earlier than the dykes with which they are seen in contact, and appear to be often thrown by faults. For instance, a little E. and S.E. of Cnoc Càrnach (S.S.E. of Broadford) a series of sills in the Secondary rocks are repeatedly displaced by faults which strike between N.N.W. and W.N.W. There are, however, various sheets which are not crushed or displaced by the faults which strike across them. For instance, a N.N.E. sheet on the coast about a quarter of a mile N. of Tarskavaig Point comes up to a N. and S. fault, and runs along it for a short distance, but is not crushed or thrown by it: the sheet is older than a close series of N.N.W. dykes, which cut it distinctly. Again, in the bay E.N.E. of Rudha Chaìrn nan Cearc there are thin sheets which cut a series of E. and W. crushes: these sheets are, however, probably of later age than most of the sheets, and they cut some N.W. dykes".

That the sill-habit should be maintained with less regularity among the coarser and more massive strata of the Torridonian than among Jurassic shales, and should often be wholly lost in the former, might be anticipated, and seems to be generally true. It is well seen along the northern coast of Scalpay, where a number of basic sheets, from 2 to 5 feet thick, occur in the coarse pebbly Applecross Grits. They have as a rule a north-westerly dip, agreeing roughly with that of the stratified rocks, but the angle of dip is sometimes different, and in places the sheets are seen cutting obliquely across the strata.

That typical sill-formed intrusions are of earlier date than most of the dykes, and in general earlier than the chief epoch of Tertiary faulting, is also an observation of general application. Indeed it might be inferred on mechanical grounds that regular sills of any important extent would not readily be formed after the country rocks had been disturbed and broken.

Petrographically the smaller basic sills and sheets of the southeastern part of Skye offer much greater variety than those belonging to the great group as typically developed in the north and west. Some, especially in the Broadford and Strathaird districts, seem to have a composition similar to that of the great group, to which they are probably to be attached. Their closer texture may be attributed to the smaller size of the sills. Others, however, present types which are not to be matched in the northwestern parts of the island, and must be referred to distinct groups. Although these have not been studied exhaustively, some of them deserve passing notice. A. peculiar sill of a spherulitic basalt at Camas Daraich, Point of Sleat, will be described in Chapter 19, and a group characterised by abundance of olivine and the presence of picotite will be included with the later ultra-basic rocks in Chapter 22. One thick sill occurring at the base of the Mesozoic rocks in the southern part of Sleat may be mentioned here. It is an ophitic olivine-dolerite with abundant porphyritic crystals of labradorite. Olivine is also abundant, and seems to belong to two distinct generations (S7365) [NG 555 035]. The rock has a specific gravity 2.96. It resembles certain dykes, also rich in phenocrysts, which are found in the neighbourhood, and will be noticed in their place (Chapter 18).

It is, however, in another part of Skye that we find the most interesting of the basic sills not referable to the "great group". These we shall for clearness call the *Roineval type.* They are *composite double sills or laccolites,* the limited extent and swollen shape of some examples meriting rather the latter description; and they are composed, not of a basic and an acid rock, but *of two basic rocks* of different kinds. We shall show that, in some cases at least, the two rocks have been in a more or less fluid condition at the same time, and have to some extent intermingled during or after their intrusion; but, the petrographical difference between the two rock-types involved being much less here than in the Cnoc Càrnach group of intrusions, their mutual reactions are of a less remarkable kind. The distribution of the double sills in question, at least in that part of Skye surveyed, is very restricted. They have been mapped in three localities, and the separate intrusions known are not more than eight or nine in number. Their precise age has not been fixed with certainty. They are younger than the sills of the great group, and not improbably belong to a much later epoch, perhaps that of the trachy-andesite dykes to be described in Chapter 23. All the intrusions occur among the basaltic lavas.

The first locality to be noticed is Druim na Crìche, a flat ridge 2 miles N.E. of Roineval and 5 miles S.S.W. of Portree. The basalts here dip to the south-west, and the outcrops of the several sills in question form in general strong features divided by peaty flats. They are five in number, four being of composite structure, while the fifth (at its outcrop at least) consists of one rock only. This last, since the missing member is the stronger rock, does not make any marked feature. The apparent relations are shown in the accompanying section (Figure 55). The rock which occasions the prominence of four of the sills is an olivine-dolerite crowded with large porphyritic felspars of fresh glassy appearance. In each case this constitutes the upper member, and usually much exceeds the other in volume. In the highest or most south-westerly intrusion the porphyritic dolerite itself seems to be doubled, so that the whole sill is really triple. The other rock which constitutes the lower member, or in one instance (the second from the bottom) apparently occurs alone, is, when fresh, a black compact-looking rock without phenocrysts. In most places it is much weathered, assuming a dull yellowish-brown colour and a fissile structure parallel to the surfaces of the sill, which gives it a platy fracture. As this rock will be referred to frequently, and belongs to a peculiar type, we shall find it necessary to give it a provisional name. It will be spoken of as "mugearite", a name adopted from that of Mugeary, the crofter village lying at a short distance north. The thick peat which covers most of this tract renders it difficult to ascertain the extent of the intrusions in the direction of strike. Towards the south-east they disappear in a short distance, but this may be owing to a concealed fault. Having regard to the variations in thickness shown in the visible outcrops, it seems probable that they have something of the laccolitic habit, with no great lateral extension. It is also to be noticed that the relative thickness of the two members varies, even in one double sill, and one or other of the two may thin away. It is not improbable that the sill which appears to be a simple one has in reality the same constitution as the others, the porphyritic dolerite dying out before reaching the actual outcrop. This latter rock is on the whole very decidedly the predominant one, and attains in places a thickness of fully 100 feet.

The second locality is Roineval itself, a bold moorland hill, 1440 feet in altitude, situated some 2 miles N. of Drynoch and about 5¼ miles N.W. by W. of Sligachan. Even from a distance its outline is seen to be decidedly more rugged than that of the neighbouring hills, and examination shows that the summit is made by a thick sheet of porphyritic dolerite similar to

those mentioned above. At least 150 feet of this rock are exposed, and the thickness may have been greater before erosion. Below and in contact with this rock is a sheet of mugearite about 9 feet thick. This can be traced along the base of the summit-escarpment round more than half the circumference of the hill (*see* Map, (Figure 56)), but its thickness varies somewhat, and on the north-eastern side it is wanting. The whole has a dip of about 9° to W.S.W. At a lower horizon another sill of the porphyritic dolerite, about 40 feet thick, is exposed on the southern slope, but does not continue round the hill. Just below is another sill of mugearite, which makes some spread on the western slope of Roineval, as shown on the map and in the section (Figure 57). The two members of this lower pair do not actually come together here, but they do so a short distance farther east, forming a double sill exposed as an outlier to the south-east of the main hill (Figure 56). Excepting the porphyritic dolerite of the summit, the original shape of which cannot be ascertained, the Roineval intrusions seem to have more of the typical sill habit than those of the former locality.

When we examine the surfaces of junction of the two associated rocks in the several occurrences, some interesting points are observed. At Druim na Crìche, in the few places where the actual contact is exposed, it shows a perfectly sharp boundary with no appearance of intermingling. No positive evidence bearing on the relative age of the two rocks is there obtainable, though the infraposition of the mugearite in every instance seems to indicate that it is the younger. In the summit escarpment of Roineval there are abundant exposures of the junction of the two rocks, and these suffice to show that the relations differ in certain respects from those at the former locality. The mugearite, at one or two places on the south side, sends little tongues 3 or 4 inches wide a short way into the overlying rock, and is clearly the younger of the two. Further, the junction between the two rocks does not always present a perfectly sharp line, and the mugearite close to the junction encloses porphyritic felspars derived from the porphyritic dolerite above. These are found, in diminishing numbers, to distances of 4 or 6 inches from the line which we take to mark the actual division. Turning to the lower double sill, as exposed in the outlier to the south-east, we find that here the mugearite contains scattered felspars throughout its whole thickness of 6 or 8 feet. They are identical with the felspars in the porphyritic dolerite, and have undoubtedly been derived from the immediately overlying rock subsequently to the intrusion. In proof of this we find that farther west, where the mugearite sill has parted company with its associate, it contains no porphyritic felspars. The crystals seen in the mugearite have, then, sunk into it while it was in a fluid state; and what we have seen in the sills of the Cnoc Càrnach group (Chapter 13) suggests that at that time the matrix of the porphyritic dolerite may also have been partially fluid. The two rocks involved being in the present case not very different in composition,<ref> The comparison is between the mugearite and the *groundmass* of the porphyritic dolerite, which would differ much less than the bulk-analyses given below.</ref> the tendency to interchange by diffusion would doubtless be much less than in the basalt-granophyre sills.

Roineval affords better opportunities than Druim na Crìche of investigating the field-relations of the rocks, and here we find certain dykes which not improbably mark the channels of supply of the sills. One large dyke is a prominent object on the east side of the hill, about 200 yards E. of the principal tarn (*see* Map, (Figure 56)). It is porphyritic olivine dolerite closely resembling that of the sills. At several places too there are dykes of a close-textured, brown-stained rock with strongly fissile structure parallel to the walls, and these may perhaps represent the feeders of the mugearites. They resemble equally in their general appearance the trachytic dykes of the Drynoch group, to be described later (Chapter 23), but they are not sufficiently well preserved for detailed examination. The Drynoch dykes have many points in common with the mugearites, and we are inclined to refer these latter to the same epoch, which is certainly a very late one. It is in any case important to observe that the dykes on Roineval intersect all the ordinary dolerite sills. At one or two places in the Drynoch neighbourhood there are double dykes, one member being a highly fissile close-textured rock and the other a porphyritic olivine-dolerite or basalt, not unlike the Roineval type but of finer texture. The dykes on Roineval itself are, however, simple ones.

The third locality where a sill comparable with those of Roineval has been studied is more than six miles distant. Two miles from Talisker in the direction N. 15° W., and 600 yards N.N.E. of the tarn named Loch Dubh, is an abrupt isolated hill crowned by a ruined fort or Dùn.<ref>The situation is thus particularised because on the Ordnance maps, down to the date of writing, the hill and Dùn are incorrectly placed. They are 400 yards N.N.E. of the position marked on the maps.</ref> This hill is made by an outlier of a strong sill about 100 feet thick. To the S.W. and S. of the hill the main outcrop of the sill is seen running along the lower slopes of Beinn an Dubh-lochain, overlooking Huisgill. Towards the N.W. it dies out rapidly, but in the opposite direction it can be traced for a considerable distance. The best section is

offered by the Dùn hill. Here the upper part is composed of porphyritic dolerite, in appearance like that of Roineval and Druim na Crìche. From the summit to about half-way down the large felspar crystals are as abundant as in the former occurrences; but lower down, without any dividing line, they become sparser, and increasingly so downward. At the actual base they are almost or quite wanting. The lower part of the sill, in which the felspars occur at the most sparingly, resembles in the field the mugearite of the other localities. It is generally in a fresher condition, but shows the characteristic fissile structure.

That part of the main outcrop which is nearest to the outlier seems to have a like constitution, but it is not well exposed. Following the sill south-eastward and southward, we find the porphyritic felspars still richly abundant in the upper part and rare at the base, until we reach the corrie drained by the burn which comes down eastward from Beinn an Dubh-lochain. Here the sill is for some space lost under the peat. When it emerges beyond this place (Buile na h-Airidh), it contains only scattered felspars, and these become still rarer southward. The dark matrix also assumes a very fine-textured, compact character, with a splintery fracture. We have not been able to trace the sill far beyond this place.

We see that not only do these double sills recall in a general way some of the characteristic features of the composite triple sills of the Heast and Broadford tract, but they also show, when the several occurrences are compared, a somewhat similar range of variety as regards the intimacy of association of the two rock-types involved. On Druim na Crìche there is a sharp junction between the two rocks, and no sensible modification of either towards their contact. In the upper double sill of Roineval the sharp line of demarcation is softened to some extent, and phenocrysts from the upper and earlier rock have penetrated the lower one for a few inches. In the lower double sill at the same locality the phenocrysts have sunk, though only in small numbers, through the whole thickness of the lower and younger member. They have not, however, been carried far in a lateral direction. At the Dùn hill, although it cannot be doubted that the sill represents two successive intrusions, intermingling has obliterated the boundary between them, and the porphyritic felspars pass down, in diminishing numbers, practically to the base of the whole sill. Separating in imagination the two members which thus merge into one another, we may explain the scarcity of the phenocrysts throughout the thickness of the sill south of Buile na h-Airidh by supposing that the upper member dies out at or near this place. In the last exposure, some 65 or 70 feet thick, on the north side of the concealed ground the large felspars are abundant throughout the greater part of the section. On the other side they have become scarce throughout the whole thickness, and what appears to be the same sill on the opposite side of Huisgill,

¼ mile to the east, contains no phenocrysts. The scattered crystals seen in the prolongation of the lower member beyond the limits of the upper may have been carried forward with it from the place farther north where they were received; but it is also possible that they are "antecedent" xenocrysts taken in prior to the intrusion.

We have tacitly assumed that the sill at the Dùn hill belongs to the same group of intrusions as the double sills of Roineval and Druim na Crìche, its upper and lower portions representing respectively the two distinct members in those other localities. We do not, however, imply petrographical identity, but merely, or primarily, equivalence from the genetic point of view. The rocks present, as we shall see, a considerable range of variety.

We proceed to describe the petrographical characters of the two rock-types which constitute the double sills of the Roineval group. They have been judged worthy of chemical examination, and Dr Pollard has accordingly made the two full analyses quoted below. Both have a silica-percentage of about 50. Compared with the basic sills of the great group, or with other basic rocks of our area, both show a decided poverty in magnesia and lime and a relative richness in the two alkalies. In these respects the mugearite represents a greater departure than the porphyritic dolerite from the common standard.

The two rock-types have mineralogical characters which would serve to link them together even apart from their intimate association in the field. Olivine occurs in some quantity in both the specimens analysed; in the first with labradorite and augite; in the second, in more unusual association, with felspars rich in alkalies and only subordinate augite. Both rock-types, moreover, present varieties (not analysed) in which the place of olivine is taken partly or wholly by another and unknown mineral.

This problematical mineral seems to be the same in the two rocks. It is first detected in the thin slices, and has the general appearance of a brown mica. It usually builds idiomorphic crystals with rectangular sections, but sometimes also irregular plates into which the little felspar crystals project. It also occurs in a few places in confused aggregates, which rather suggest that it may have originated in part from the alteration of olivine or some other mineral; but these possible pseudomorphs are in no case so evident as to permit of a decisive conclusion on this point. The little flakes, in which the mineral most commonly occurs, are about 1/100 inch long. There is a strong cleavage parallel to that pair of faces which is most developed, and occasionally some indication of a second weak cleavage making an oblique angle with the first. The absorption-colours are light brown, with strong pleochroism. The interference tints are not so high as in the mica group, and the extinction-angles, measured from the strong cleavage-traces, are much higher. About 22° is a common angle, but the measurements range up to about 32°. The mineral is therefore monoclinic or triclinic; and the fact that a number of flakes in which the cleavage is particularly well marked give straight extinction rather suggests monoclinic symmetry. In all cases tested that axis of vibration nearer to the cleavage-traces was found to correspond with the lower index of refraction and the stronger absorption.

The characters here recorded do not agree with those of any common rock-forming mineral. There are points of resemblance to iddingsite, but that mineral, according to Lawson, has rhombic symmetry.<ref>*Bull. Dept. Geol. Univ. Calif.,* vol. i., p. 33; 1893. </ref> Our mineral also recalls in some respects some of the ill-characterised alteration-products of olivine observed in Skye and elsewhere, such as the "ferrite" of Heddle.<ref>*Min. Mag.,* vol. v., p. 29; 1882,</ref> But, as we have stated, the brown micaceous-looking mineral in the rocks now in question is only doubtfully and exceptionally, if ever, a secondary product, presenting in general all the appearance of a primary constituent.

The *porphyritie olivine-dolerite* is a remarkably handsome rock full of large crystals of labradorite, ½ inch to 1 inch in length, set in a dark, finely crystalline ground-mass. Specimens from the several occurrences are identical in general appearance, and show very close resemblance when studied, but there are certain differences to be noted. The Roineval rocks are perhaps slightly less basic than those of Druim na Crìche, while the corresponding rock from the Talisker neighbourhood is decidedly more basic.

	I	II	A	III
SiO_2	50.33	49.24	49.25	46.423
TiO_2	1.81	1.84	1.41	not det.
Al_2O_3	19.97	15.84	16.97	14.010
Cr_2O_3	trace	trace		
Fe_2O_3	2.81	6.09	15.21	5.027
FeO	6.23	7.18	not det.	9.022
NiO, CoO	trace	trace		
MnO	0.17	0.29	trace	not det.
MgO	3.24	3.02	ca. 3.00	3.820
CaO	8.03	5.26	7.17	8.104
BaO	0.06	0.09		
SrO	trace	trace		
Na_2O	4.30	5.21	4:91	3..820
K_2O	1.19	2.10	2.01	2.000
H_2O above 105°	0.99	1.61	ca. 0.30	7.222
H_2O at 105°	0.87	1.08		
P_2O_5	0.17	1.47	016	not det.
F	not sought	0.18		
S	not found	0.03		
	100.17	100.46*	ca. 100.99	99.448
Specific gravity	2.81	2.79		

I. (S9250) [NG 436 367]. Porphyritic Olivine-Dolerite, upper member of a composite double sill or laccolite, Druim na Crìche, 5 miles S.S.W. of Portree: anal. W. Pollard. Both this and the following rock contain chromium, vanadium, and

strontium, as determined spectroscopically by Sir J. Norman Lockyer.

II. (S8732) [NG 437 366]. Mugearite, lower member of the same composite intrusion, viz., the middle one of the five mentioned in the text: anal. W. Pollard. The fluorine may be somewhat overestimated. * The total is 100.53, less 0.07 (for oxygen-equivalent of fluorine).

A. Essexite, Dignas, near Gran, Norway: anal. A Damm and L. Schmelck, cit. Brögger, *Quart. Journ. Geol. Soc.,* vol.1, p. 19; 1894.

III. "Dolerite", sill near summit of approach to Quiraing; anal. M. F. Heddle, *Min. Mag.,* vol. v , p. 8; 1882.

This last has a specific gravity 2.87 to 2.88, while the rocks from the former localities, which we take as the regular type, give only 2.78 to 2.82 in the different intrusions. Dr Pollard's analysis (I.) shows that the type is somewhat less basic than the ordinary dolerite sills of the region. The composition is not markedly peculiar, but we may note a certain tendency towards those special characters which become more accentuated in the associated mugearite, in particular the low magnesia and high alkalies. A rough calculation of the mineralogical constitution gives about 77 per cent. of labradorite, 11 of augite, and 12 of olivine, magnetite, and apatite.

The most conspicuous feature of the rock is the abundance of large and usually well-shaped felspar-phenocrysts. It is remarkable that, in each occurrence, these seem to be of two distinct kinds; one perfectly clear and colourless, the other, though still quite fresh, having a yellow tinge. The latter are commonly larger than the former. We have not been able to verify any other difference, or to discern any significance in the occurrence of the two kinds. Carlsbad and albite twinning are evident to the eye, and thin slices show pericline-lamellation capriciously distributed in some of the crystals. The inclusions are scattered glass-cavities, with occasionally a scrap of augite, a crystal-grain of magnetite, or a little patch of the ground-mass. In places too the small elements of the ground-mass project slightly into the border of the phenocryst, showing that this has continued or resumed its growth to a certain extent at a late stage of the consolidation. This feature is most strongly marked in the Talisker sill, and it is evident in polarised light that the border is of slightly different composition from the rest of the crystal. The extinction-angles of the porphyritic felspars point to a medium labradorite of composition near $Ab_3\ An_4$ or $Ab_5\ An_6$.

The ground-mass consists of felspar, augite, olivine or its pseudomorphs, magnetite, and rather abundant needles of apatite, besides a variable amount of the brown micaceous-looking mineral described above. This occurs in different specimens apparently in inverse proportion to the olivine, as if the two minerals played the same role in the rock. The small felspars, averaging about $_{1\ 0}$ inch in length, are not very well shaped, having crystallised at a late stage. Most of the crystals show carlsbad and albite twinning, with extinction-angles up to 32° in symmetrical sections; and they are therefore labradorite, probably of a rather more acid variety than the phenocrysts. The augite, of a very pale tint in the slices, is usually idiomorphic towards the felspar, and sometimes towards the iron-ore. Olivine is only exceptionally found in a fresh state, but is plentifully represented by green or greenish brown serpentinous pseudomorphs. Magnetite in more or less perfect octahedra is sometimes quite abundant, and apatite is constantly present in slender rods, often enclosed in the felspars.

The above description of the typical rocks will serve also with little modification for the denser variety at the Dùn hill, near Talisker. This shows a rather larger proportion of olivine and magnetite, especially the former. On the other hand, the augite (here in little interstitial patches (S9807) [NG 319 333] or in ophitic plates (S9809) [NG 323 325]) is not very plentiful, and the little felspars, instead of being of a more basic variety, seem from their extinction-angles to be more acid. These points indicate a certain assimilation in composition to the associated mugearite, and are probably to be attributed to some degree of admixture by diffusion between the two magmas.

The *mugearite* of Druina na Crìche, in its freshest state, is a dark, finely crystalline rock, without phenocrysts, and might pass in hand-specimens for an ordinary basalt. Its mode of weathering is, however, sufficient to distinguish it in the field from all other sill-rocks in our area; and the exposed outcrops, with their dull yellowish brown tint and highly fissile character, look much more like the trachyte dykes of Drynoch, to be described in a later chapter. The specimen analysed has the specific gravity 2.79, while others gave 2.77 and 2.75. These lower figures are doubtless connected with partial

weathering, and a specimen selected for its fresh appearance gave 2.82. The chemical analysis (II. above) shows a composition quite removed from those of most other rocks in our area, and not reducible to any of the more widely distributed rock-types. The special features, as compared with average rocks of like silica-percentage, are the low magnesia and lime and the high alkalies, including potash as well as soda. Chemically the rock falls most nearly into the essexite family, though its petrographical characters do not assimilate it closely to any example hitherto described. We cite for comparison (in column A) the analysis of an essexite (the more acid variety) from the Gran district in Norway. This was first given by Brögger under the name "olivine-gabbro-diabase", and has since been included by the same writer<ref>*Eruptivgesteine des Kristianiagebietes,* part II., p. 50; 1895.</ref> among the olivine-monzonites, with which it has evident affinities. The rather high amount of phosphoric acid in the mugearite is also a characteristic of the Norwegian and some other essexites. The only important point distinguishing our rock from the true essexites is its lower proportion of lime. This has given rise to a peculiar mineralogical constitution, and seems therefore to justify us in regarding the mugearite as a distinct type.

The chief mineralogical pecularities of mugearite, which result from its unusual chemical composition and go to characterise it as a special rock-type, are two. Firstly, the felspar is not labradorite but oligoclase, with subordinate orthoclase; and, secondly, the ordinary bisilicate minerals are very poorly represented, augite being typically quite subordinate to olivine (or its equivalent the brown mineral already described) and iron-ore. Among minor points of interest may be noted the unusual richness in apatite. The percentage mineral composition of the rock analysed must be approximately as follows:

Oligoclase	57½
Orthoclase	12½
Olivine, iron-ore, and augite,	26½
Apatite	3½
	100

Felspars of species rich in alkalies thus make up about 70 per cent. of the rock. They appear in thin slices as a crowd of little elongated sections, averaging about .005 inch in length, with parallel or subparallel arrangement at any given point, the microstructure being consequently of the trachytic type. Most of the little crystals show albite-twinning, often with repetition. They give nearly straight extinction, and must belong to oligoclase. The untwinned crystals are doubtless to be identified as orthoclase, for the amount of potash in the rock is much too great to be contained in a felspar of the oligoclase type. On this understanding the composition of the oligoclase may be reckoned as nearly Ab_7 An_2, which agrees with the approximately straight extinction observed.

Of the other constituents, the olivine forms little well-shaped crystals or rounded grains, usually about 1/100 inch in diameter The mineral is commonly fresh. The augite, sensibly colourless in thin slices, has the ophitic habit; but it is present in such small quantity that the several minute pieces belonging to one ophitic plate are only perceived to have that relation by their polarisation. The magnetite is in minute octahedra, and there is often in addition a certain amount of limonite of secondary origin. The apatite is in very slender needles. The analysis of the rock proves that it is a fluor-apatite, contrasting with the chlor-apatite of our acid rocks, and making an exception to the general rule. The mugearite sometimes contains a few microscopic amygdules of spherical shape, occupied by analcime (S9252) [NG 436 367]. It will be observed that the textural and structural characters of the rock remove it from the essexite type as represented by the known (plutonic) examples.

Regarding the rock selected for analysis as the type of mugearite, we may note as the only important variety at Druim na Crìche that in which the place of olivine is taken by the unknown brown mineral (S9251) [NG 436 367]. The mugearite of Roineval has the same general characters as the type rock, but seems to be more highly felspathic. A specimen from the higher of the two intrusions is entirely free from augite, and is judged (though doubtfully) to have a larger proportion of potash-felspar than the rock taken as type. Olivine is absent in this slice (S8190) [NG 418 351], the brown mineral occurring instead, and with forms that forbid us to regard it as pseudomorphic. This specimen gives a specific gravity only 2.62, and, even allowing for weathering, it must be very decidedly less dense than the type of Druim na Crìche. It may be mentioned that on the south side of the summit-escarpment it contains fusiform amygdules of chalcedony, 2 or 3 inches long. A specimen of the lower sheet contains very little augite. Here again olivine is wanting, but there are instead, and

probably replacing it, abundant elongated crystals or pseudomorphs of a deep-brown mineral, apparently of the iddingsite kind. This substance, or one very like it, is also found occasionally in the Druim na Crìche rocks. It is clearly quite distinct from the brown mineral already described above, which occurs in small amount in the same slide. The colour is deeper, the pleochroism much feebler, and the extinction sensibly straight. In other specimens unaltered olivine occurs with its usual characters.

Turning now to the third locality, we have to notice in Huisgill, near Talisker, a *more basic variety of mugearite.* This is sufficiently evident from its high specific gravity, ranging from 2.91 to 2.96 in four examples selected, but we shall see nevertheless that the rocks bear the unmistakable stamp of consanguinity with the typical mugearite. For characteristic examples we must examine the southerly prolongation of the sill beyond its interruption by the peaty flat of Buile na h-Airidh. Here, as has been shown, the overlying porphyritic dolerite has died out, and its modifying influence on the lower member which persists is scarcely noticeable, except by the occurrence of a few scattered phenocrysts (here more properly xenocrysts), which become rarer southward. There is indeed no longer any essential difference between the upper and lower portions of the sill as displayed in this place (S9810) [NG 322 321], (S9811) [NG 322 321]. The rocks are fresher than in the other localities, and also of decidedly finer texture, presenting to the eye a very compact appearance, sometimes lustrous enough to suggest the presence of a glassy base.

Thin slices show that the relatively basic nature and high density of the rocks are connected chiefly with the abundance of magnetite, which in this respect is of next importance to the felspar. It is sometimes present as innumerable minute granules, in addition to the usual little octahedra. Olivine is abundant in fairly well shaped little crystals with a pronounced elongation parallel to the a-axis. There is often a relatively large glass-cavity in the centre, and in the most fine-textured rocks the olivine sometimes builds mere skeletons. The peculiar brown mineral formerly described is sometimes present (S9811) [NG 322 321]. Augite occurs in very small interstitial granules, but not usually in any abundance. The little felspars, which make the principal constituent, are closely packed, giving something of the trachytic structure. They have in general quite low extinction-angles, and often the sensibly straight extinction of an oligoclase. We have not been able to decide whether orthoclase is also present. In some cases there occurs a certain amount of interstitial glass, colourless but charged with magnetite dust. In a later chapter (Chapter 19) we shall have to notice a rock of much more vitreous nature, which probably has affinities with those here described. These basic mugearites, like the typical rocks of Druim na Crìche, contain a few microscopic amygdules of analcime.

A chemical analysis of this variety would be of interest. From what has been said, we may infer that it has the same low magnesia and lime, with high alkalies, as the typical mugearite, but is poorer in silica and richer in iron.

We have stated that farther north, where the equivalent of this rock underlies the porphyritic olivine-dolerite, there has been an intermingling of the two magmas; but, owing to the want of sufficient exposures, it is not easy to study the phenomena in detail. Specimens from the lower part of the Dùn hill, where the large porphyritic crystals occur only very sparingly, are dark, finely crystalline rocks of specific gravity 2.95 to 2.96. A thin slice not containing any large phenocryst shows, however, a certain micro-porphyritic structure (S9808) [NG 319 333]. There are abundant little crystals of labradorite about 0.02 to 0.05 inch long, but the chief element of the ground-mass in most places consists of smaller felspars which, from their low extinction-angles, seem to be near oligoclase and oligoclase-andesine. An appearance of coarser and finer texture in different places depends on the preponderance of one or other of the two kinds of felspar, and rather suggests an imperfect mixture of two different magmas. Where the small labradorite crystals are only thinly distributed, there is a trachytic structure and a general resemblance to the typical mugearite. Augite is represented only by minute interstitial granules, but magnetite is abundant, and there is a considerable amount of olivine.

Comparing the several intrusions in the localities which we have considered, we find that, where there is noteworthy variation, the two associated rocks seem to vary together, although the variation has a much greater range in the mugearite than in the porphyritic olivine-dolerite. The specific gravities of the rocks, as shown below. bear out this remark:

	Upper Member	Lower Member
Roineval, higher double sill	2.775	2.62
Roineval, lower double sill	2.80	2.82

Druim na Crìche, highest double sill	2.82	—
Druim na Crìche, second from top	2.79	2.77
Druim na Crìche, third from top	2.81	2.79
Dùn Hill, near Talisker	2.88	2.96

If we are to regard the two associated rocks as, in Brögger's phrase, "complementary" products of differentiation, this joint variation seems to imply that such differentiation was a process effected separately for each double intrusion. The greater range of variation in the mugearite, as compared with the porphyritic olivine-dolerite, connects itself with the fact that the former is usually much inferior in bulk to the latter. At Druim na Crìche where the disparity is not very marked, the mugearite is least variable; while on Roineval, where the mugearite forms only thin sheets beneath the massive porphyritic dolerite, the greatest range of variation is found.

The specific gravities given above suggest another point, which may be of significance, but would require further testing. The denser rocks seem to have been intruded at the lower levels. The Roineval sills are much higher up in the basalt group than those of Druim na Crìche, and the occurrence near Talisker is probably, though not demonstrably, lower.

In leaving these remarkable double sills we may remark that, although composite intrusions of this kind have been discovered only in the three localities mentioned above, it is not impossible that separate intrusions of one or other of the two rocks may be found, whether as dykes or sills, in other parts of Skye. Certain dykes, apparently by no means common, will be mentioned in their proper place, which have the general composition of mugearites, and approximate in some measure to the type described above. The porphyritic olivine-dolerite, being a less strongly characterised type, is naturally less easy to identify elsewhere.<ref> Conspicuously porphyritic sills with the same general characters have since been found in Canna, where on the higher ground they become the prevalent type. Two or three occur also in Eigg. Mugearite has also been recognised in these two islands; while in the western part of Rum it occurs as a number of sheets with a total thickness of about 500 feet. These observations make it very doubtful whether the rocks now described are to be sharply separated from the "great group" of sills, and referred to a different epoch.</ref>

One sill-rock worthy of notice in this place is that analysed by Heddle from the Quiraing. We have not had the opportunity of examining any specimen of this, but a rough calculation shows that the dominant felspar must be a basic oligoclase, while orthoclase must also be present. The chemical composition alone, as quoted in Column III. above, seems sufficient to remove this rock from the "great group" of sills, and to assimilate it in some respects to the rocks of the Roineval group of intrusions. The occurrence of a glassy selvage is a point of interest, and one which we have in no case met with among the sills of the great group.

Certain *porphyritic basalt sills in the Isle of Soay* deserve special mention. This island is built of Torridonian grit, a rock which, as we have remarked, does not in most places contain intrusions with regular sill habit. Here, however, there are numerous intrusions in the form of sheets approximating more or less closely to the regularity of typical sills, and it appears further that some rocks which elsewhere take the form of dykes occur with the stratiform habit in the Torridonian. of Soay. This is certainly true of the younger peridotite group to be described later (Chapter 21), and it seems to be so also of some of the minor basic intrusions. Without asserting that the great group of sills is quite unrepresented in Soay, we are thus led to refer some at least of the sheet-like intrusions there observed to some later epoch. This is especially the case with the conspicuously porphyritic rocks now to be noticed. It is worthy of remark that, in addition to the sills or sheets, dykes of similar petrographical type are found in the district.

The rocks show large glassy-looking felspars closely set in a dark finely crystalline ground. They resemble in general appearance the olivine-dolerite of the composite sills on Roineval and elsewhere; but they are of less basic composition and devoid of olivine. An interesting point is the varying size and frequency of the porphyritic felspars in different parts of a sill. In the interior they attain very large dimensions; Mr Clough records masses of felspar as much as 8 inches long and 4 in width. "These felspar crystals, however, never occur near the chilled margins. They are largest and most abundant in the centre of a sill, and gradually diminish in size and abundance as the chilled margins are approached. They are usually quite small at about 9 or 10 inches from the margins, and not visible at 5 or 6 inches. I have noticed this phenomenon so often, that I am driven to conclude that the crystals in these cases have been developed in the sill, and are not importations ready made". (C.T.C.) That the phenocrysts in intrusive rocks, as distinguished from lavas, have in

many cases not been brought up in the magma, as supposed by Rosenbusch, but formed in *situ* after the intrusion, is a thesis which has been maintained by several petrologists,<ref> Zirkel, *Lehrbuch der Petrographie,* 2nd ed., vol. i., p. 737; 1893: Whitman Cross, 14th *Ann. Rep. U.S. Geol. Sur.,* p. 231; 1895: Pirsson, *Amer. Journ. Sci.* (4), vol. vii., pp. 271–280; 1899. See also Crosby, *Amer. Geol.,* vol. xxv., p. 299; 1900.*DifferentEpochs of Acid Intrusions.* 271</ref> and Mr Clough's observations seem to be conclusive on this point as regards the sills in question. It is to be observed that, not only the size of the phenocrysts, but their relative abundance decreases from the centre to the margin of the sill, so that the interior is more felspathic, and doubtless somewhat less basic in composition, than the marginal portions. This comes out clearly from some of Mr Clough's determinations of specific gravity:

(i) Sill ½ mile S.E. of Doire Chaol:

Interior (felspars up to 1 inch and more),	2.72
Margin (non-porphyritic),	2.75

(ii) Sheet at Leac nan Faoileann:

Interior (felspars up to 1 inch and more),	2.76
Margin (non-porphyritic),	2.79

The porphyritic felspars are labradorite with albite and carlsbad twinning. The ground-mass, in the only specimen sliced, is an ordinary basalt or fine-textured dolerite without olivine. This example, from the interior of a sill on the east coast of Soay, has a specific gravity 2.78.

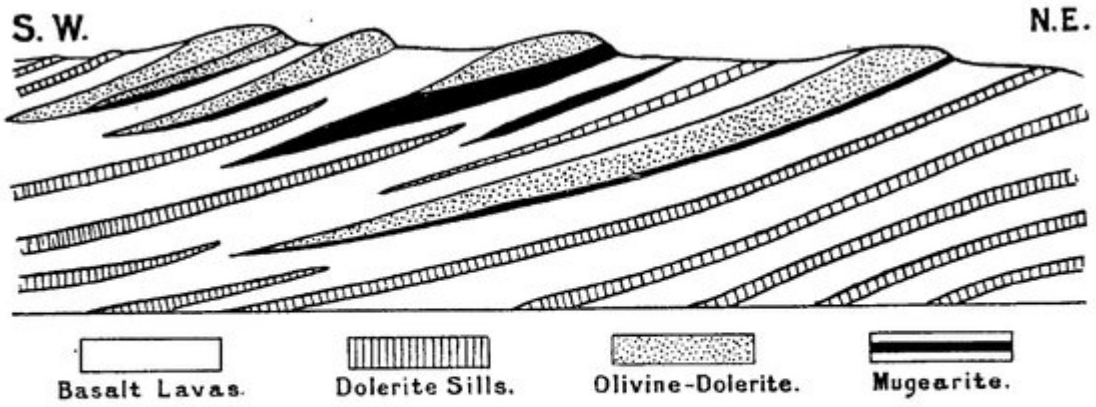

FIG. 55.—Section through Druim na Crìche, about 5 miles S.S.W. of Portree and 5½ miles N.W. of Sligachan; showing composite double sills or laccolites of the Roineval type. Scale: 6 inches to a mile. The prolongation below the surface is partly conjectural.

(Figure 55) Section through Druim na Crìche, about 5½ miles S.S.W. of Portree and 5½ miles N.W. of Sligachan; showing composite double sills or laccolites of the Roineval type. Scale: 6 inches to a mile. The prolongation below the surface is partly conjectural.

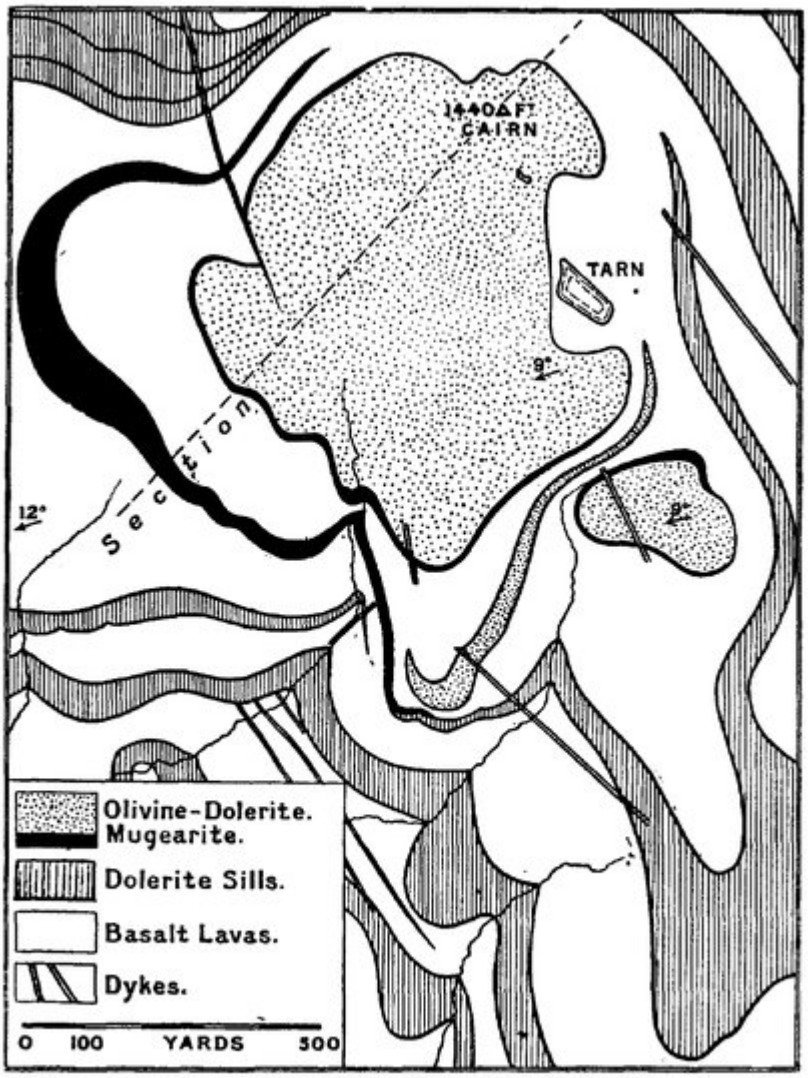

FIG. 56.—Geological map of Roineval, showing the composite double sills. Scale: 4½ inches to a mile.

(Figure 56) Geological map of Roineval, showing the composite double sills. Scale: 4½ inches to a mile.

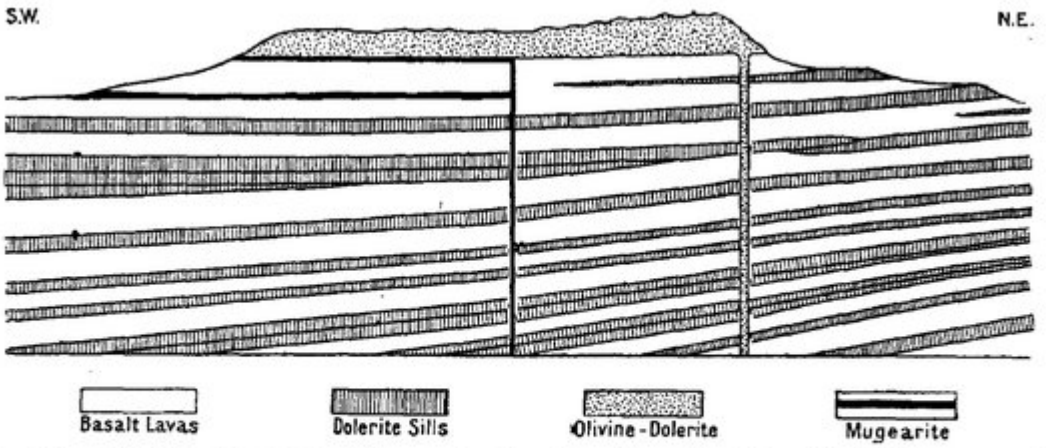

FIG. 57.—Section through Roineval, showing the double sill at the summit and the lower mugearite sill; also conjectural relation of the sills to dyke-feeders. Scale: 4½ inches to a mile.

(Figure 57) Section through Roineval, showing the double sill at the summit and the lower mugearite sill; Mugearlte dyke-feeders. also conjectural relation of the sills to Scale: 4½ inches to a mile.