# Chapter 13 Composite sills and dykes: detailed description

Having considered the general characteristics of the peculiar composite intrusions with symmetrical habit, and obtained some partial conception of their geological relations and their significance as members of the great suite of Tertiary igneous rocks of the Skye centre, we have next to describe the characters of the rocks winch constitute these intrusive bodies. These include primarily some of thoroughly acid and others of thoroughly basic composition, but the petrographical interest attaches chiefly to the remarkable reactions which these closely associated rocks have exercised upon one another. These reactions have resulted, in varying degree, in a certain acidification of the basic rocks and a correlative basification of the acid rocks; but such a rough characterisation expresses only in a general way the modifications of the bulk-composition of the respective rocks, the actual phenomena being of a complex kind. The extreme result of intermingling, however effected, has been in certain cases the production locally of rocks of mean acidity, but normal intermediate rock-types do not occur. The peculiar mutual relations of the basic and acid members will be best illustrated by describing the distinct occurrences severally, and only a few preliminary remarks on the petrography of the acid and basic members will be necessary.

In all but one case — the composite sill of Rudh' an Eireannaich, to be described later — the normal acid rocks fall under one general head. The common type is a granophyre of an ordinary kind and with a chemical composition not differing in any essential from that of the large plutonic masses of the Red Hills. This appears from an analysis already given in Chapter 10 and here reproduced (column I.). The rock selected for analysis is a granophyre of a spherulitic type, and, in addition to phenocrysts of felspar and quartz, contains green hornblende, both as little crystals and as slender rods. Such rocks, except that augite sometimes takes the place of hornblende, constitute the acid members of these composite sills and dykes in general. There are variations in micro-structure, the spherulitic arrangement becoming in some cases more pronounced and regular, or in other cases the granophyric giving place to a merely granular structure. Such variations are found in the ordinary minor acid intrusions of the district, and do not necessarily import any special conditions; but it is possibly not without significance that in the composite intrusions a change from a granophyric to a microgranitic structure is often associated with a modification of the acid rock by the inclusion of basic material.

| | I | A |
|---|---|---|
| $SiO_2$ | 71.98 | 70.34 |
| $TiO_2$ | 0.37 | 0.46 |
| $Al_2O_3$ | 13.13 | 13.18 |
| $Fe_2O_3$ | 1.33 | 2.65 |
| FeO | 1.64 | 2.24 |
| MnO | 0.14 | 0.19 |
| MgO | 0.56 | 0.40 |
| CaO | 1.15 | 1.24 |
| BaO | trace | trace |
| $Na_2O$ | 2.98 | 3.61 |
| Li2O | not found | trace |
| $K_2O$ | 4.93 | 4.90 |
| $H_2O$ above 105° | 1.38 | 0.76 |
| $H_2O$ at 105° | 0.39 | 0.46 |
| $P_2O_5$ | 0.19 | 0.10 |
| Cl | 0.01 | 0.02 |
| | 100.18 | 100.55 |
| Specific gravity . | 2.63 | 2.66 |

I Hornblende-Granophyre (S7064) [NG 630 172], Beinn a' Chaìrn, 3½ miles S. by W. of Broadford: anal. W. Pollard, *Summary of Progress* for 1899, p. 173. (The Cl here and the $P_2O_5$ and Cl in the next analysis have been inserted subsequently. Fluorine and sulphur sought but not found.)

A. Hornblende-Granophyre (S7124) [NG 526 246], Druim Eadar da Choire: anal. W. Pollard, *ibid.,* p. 174. This is from part of the great plutonic mass of the Red Hills, and is quoted here to show its substantial identity with the preceding.

The basic rocks studied present wider variation, but this is due to the difficulty in many cases of finding a specimen which can with confidence be regarded as representing the normal rock. We have already seen that in these composite intrusions the acid member is always in considerably greater volume than the basic, and it has resulted from this that the basic rocks are liable to be much more radically modified in composition than the acid, and are often completely disguised. Those of them which have not suffered in this way have, however, in general well-marked characteristics common to them as a group. They are basalts or fine-grained dolerites, of thoroughly basic composition but without olivine. The structure is usually the micro-ophitic, though "granulitic" varieties, in Professor Judd's sense of the word, are not wanting. They resemble in these respects the commonest type of basic sills in Skye, which, as we shall see later, are found in extraordinary profusion in the north-western portion of the island, far from any acid rocks. They differ, however, from those in that they are generally porphyritic, enclosing conspicuous felspar crystals, which probably have not always the same significance. In some cases, as we shall see, the inclusion of felspar crystals is one feature of the special modification of the basic sills in contact with the accompanying acid rocks. More usually the felspars must have been introduced with the basic magma itself, but even in this case there are circumstances which prove that some of the crystals are not normal constituents formed from the magma. In these respects the phenomena recall those of the marscoite of Glamaig and other places, as described in Chapter 11, but there are differences of degree, if not of kind. The peculiarities of the marscoite resulted from processes effected prior to intrusion, and only in a less degree from reactions with an acid magma after intrusion; in the rocks now under consideration the reverse was the case. We shall employ the name "basalt" for these rocks notwithstanding the abnormal characters which they so frequently exhibit.

We shall briefly describe the several composite intrusions of this group in order from south to north. This order will have the advantage of introducing us by degrees to the more peculiar effects of mutual reactions between the associated rock-types. We refer here to special modifications affecting the constitution of both the rocks involved. Of mere bodily destruction of the earlier basic by the later acid intrusion the southerly occurrences present more striking instances than the northerly, owing to their larger size and to the greater preponderance of the acid over the basic rock in respect of volume.

The first of the composite sills to be noticed is that of *Carn Dearg, near Suishnish Point,* with its small outlier forming the summit of Beinn Bhuidhe. Apart from the picrite below, which gives rise to a prominent feature on the sea-ward slope, but is probably an entirely independent and later intrusion, this occurrence presents some degree of complexity as regards field-relations. The granophyre which is the principal member not only has a thinner basic sill below (besides probably one above, now removed by erosion), but also encloses relics of others enveloped in its interior. It appears that a multiple basic sill was here invaded by an overwhelming volume of acid magma, which separated the several members and in great part corroded and destroyed them. There are nevertheless indications that the lowest basalt sill holds a more intimate relationship with the granophyre than the other basic members do, and is of later age, having preceded the acid intrusion by a brief interval only.

The granophyre shows, except at its base, no noteworthy peculiarity (S3188). The underlying basic member is a porphyritic basalt or fine-textured dolerite, without olivine. It has a micro-ophitic structure, and, without the porphyritic elements, would be identical with a common type among the ordinary basic sills of the "great group" to be described in a later chapter. The porphyritic crystals are felspars, and are of two kinds. Some are labradorite, and are quite clean and fresh; the others give lower extinction-angles, and are crowded in the interior with glass-inclusions,  presumably of secondary origin (S7072) [NG 603 160]. The latter are doubtless in some sense xenocrysts. Another feature found here, as in many of the basic sills of this group, is the occurrence of little patches which appear to be microscopic druses. They consist of quartz with good crystal-faces and crystalline calcite filling in the interspaces. This rock, with a specific gravity 2.86, is from a place beyond the direct Modifying influence of the acid intrusion. At its junction with the overlying granophyre the basalt is obviously much corroded, and xenoliths of it occur plentifully in the acid rock. These xenoliths (S7068) [NG 606 169] differ from the basalt in place chiefly in the presence of a certain amount of interstitial quartz, which must be ascribed to an impregnation by the acid magma. The acid rock contiguous with the xenoliths is very noticeably modified: it not only loses its granophyric structure, as is very generally the case in these circumstances, but is rendered decidedly less acid in composition. The ferro-magnesian element (now chloritised) is in greater abundance, and in some places the basification is such that a quartz grain has been surrounded by a green corrosion-border.

The discontinuous relics of basic sheets involved in the body of the granophyre show some variety. One is a basalt of specific gravity 2.83 with small porphyritic felspars. Besides the microscopic druses already noticed, it has a few small round vesicles, sometimes filled with a felsitic-looking substance which may represent the granophyre magma. In other respects there is no peculiarity (S7073) [NG 606 161]. Another sheet is represented by specimens of a porphyritic dolerite of sp. gr. 2.89 and a rather coarser example of sp. gr. 2.92, which are quite normal in their characters, though metamorphism has given rise to a considerable amount of green and brownish-green hornblende (S7074) [NG 603 162], (S7075) [NG 603 162]. In these rocks there has been, at least in general, no transfusion of the acid magma causing acidification.

A specimen (S3210) [NG 599 159] among the older collections of the Geological Survey, labelled as from a sill beneath the granophyre of Carn Dearg, is probably from a distinct intrusion, but we have not identified the locality. It is a quartz-dolerite with interstitial micropegmatite. Although such rocks occur in some other regions as normal products of magmatic differentiation and crystallisation, its presence here as a unique occurrence is probably significant. If it is to be regarded as a hybrid rock, it most likely represents the result of admixture prior to intrusion.

The *Beinn a' Chaìrn* mass consists, in its present eroded state, merely of a thick sheet of hornblende-granophyre with a few feet of basalt at the base. The former rock sends veins into the latter, and encloses near the junction abundant xenoliths of it; while the basic rock is much corroded by the acid, and, as at Carn Dearg, is in some parts of the boundary totally destroyed. The granophyre, away from the junction, is the quite normal acid rock of which we have given a chemical analysis above. The underlying basalt is a dark fine-grained rock of specific gravity 2.90 to 2.91, free from olivine, and with micro-ophitic structure, like the corresponding rock at Carn Dearg. The scattered porphyritic felspars, however, present points of difference. They are of labradorite, the more acid variety being apparently rare or wanting; but these labradorite crystals are much fissured, as if by heat, and contain the round glass-inclusions elsewhere found to characterise xenocrysts ((Figure 47), C).

The contact-phenomena are more remarkable than in the former case, the xenoliths of basalt in the granophyre being more highly modified. They contain quartz not only interstitially and in the usual microscopic druses, but also as rounded grains with the characteristic green corrosion-border ((Figure 47), H, K). They also enclose very turbid crystals of acid felspars, oligoclase with some orthoclase ((Figure 47), F). Since the xenoliths have undoubtedly been detached in the first place from the immediately adjacent basalt sheet, in which no such abundant quartz-grains and alkali-felspars occur, these elements can only have been introduced into the xenoliths from the surrounding acid magma in which they did and do occur. This implies that the xenoliths have been in an effectively fluid state within the fluid acid magma, without mingling freely with it and losing their identity. Similar phenomena have been described, and a like interpretation given, by Professor Grenville Cole<ref>*Sci. Trans. Roy. Dubl. Soc.* (2), vol. v., pp. 239–248; 1894.</ref> in the case of a composite triple dyke at Glasdrummon Port, County Down; and some of the junctions of marscoite with granophyre described above present somewhat analagous phenomena. The fusion of the basalt offers no difficulty, and indeed it is by no means certain that these xenoliths were completely consolidated when the acid magma picked them up; the remarkable feature is that the xenoliths, though often partially rounded, still preserve a sharp boundary against their matrix. When they were sufficiently fluid to permit not only molecular diffusion but the bodily entrance of foreign crystals, it might have been expected that they would become completely merged in their surrounding.

The acid rock near the junction, at least where it encloses basalt xenoliths, is very sensibly modified. In most places it becomes a quartz-porphyry instead of a granophyre, and its felspar phenocrysts assume rather rounded outlines. The ferro-magnesian mineral here is a pale green augite, though in the altered xenoliths it is hornblende (S7066) [NG 638 181], (S7067) [NG 638 181]. The conditions which have governed the formation of one or other of these minerals might furnish an inquiry of some interest, but unfortunately both are often replaced by chlorite, and in that form frequently indistinguishable. A noteworthy point is the occasional occurrence of an augite crystal showing the basal striation suggestive of derivation from gabbro.

We may notice in passing the composite triple dyke immediately south of *Loch na Starsaich.* Here the principal rock is not a granophyre but a microgranitic quartz-felsite. The phenocrysts are pale augite, quartz, and felspars, which include an oligoclase-andesine; and all have rounded outlines (S3214) [NG 645 187]. As usual in these dykes, the flanking basalts are in great part destroyed by the acid magma, and are represented in many places only by xenoliths in the felsite.

The composite sill forming the main ridge of Cnoc Càrnach, has the symmetrical triple arrangement, with both upper and lower basalts preserved in most places. Only where the granophyre swells out to its thickest in Cnoc Càrnach itself is the lower basalt entirely destroyed for about 500 yards. The chief member is a hornblende-granophyre with rather rounded phenocrysts of quartz, orthoclase, and oligoclase up to about 1/10 inch. Green hornblende, magnetite, and apatite are seen, the rest of the rock being of micro-pegmatite (S3189) [NG 657 196]. The basic members are dark rocks with scattered porphyritic felspars, resembling in general characters the corresponding rocks of Carn Dearg and Beinn a' Chaìrn. A thin slice of the upper basalt (S6735) [NG 655 197] bears out the resemblance, except that the ophitic development of the augite is no longer seen. There are phenocrysts of labradorite, well shaped and quite clear, though fissured ((Figure 47), A, B); but also occasional corroded xenocrysts of quartz and felspar, the former with the usual corrosion-border and the latter (oligoclase and orthoclase) crowded in their marginal parts with secondary inclusions and sometimes deeply corroded ((Figure 47), D, G). Since the basalt, in this specimen, has been in no wise modified by the granophyre which it overlies, these xenocrysts must certainly have been brought up in the basalt magma itself. It is clear that in the basic rocks of this group we have in different cases acid xenocrysts, acquired perhaps from the same ultimate source, but at two different stages. Sometimes, as in the present case, they have been enclosed by the basic magma before its intrusion: sometimes, as in some xenoliths already described, they have entered the basic rock (fused at the time) after the intrusion of both it and the acid rock, which in this case directly furnished the xenocrysts. In the latter case there is evidently no reason why xenocrysts derived in these two different ways should not coexist; and we have already found ground for this supposition in the parallel instance of the marscoite of Sròn a' Bhealain, etc. The identical characters presented by the two sets of xenocrysts and their resemblance, except for corrosion-effects, to the phenocrysts of the granophyre, are among the facts which go to establish a common origin and peculiarly intimate relationship for the basic and acid rocks associated in these composite intrusions.

In the *lower composite sill of Cnoc Càrnach,* which passes just east of Loch a' Mhullaich, the acid member, an ordinary hornblende-granophyre, is of moderate thickness throughout, and the basalt is never wanting either above or below. This is the case also with the remaining sills northward of this, which never attain the great thickness of the more southerly examples.

The composite sill upon which the *Heast road* runs for nearly a mile, from Aodann Clach to Braigh Skulamus, presents new points of interest. The acid member is, near its junction with the lower basic one, a quartz-porphyry enclosing in most places numerous altered xenoliths. These, as at Beinn a' Chaìrn, not only have insterstitial quartz introduced into their ground-mass, but enclose quartz-grains similar to those in the surrounding quartz-porphyry (S6733) [NG 660 204]. Xenoliths are much less frequent at the upper junction, and it appears that the overlying basalt has, at least in the places examined, been less energetically attacked than the underlying. This is true not only as regards bodily destruction, but also as regards impregnation, as is seen on comparing specimens of the two. The upper basalt is a dark rock of specific gravity 2.89, and a thin slice (S6734) [NG 659 204] shows no indication of modification to be ascribed to the acid intrusion. There are, however, in addition to clear phenocrysts of labradorite an occasional grain of quartz with its corrosion-border of granular augite and crystals of oligoclase and orthoclase full of secondary glass-incluSions. These are evidently xenocrysts picked up prior to the intrusion of the basalt. The lower "basalt" is very different. It is a dull-grey rock showing to the eye rather numerous grains of quartz, as well as scattered felspars of dead-white colour. The specific gravity is only 2.69. A thin slice shows that xenocrysts are present in abundance, and also that the general mass of the rock has been considerably modified in the sense of acidification (S6732) [NG 660 204]. The felspar xenocrysts, including both orthoclase and oligoclase, are as usual crowded with secondary glass-cavities except in their central parts ((Figure 47), E), and the quartz-grains are rounded and have a corrosion-border of granular augite, now replaced by calcite and chlorite. This last feature, so characteristic of foreign quartz-grains in a basic rock, is not seen in the altered xenoliths, where acidification has proceeded farther, and the quartz was more nearly in chemical equilibrium with its environment. The normal micro-structure of the basalt ground-mass is, as invariably observed in like circumstances, quite lost, and a noteworthy proportion of interstitial quartz is present, apart from the microscopic druses of quartz and calcite which we have remarked in other examples. It is evident then that at the locality studied, viz. Creag Bhriste, not only the basalt xenoliths, but in somewhat less degree the basalt in place beneath, has been acidified by the later magma intruded in juxtaposition with it. This we have already observed in the case of Bheinn a' Chaìrn; but in the present instance the modification of the underlying basalt has gone farther, for the rock has not only been impregnated with the acid magma, but has also, like the xenoliths, had xenocrysts of quartz and alkali-felspars introduced into it at the same time. This can scarcely be doubted on comparing the lower with the upper basalt, where such xenocrysts are much fewer; and the proof would be complete if we could assume, what is probably the case, that the upper and lower basalts represent not a double sill but a single one, which, while still scarcely consolidated in its interior, was eviscerated by the acid intrusion. We have hitherto left this question open; but facts to be detailed below, especially the phenomena at Rudh' an Eireannaich, show that in some at least of our composite sills the supposition here made is the only one admissible.

We may conveniently distinguish the two orders of acid xenocrysts already recognised in our basic rocks by using the term *antecedent* for those acquired prior to the intrusion, and *consequent* for those forced upon the rock posterior to its intrusion; and a like distinction may be made in respect of the partial acidification of the general mass of this rock. In the marscoite described in a former chapter the peculiarities observed were mainly of the antecedent order, though at some of the junctions consequent effects of the same general kind were to be verified. In the upper basalt at Creag Bhriste, and in the other rocks described which have not been directly affected by the subsequent intrusions of granophyre, we have only antecedent xenocrysts sparsely distributed and no demonstrable acidification of the ground-mass. In the xenoliths described at Carn Dearg we had consequent acidification of the ground-mass only, and in those at Beinn a Chairn consequent xenocrysts in addition. in the lower basalt at Creag Bhriste, and still more in the xenoliths, we have consequent acidification in an advanced degree with consequent xenocrysts in abundance, and these prevent the verification of any like effects of an antecedent order. As already remarked, the mutual relations of the two rock-types involved become more complicated as we proceed northward, and we shall see that they are most complicated of all in the Rudh' an Eireannaich occurrence. Comparing the several composite sills with one another, we may conclude that the variable factor determining these petrographical peculiarities was the interval between the intrusions of the basic and acid members. On the other hand, the chief variable factor determining the bodily destruction of the basalt by the acid magma was the relative volume of the latter, allowing in the case of the dykes for prolonged flow.

The xenoliths of basic in acid rock at Creag Bhriste introduce us to a further complication in the curious mutual relations of these rocks (S6733) [NG 660 204]. Here the ground-mass has undergone a notably greater degree of acidification than in the basalt sill below. Interstitial quartz is abundant, and the felspar, judged by its extinction-angles, seems to be andesirte rather than labradorite. Concurrently with these changes the ophitic structure is, as usual, lost, and the ferro-magnesian mineral becomes idiomorphic. Its forms point to hornblende, but it is completely chloritised. The xenoliths enclose the usual xenocrysts derived from the acid rock, their abundance showing that they are mainly of the consequent kind. It is evident that, by the time that the acidification of the ground-mass was completed to the degree observed, these xenocrysts must have found themselves in a medium not differing greatly from an acid rock-magma. It is to be expected therefore that corrosive action upon the xenocrysts had ceased before this point was reached, and it is conceivable even that an opposite tendency had been set up. These suppositions are borne out by the facts. The numerous quartz-grains have been eaten into highly irregular shapes, but they have no corrosion-border of granular augite ((Figure 47), L). Either this has never been formed or, what is much more probable, it has been absorbed at a later stage of the progressive acidification. The xenocrysts of alkali-felspars have rounded outlines and are crowded throughout most of their extent with the usual secondary inclusions, but each has a narrow border of similar felspar substance which is quite clear. This border is sharply defined against the turbid mass of the crystal, but rather ragged in places against the surrounding matrix; and we interpret it as a new growth added at a late stage, when the xenolith had become sufficiently rich in silica and alkalies to secrete alkali-felspars.

Another feature of these xenoliths of greatly modified basalt is that they enclose smaller basalt xenoliths which have undergone no such modification. These xenoliths within xenoliths do not exceed a fraction of an inch in length, and have the shape of fragments, though somewhat rounded at the angles. They are of rather fine texture, and have been partly metamorphosed, either by the basalt which caught them up or subsequently by the acid intrusion, the chief new mineral product being brown mica. These little chips cannot be derived from the country rock, which is Jurassic shales. They probably represent the marginal part of the basalt sill itself, as rather rapidly consolidated in contact with the shales, subsequently broken up, and enclosed in the still fluid basalt magma. Whatever their origin, they were clearly solid when caught up by the basalt of the sill, and have not been fused either then or since. The fact that they have not, like the basalt enclosing them, been permeated by the acid magma, enforces this conclusion. If the enclosing basalt, now itself in the form of xenoliths, had been fused by the heat of the acid magma, the little chips would have been fused and permeated in common with it. This is one among other considerations which go to show that, where the basalt of the sills (and of the xenoliths) has been thus permeated and acidified, it is merely because, in those places, it had not yet completely consolidated when the acid magma invaded it.

This last conclusion accords with other features which indicate that, where these peculiar phenomena are found in triple composite sills, the acid member has not been thrust in between the two members of a double basic sill, but has found its way along the middle of a single basic sill, the central zone of which was still in a partially fluid or potentially fluid condition. Quite apart from the petrographical evidence this alternative is inherently the more probable. Double basic sills are indeed frequent in some parts of Skye, but not in this district; and the hypothesis that a number of double sills have been intruded in this belt of country at various horizons, the two members being in each case of nearly equal thickness, and not more than two being intruded in any instance, is an unnatural one.

That the symmetrical triple arrangement is due to the evisceration of a basic sill by a slightly later intrusion of acid magma along the same channel admits of no reasonable doubt in the case of the composite sill next to be discussed, that of *Rudh' an Eireannaich,* forming the western horn of Broadford Bay. This is not only the most easily accessible of the group, but also in some respects the most remarkable. The intimate association of the two component rock-types is here exhibited in its most extreme phase, the effect being that of a gradual transition from one type to the other affecting almost the whole thickness. In other words, the interval between the two intrusions was in this case the briefest of all, and the basic sill must have been still practically fluid throughout almost the whole of its thickness when the acid magma was intruded into it. There is another respect in which this composite sill differs from the others. The acid member is not in this case a granophyre or quartz-porphry, but a felsite of a less common type, poorer in silica but richer in alkalies.

As approached from Broadford the sill is first seen in a small cliff, some 20 feet high, a little before the headland is reached, and the upper surface of the sill itself forms the top of the cliff for a short distance (Figure 48). It is more conveniently studied a little farther north, beyond a small fault, where it forms a small escarpment running out eastward into the sea (C in the section). Here again the upper surface is exposed as a dip-slope, but its inclination soon carries it out of sight. The total thickness of the sill is 14½ feet. Of this we may reckon perhaps 2 feet to the upper basalt and about 2½ feet to the lower, leaving nearly 10½ feet for the middle member. These measurements, however, have no accurate meaning, for divisional lines of any true significance can scarcely be said to exist between the several members. In the field an observer will readily set down the rock forming the summit and that forming the base as basalts and the middle part as a felsitic rock, but the dark colour of the one passes so insensibly into the light grey of the other that no precise separation is possible. Microscopic evidence only serves to confirm this conclusion, and specific gravity determinations (in default of chemical analyses) give a general indication of the gradual nature of the transition (*see* (Figure 49)). To speak more accurately, there are a few inches of rock at the top and a similar thickness near the bottom which may be taken as representing the original basalt as intruded, these being presumably the portions which had become effectively solid before the more acid magma was forced in. In the middle part of the felsite there is a thickness of about 3 feet in which no appreciable variation of composition is to be detected, though we cannot safely assume that even this represents accurately the felsite magma. All the rest is to be regarded as hybrid rock of variable composition, due to the admixture in different proportions of the basaltic and felsitic magmas, both effectively fluid at the same time. The specific gravities given in (Figure 49) show that the varieties are regularly arranged, the rock becoming denser by degrees, both upward and downward, from the felsite to the basalt. The variation is more gradual towards the felsite, which was presumably the more fluid of the two magmas, and becomes more rapid towards the basalt. The exposed upper surface of basalt forming the roof of the sill is fine-textured, and has a rough, wrinkled, and broken aspect. The lower surface is not so well exhibited, and is less regular, but in places it shows a narrow selvage of quite compact texture. The middle portion of the sill has a well marked rudely columnar jointing, and the joints often pass upward and downward into the basalt, indicating that the whole thickness has cooled in common.

The basalt, taken where it is not perceptibly affected by the later intrusion of felsite, is a dark fine-grained rock of specific gravity 2.79 to 2.82 in several specimens. It encloses little felspars, usually not more than ■ inch in length; and, as usual in these rocks, we can distinguish among them dull white crystals of squarish shape and fresh glassy-looking crystals of more slender tabular habit. The former are xenocrysts of alkali-felspar, belonging of course to the "antecedent" category, while the latter are the labradorite phenocrysts indigenous in the rock. Thin slices show that the basalt differs in no essential respect from those of the other composite sills, the abundant augite having in this case the "granulitic" habit. Only in the xenocrysts do we find a difference. These are all of alkali-felspar, with the usual corrosion-effects ((Figure 47), M), quartz-grains being wholly wanting. This is to be correlated with the absence of quartz-phenocrysts in the felsite; and we have here a strong confirmation of what we have already inferred, that the antecedent as well as the consequent xenocrysts in the basalts of these composite sills have been derived in each case from the immediately associated acid rock.

The felsite is, in the purest specimens, a dull, compact-looking rock of pale grey to bluish white colour, with a specific gravity 2.59 or 2.60. There are dull white felspar crystals up to ¼ inch or more in diameter, and a little pyrites is sometimes seen. The rock is not so fresh as the basalt, and thin slices are obscured by secondary calcite (S6727) [NG 645 247], etc.. The felspar phenocrysts are so much altered that their true nature is not easily made out. Some of them show fine twin-striation, with the nearly straight extinction of oligoclase. Others show no definite twinning except on the Carlsbad law, but there is often a patchy appearance suggestive of a cryptoperthitic intergrowth. Associated in clusters with the felspar are yellowish pseudomorphs which probably represent augite, and a little of this mineral is seen in some of the slides. There are also occasional small cubes of pyrites and prisms of apatite. The ground-mass is composed essentially of little felspar crystals giving imperfect rectangular sections 0.004 to 0.007 inch in length. They may be either simple or twinned, but all give nearly straight extinction. There is usually a certain amount of interstitial quartz, but this is wanting or almost wanting in the freshest specimens, and is perhaps wholly of secondary origin. The rock, then, consists essentially of alkali-felspars, or felspars rich in alkalies, with little or no quartz. It probably falls into the ceratophyre division, though on this point chemical evidence is to be desired, and it approaches in many respects the bostonite type. We shall have to notice certain rocks of somewhat similar characters among the minor acid intrusions of simple habit, where again they are of exceptional occurrence.

The hybrid rocks produced by admixture of the basalt and felsite exhibit, as we have said, a wide range of variation, with fairly regular gradation. Specimens taken at about a foot from the top of the whole sill are dark grey rocks with specific gravity 2.74 to 2.72. To the eye they are very like the normal basalt, though less dark in colour. The xenocrysts are rather larger, ranging up to ¼ inch in diameter. They are also more numerous, preponderating very decidedly over the labradorite phenocrysts, and we must suppose them to be in part of "consequent" derivation. In thin slices the ground-mass has at first glance a sufficient resemblance to that of the normal basalt, except that the augite, now mostly decayed, has evidently been less abundant. On further examination we find that the little felspars, which are the principal element, are not, as before, labradorite. They give much lower extinction-angles, and may be set down as in the main oligoclase-andesine or one of the more basic kinds of oligoclase. We see then that this rock is of anomalous composition, being clearly much richer in silica and soda than any true basalt. A specimen from a corresponding situation near the base of the sill shows closely similar characters, the diminution in the amount of augite (here better preserved) and the relatively acid nature of the felspars of the ground-mass being well shown. Small flakes of brown mica are sparingly distributed, their formation being connected doubtless with an accession of potash to the basalt. There are little sharply defined patches of fine texture, doubtless xenoliths of the first consolidated basalt at the actual base.

Somewhat farther from the base — between 3 and 4 feet — where the specific gravity has fallen to 2.70 or less, the rock has little of the appearance of a basalt, either in hand-specimens or under the microscope. The colour has become paler, the general mass duller of aspect, and the visible crystals of felspar perhaps rather more abundant. Among these latter the glassy-looking labradorites are no longer to be recognised. A thin slice (S6729) [NG 645 247] shows that they still occur, but they are corroded and turbid like the alkali-felspars. It appears that the phenocrysts proper to the basalt, as well as those proper to the felsite, reacted with the hybrid magma of intermediate composition. The little felspars of the ground-mass probably include both oligoclase and orthoclase: they give sensibly straight extinction, and twinning is with difficulty detected. There is quartz present, but it is not possible to decide to what extent it is of secondary origin. The augite granules have been replaced by calcite, etc., but this mineral has certainly not been very abundant. Little granules of magnetite are fairly plentiful, and there are larger grains and crystals of pyrites, visible in the hand-specimens. Rock comparable with this also occupies a corresponding position relative to the other (upper) surface of the sill.

We see that rocks which stand midway, in a general petrographical sense, between the basalt and the felsite are reached at 2 or 3 feet from the contacts. The transition from these to the felsite of the middle part of the sill is less rapid. The magnetite granules and augite of the ground-mass gradually disappear. The enclosed crystals of labradorite are quickly lost, and it appears that crystals of a basic felspar in an alkaline felspathic magma are more energetically attacked than crystals of alkali-felspar in a basic magma. As we pass to rocks more nearly approximating to the normal felsite, the enclosed crystals of alkali-felspar must be regarded as phenocrysts rather than xenocrysts. They show less rounding of their angles, and begin to occur in clusters. They are still very turbid, but this is due now to chemical decomposition, apparently the production of finely disseminated white mica. The coming in of the scattered augite phenocrysts, or of pseudomorphs representing them, completes the transition to the felsite as described above.

The steady gradation indicated by the specific gravities shown in (Figure 49) shows few irregularities. The most considerable exception to the rule is only in appearance an irregularity. The rock of intermediate composition and specific gravity 2.70, which occurs at the actual base in this section, belongs in reality to a separate thin sill. This becomes evident a short distance away, where a bed of calcareous sandstone intervenes between this thin sill and the main one above. It is probable, however, that the small lower sill is not in origin quite independent of the other, and the same may be predicated of two other thin sills at horizons a little above the main one, shown at D and E in the section in (Figure 48). These show in the field no bilateral symmetry or other evident complexity of structure; but closer examination reveals some anomalous characters which are highly suggestive. Specimens from the uppermost sill (E), which is only one foot thick, show a dark close-grained rock enclosing little felspars about ■ inch in length. Of these some are fresh and of tabular habit, while others are dull and of squarer shape, corresponding respectively with the phenocrysts of labradorite and xenocrysts of alkali-felspar described in the marginal parts of the composite sill. Moreover the rock of this thin sill is itself heterogeneous, though without regular arrangement so far as we have observed. Two specimens, taken only a short distance apart and certainly belonging to a single intrusive body, give specific gravities 2.83 and 2.72.

A comparison of these two specimens in thin slices gives interesting results. Both contain xenocrysts of the kind observed in the larger sill, chiefly of striated oligoclase and always showing an advanced stage of corrosion (*see* (Plate 21), Fig. 4). Apart from these, the former specimen (S9370) [NG 645 249] consists of little crystals of labradorite, 0.03 to 0.06 inch long, granules of augite, and abundant brown glass. A higher magnification shows that this glass is crowded with very slender felspar fibres, and encloses numerous little rods of magnetite. This rock then may fairly be regarded as the partially vitreous representative of that which forms the marginal zones of the neighbouring composite sill. The other specimen (S9371) [NG 645 249] is somewhat richer in brown glass of the same characters as before; but this is not sufficient to account for its much lower density, and examination shows that it is of decidedly less basic composition than the former rock. Augitegranules are no longer present, and the little felspars give low extinction-angles, most of them apparently being near oligoclase in composition. It seems then that this is the glassy representative, not of the unmixed basalt, but of one of the hybrid varieties met with in the composite sill.

The largely vitreous nature of these rocks must, be attributed to the small dimensions of the intruded body and the consequent rapid cooling of the magma. This, on reflection, is a point of considerable interest; for we are forced to the conclusion that in this case the admixture of which we have such clear evidence was already effected when the magma was intruded into its present situation, and forthwith began to cool: in other words, that the partial intermingling of the basaltic and felsitic magmas took place either in the channel of uprise or in some deeper-seated reservoir. The absence of any symmetrical arrangement of the different varieties of rock in the sill points to the same conclusion. The conception of a local magma-basin or reservoir, in which the basalt-and felsite-magmas have coexisted in a fluid state, has already been foreshadowed by the unfailing occurrence of "antecedent" xenocrysts in the composite sills of this group. A like hypothesis seems to be necessitated by the peculiar characters of the marscoite as described in a former chapter; and we shall be brought to contemplate it again, on a larger scale, in discussing the xenocrysts in the basic dykes of this region. We do not picture all the composite sills of the group under discussion as derived from a single reservoir. Their distribution rather suggests that they belong to a number of distinct centres, at each of which the parent magmas underwent a like series of processes; and the unique nature of the felsite of Rudh' an Eireannaich decidedly supports this view.

If in these symmetrical composite sills the basic and acid magmas have risen through the same fissures and spread along the same bedding-planes, the one closely following the other, it is difficult to resist the conviction that they not only came from a common reservoir, but were intimately related in origin. They may have been, in Brögger's phrase, complementary products of differentiation, and a certain rough proportion between the two rocks in the several occurrences is consistent with this hypothesis. The proportion is not a strict one, for in the largest composite sills the acid rock greatly outweighs the basic; but it is nevertheless very noticeable that the thicker basic sheets are always associated with the thicker acid ones and the thinner with the thinner. The proportion would doubtless become more evident, and might perhaps be precisely realised, if we could restore those portions of the basic sills which have been destroyed by the acid magma and absorbed into it.

The several composite sills of this group, taken in order from Suishnish to Broadford, illustrate, as we have pointed out, successive advances in the intimacy of relationship and the degree of intermingling of the associated rock-types. In this view, the small subsidiary sills at Rudh' an Eireannaich present almost the extreme type. The actual final term of the series, which may perhaps be represented in small sills and dykes not specially examined, would be a complete admixture resulting in a homogeneous rock of medium acidity. It is to be expected that a rock resulting from such complete admixture, even if all xenocrysts were entirely absorbed, would still present petrographical peculiarities distinguishing it from, *e.g.,* a normal andesite.

On this last point it is proper to make some remarks of a general kind, which will apply not only to the composite sills and dykes, but to the mixed rocks already described in Chapter 11. and to other instances to be noticed later. We consider that all these *hybrid rocks are essentially abnormal in composition,* and do not find any place in a classificatory system of normal igneous rocks. The processes, whatever be their nature, by which basic, intermediate, and acid rocks of ordinary types are evolved or differentiated from a common stock-magma are processes of a complex and subtle kind, and are not reversible by so crude a means as the mixture of two different rock-types. A rock of mean silica-percentage produced by the mixture of an acid with a basic rock will not have the chemical or mineralogical composition of any normal intermediate rock-type. For this reason it would be misleading to apply to such a mixed rock the name of any recognised normal type or family, such as tonalite, quartz-diorite, dacite, andesite, and the like; and we have accordingly spoken of such rocks as partially acidified gabbros, dolerites, and basalts or partially basified granites, granophyres, and felsites. For one rock, which appeared in numerous occurrences with the same peculiar characters, we have used a special name (marscoite); but this was done solely for convenience of description, and in general the variability of the rocks is such that no definite types can be profitably recognised.

That an abnormal chemical composition is to be expected in a hybrid rock follows from general considerations, and a brief statement of the argument will be sufficient in this place.<ref> For a fuller discussion of this part of the question, see Harker, Igneous Rock-Series and Mixed Igneous Rocks, *Journ. of Geol.,* vol. viii., pp. 389–399: 1900. </ref> The general laws which control the variation in composition of igneous rocks, though in the present state of knowledge empirical, are sufficiently well known. The variations in particular natural series of rocks have been studied, and are conveniently expressed in graphic form by a diagram in which abscissa; represent the silica-percentages of the several members of the series and ordinates the corresponding percentages of the other oxides. For igneous rocks in general the variations in composition have of course a wider range, but certain broad principles still hold. The magnesia, for instance, falls off as the silica increases; but it does not fall off at a steady rate: it diminishes first rather rapidly and afterward slowly. Its variation may thus be illustrated diagrammatically by a curve which is concave upward (Figure 50). Lime behaves differently, and its curve of variation will be convex upward (Figure 51). It is easy to deduce that a mixture of a basic and an acid rock will in general be richer in magnesia and poorer in lime than a normal igneous rock of like silica-percentage. If such differences, viz. a relative excess in some constituents and deficiency in others, pass certain limits, they must affect the mineralogical constitution of the resulting rock: thus an undue richness in magnesia and poverty in. lime may determine the formation of a hornblende instead of an augite. Such considerations seem to throw some light on some of the peculiarities of the rocks described above.

The application of the above argument must, however, be limited by what is in some measure a countervailing consideration. We have so far regarded admixture as a simple process, and tacitly assumed that a hybrid rock derived from the two normal types *A* and *B* can be represented, in respect of chemical composition, by such a formula as $mA + nB$, where *m* and *n* are the proportions in which the two parent rocks are mingled. In fact, however, this is not the case, the process of admixture being complicated by diffusion. We have seen in Chapter 11. that the composition of the granophyre modified by gabbro debris on Marsco does not correspond with a simple formula of the kind suggested; and both in that chapter and the present one we have seen abundant evidence that diffusion has proceeded more or less freely, even in some cases where the sharp boundary between the two rocks involved has not been obliterated. If, as is generally supposed, the origin of diverse rock-types among normal igneous rocks is in great part dependent upon diffusion, this consideration may go to modify in some degree the argument advanced above concerning the necessarily abnormal composition of hybrid rocks; but it is at most a mitigating factor.

Of the triple composite sills not yet particularly described, only one calls for any special notice. We may remark that the intimacy of association between the different members, which reached a climax in the basalt-felsite sill of Rudh. an Eireannaich, is displayed in a high, though less extreme, degree in the other northerly examples, which have the more usual basalt-granophyre combination. At Camas na Geadaig in Scalpay the central acid member is sharply delimited against the upper basalt, but seems, to the eye at least, to shade insensibly into the lower one. At Allt an 't-Sithean, near Sligachan, the boundaries are in most places fairly distinct, though of highly irregular form, but this has not prevented a remarkable degree of intermingling between the two rocks, This occurrence deserves some brief notice. It differs from most of the others in its decidedly laccolitic development, the granophyre forming a lenticular mass in the interior of a basalt sill (*see* section, (Figure 44)). This is susceptible of simple explanation. The basalt sill, prior to the intrusion of the granophyre, was swollen in this place to an unusual thickness, and its interior portion was here partly fluid when in other places the sill was consolidated throughout. Here the acid magma consequently found easy access, and entered into reactions with the imperfectly consolidated basalt. There was here, however, some peculiarity in the conditions attending the consolidation of the basalt, which enabled the process to begin in the central zone as well as at the margins, and an inconstant sheet of the rock, usually not more than 3 feet thick, was thus enclosed in the heart of the granophyre, which found its way both above and below. It is certain that some part of this middle basalt was actually solid when the acid magma came in; for, although most of the deeply corroded sheet is in a greatly modified state, a part is quite normal. It is a dark grey crystalline basalt of specific gravity 2.85, enclosing only scattered xenocrysts, which clearly are of the "antecedent" kind never absent from this type of rock. As might be anticipated, its texture is not so fine as in other basalts of this group.

Such portions of the upper and lower basalts as can be considered normal rocks do not differ, except by their finer texture, from the specimen just noticed. The normal granophyre is a beautiful spherulitic rock, but in most places deeply weathered. It does not contain quartz phenocrysts of any visible size, and this explains the general absence (to the eye at least) of quartz-grains among the xenocrysts, whether antecedent or consequent, in the basalts. On the line of our section there is not much basic rock of normal character seen in the valley of Allt an 't-Sithean itself, the rock which does duty as basalt being mostly acidified in greater or less degree. An average example of the lower "basalt at this place has a specific gravity only 2.63. It is of rather light grey colour, and contains fairly abundant dull white felspars, to ■ to ¼ inch, some of which are probably "consequent" xenocrysts. It encloses little patches, either angular or rounded, of finer texture and evidently of more normal basic composition, and in these the felspars are smaller and less numerous. They are presumably pieces of the first-consolidated marginal zone of the basalt, subsequently broken up, and xenoliths of this kind are very common in this sill. The "granophyre" near all its contacts with the "basalt" encloses very numerous partially digested xenoliths of that rock, which have the appearance of being much acidified. In the same places the acid rock itself is considerably modified in the opposite sense, and, as usual in such cases, has lost its spherulitic structure.

As we have remarked, the boundary between "basalt" and "granophyre", though highly irregular, is in general not obliterated. There has, however, been free diffusion across the boundary in both directions, and it is not difficult to select specimens from the "basalt" side of the line which are evidently more acid than some specimens from the "granophyre" side. In the absence of chemical tests, this is sufficiently proved by specific gravity determinations. Thus a specimen of quite pale grey colour representing the middle "basalt" in a greatly modified condition gives only 2.577, while a neighbouring "granophyre" (containing, however, some small xenoliths) gives 2.656.

In conclusion we may notice briefly the large composite dyke, probably connected with this sill, which is exposed not far to the north. It has a maximum width of nearly 150 feet, and, excepting a narrow border on each side, is of granophyre. It contains felspars with rounded angles and little round grains of quartz. All these are the nuclei of spherulites, and other spherulites make up the rest of the rock. It is conspicuously drusy; but, as usual, the sum total of the vacant spaces which go to produce this appearance is in reality quite small. Specific gravity determinations taken on a specimen, first in bulk and then in powder, differ by less than 0.01, and the druses certainly make up less than one part in 200 of the total volume. A fresher rock, with no lining of secondary products in the druses, would give a rather higher proportion.

The much shrunken width of the bordering basalts is in agreement with what is elsewhere observed in the dykes of this group, as compared with the sills. Equally to be anticipated is the greatly modified character of such basalt as remains, no part of which has escaped being impregnated by the acid magma. A specimen selected to represent the least altered rock has a specific gravity only 2.59, and contains conspicuous xenocrysts of felspar.

This rock is definitely divided from the granophyre, but in other places it is not possible to draw any sharp line. Both the "basalt" and the edge of the granophyre adjoining it enclose abundant xenoliths of a dark fine-textured rock, up to 2 or 3 inches in length in some places. These never contain xenocrysts, or indeed any visible crystals, and they often show but little rounding of their angles. They are probably derived from the basalt lavas which the dyke intersects.

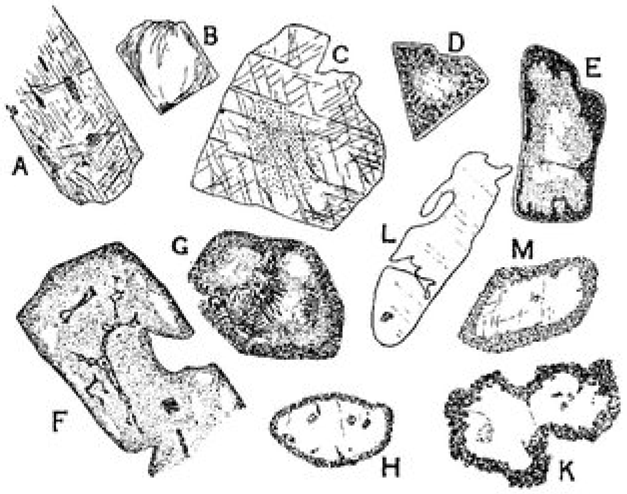



FIG. 47.—Altered phenocrysts and xenocrysts in the basalt of the composite sills; × ca. 10.

A [6735]. Labradorite phenocryst in upper basalt of Cnoc Càrnach; the cleavage cracks opened probably by heat due to the succeeding acid intrusion.

B [6735]. Labradorite phenocryst in the same rock; showing peripheral fissures with a tendency to concentric arrangement.

C [7071]. Labradorite phenocryst in lower basalt of Beinn a' Chairn; showing opening of cleavage cracks and glass-inclusions, probably of secondary origin, in interior of crystal.

D [6735]. Orthoclase xenocryst in upper basalt of Cnoc Càrnach; turbid owing to secondary glass-inclusions.

E [6732]. Oligoclase xenocryst in lower basalt of Creag Bhriste; showing similar turbidity and also rounding of the angles by magmatic corrosion.

F [7069]. Oligoclase xenocryst in basalt xenolith enclosed in acid rock of Beinn a' Chairn; showing a more advanced stage of corrosion, affecting the interior as well as the border of the crystal.

G [6735]. Oligoclase xenocryst in upper basalt of Cnoc Càrnach; showing a very advanced stage of corrosion, with formation of new felspar microlites in the interior of the crystal.

H [7069]. Quartz xenocryst in basalt xenolith at Beinn a' Chairn; rounded, and with border of granular augite (now decayed).

K [7066]. Quartz xenocryst in basalt xenolith at same place; showing more advanced corrosion and a deeper border composed of larger granules.

L [6733]. Quartz xenocryst in acidified basalt xenolith at Creag Bhriste; showing more advanced corrosion, but the augite border has been resorbed with increasing acidification of the matrix.

M [6731]. Xenocryst of alkali-felspar in lower basalt of Rudh' an Eireannaich; showing the margin honeycombed by secondary inclusions.

*(Figure 47) Altered phenocrysts and xenocrysts in the basalt of the composite sills; × ca. 10. A (S6735) [NG 655 197]. Labradorite phenocryst in upper basalt of Cnoc Mrnach; the cleavage cracks opened probably by heat due to the succeeding acid intrusion. B (S6735) [NG 655 197]. Labradorite phenocryst in the same rock; showing peripheral fissures with a tendency to concentric arrangement. C (S7071) [NG 632 174]. Labradorite phenocryst in lower basalt of Beinn a' Chaìrn; showing opening of cleavage cracks and glass-inclusions, probably of secondary origin, in interior of crystal. D (S6735) [NG 655 197]. Orthoclase xenocryst in upper basalt of Cnoc Chrnach; turbid owing to secondary glass-inclusions. E (S6732) [NG 660 204]. Oligoclase xenocryst in lower basalt of Creag Bhriste; showing similar turbidity and also rounding of the angles by magmatic corrosion. F (S7069) [NG 625 168]. Oligoclase xenocryst in basalt xenolith enclosed in acid rock of Beinn a' Chaìrn; showing a more advanced stage of corrosion, affecting the interior as well as the border of the crystal. G (S6735) [NG 655 197]. Oligoclase xenocryst in upper basalt of Cnoc Càrnach; showing a very*

*advanced stage of corrosion, with formation of new felspar microlites in the interior of the crystal. H (S7069) [NG 625 168]. Quartz xenocryst in basalt xenolith at Beinn a' Chaìrn; rounded, and with border of granular augite (now decayed). K (S7066) [NG 638 181]. Quartz xenocryst in basalt xenolith at same place; showing more advanced corrosion and a deeper border composed of larger granules. L (S6733) [NG 660 204]. Quartz xenocryst in acidified basalt xenolith at Creag Bhriste; showing more advanced corrosion, but the augite border has been resorbed with increasing acidification of the matrix. M (S6731) [NG 645 247]. Xenocryst of alkali-felspar in lower basalt of Rudh' an Eireannaich; showing the margin honeycombed by secondary inclusions.*

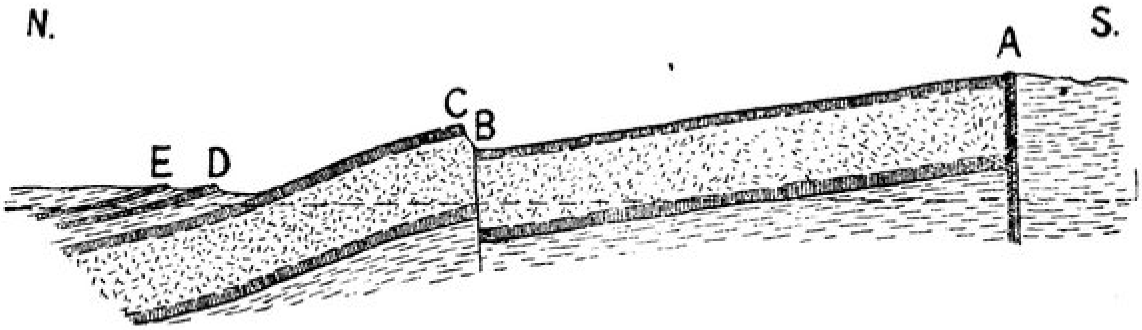



Fig. 48.—Section of composite sill in the Lias at Rudh' an Eireannaich, Broadford Bay.

A, a fault; its fissure occupied by a double basalt dyke.

B, a small fault.

C, escarpment running out to sea eastward, and forming the actual headland.

D and E, thin sills, 1½ ft and 1 ft respectively, referred to below.

*(Figure 48) Section of composite sill in the Lias at Rudh' an Eireannaich, Broadford Bay. A, a fault; its fissure occupied by a double basalt dyke. B, a small fault. C, escarpment running out to sea eastward, and forming the actual headland. D and E, thin sills, 1½ ft and 1 ft respectively, referred to below.*

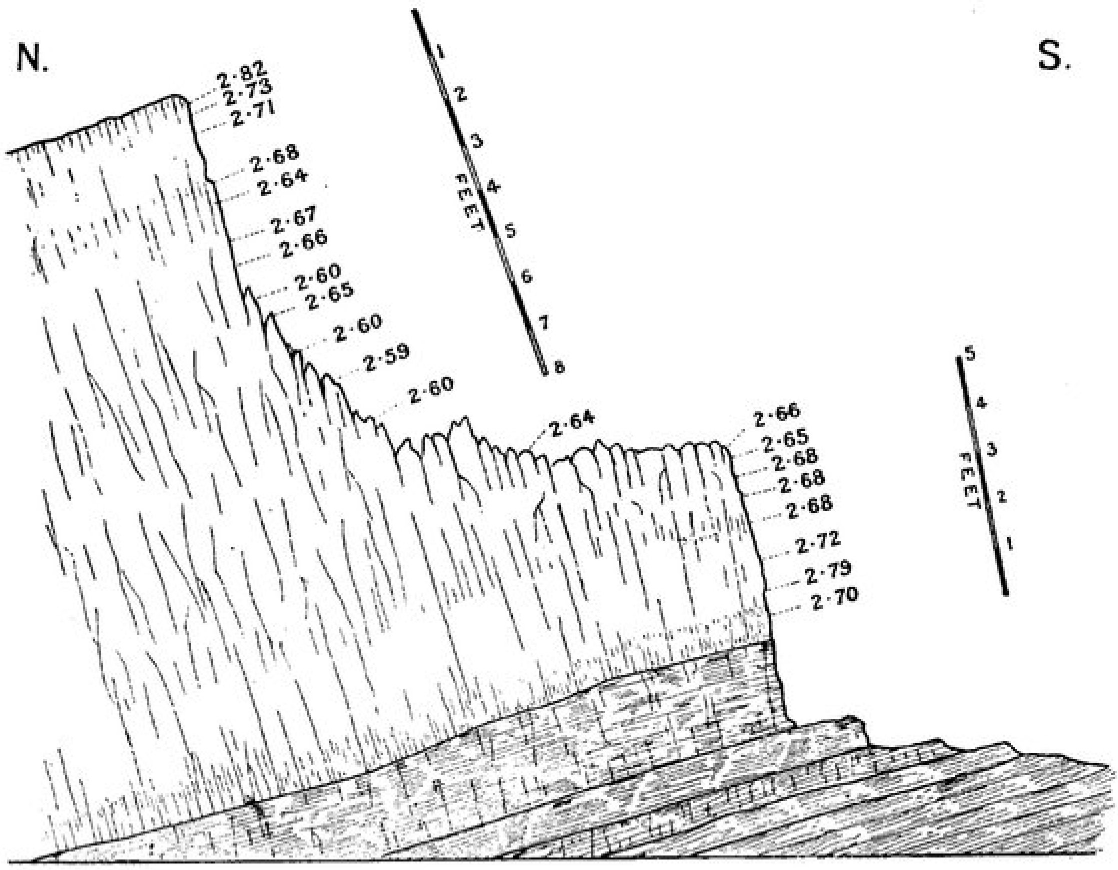
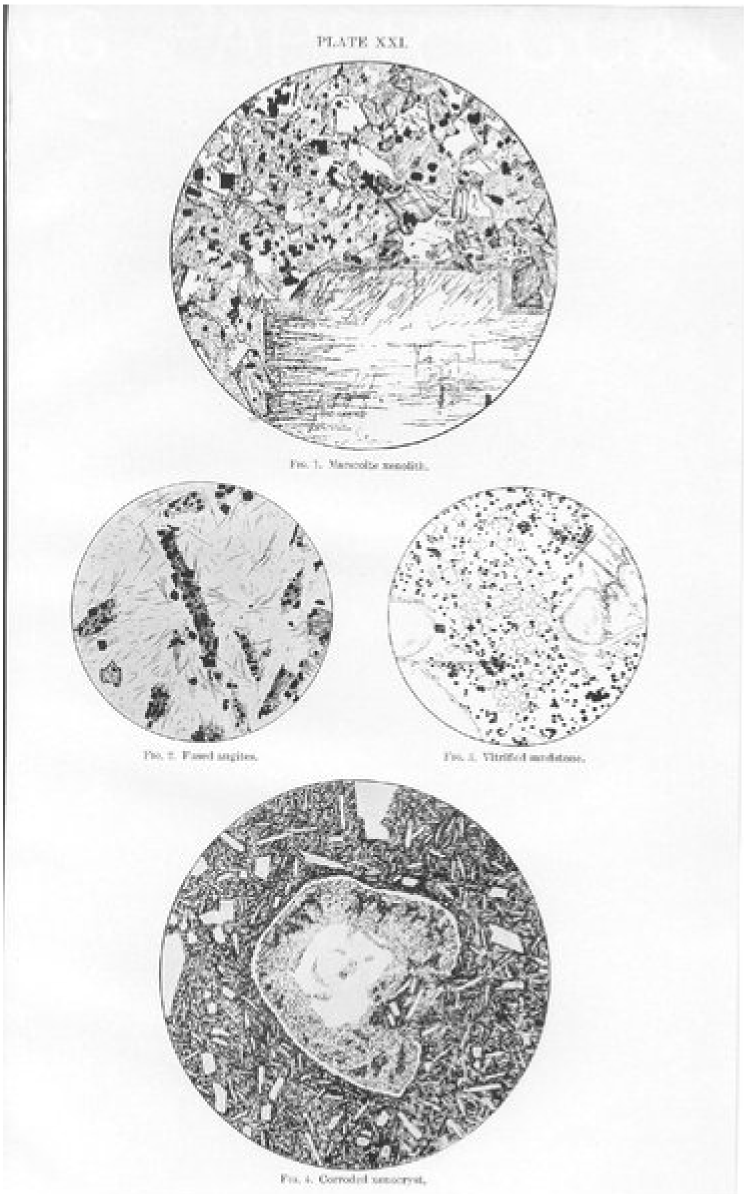



Fig. 49.—Enlarged section of composite sill of Rudh' an Eireannaich, taken at the low escarpment on the shore, the eastward continuation of C in the preceding figure.

The numbers indicate the specific gravities of specimens from different parts of the section.

*(Figure 49) Enlarged section of composite sill of Rudh' an Eireannaich, taken at the low escarpment on the shore, the eastward continuation of C in the preceding figure. The numbers indicate the specific gravities of specimens from different parts of the section.*




*(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.*

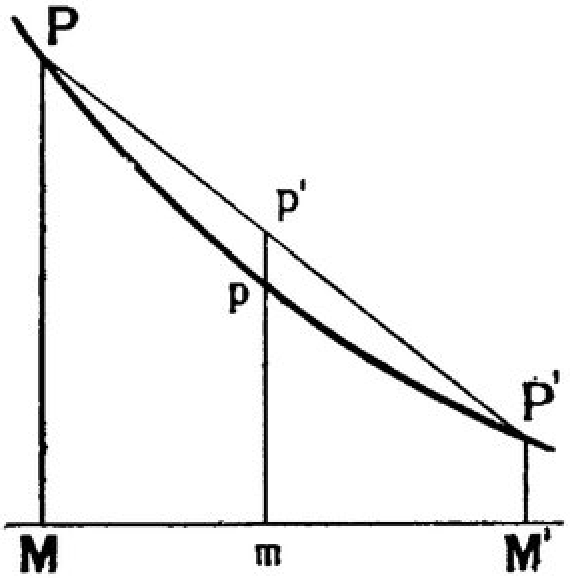



FIG. 50.—Ideal curve of variation of magnesia, $PpP^1$. Here $PM$ and $P^1M^1$ represent the percentages of magnesia in a basic and an acid rock; $p^1m$, that in a hybrid rock formed by the admixture of the two; and $pm$, that in a normal rock having the same silica-percentage as the hybrid. The latter has thus an excess of magnesia.

*(Figure 50) Ideal curve of variation of magnesia, $PpP^1$. Here PM and $P^1M^1$ represent the percentages of magnesia in a basic and an acid rock; $p^1m$, that in a hybrid rock formed by the admixture of the two; and pm, that in a normal rock having the same silica-percentage as the hybrid. The latter has thus an excess of magnesia.*

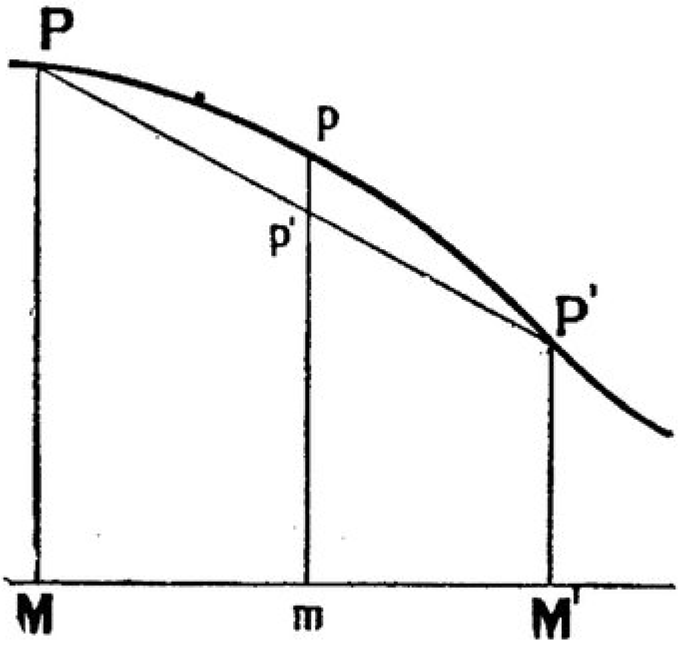



FIG. 51.—Ideal curve of variation of lime. The diagram is lettered to correspond with the preceding, lime being understood instead of magnesia. It is seen that the hybrid rock has a deficiency of lime as compared with the natural rock of the same silica-percentage.

*(Figure 51) Ideal curve of variation of lime. The diagram is lettered to correspond with the preceding, lime being understood instead of magnesia. It is seen that the hybrid rock has a deficiency of lime as compared with the natural rock of the same silica-percentage.*

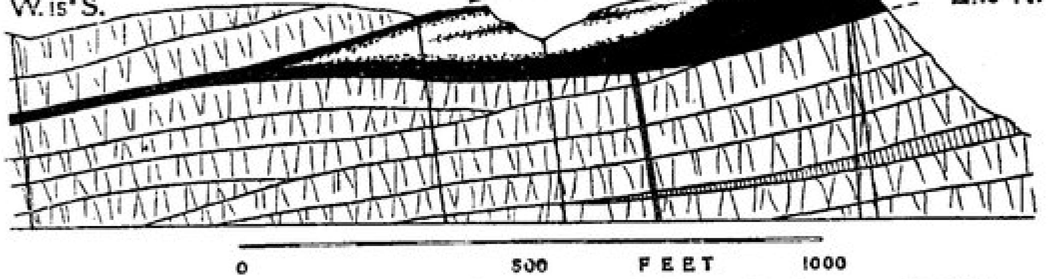



FIG. 44.—Section across Allt an 't-Sithean and through Cnoc an 't-Sithean, about 1¼ mile N.N.W. of Sligachan, to show the relations of the basalt (black) and granophyre (white) in the quintuple composite laccolite. The intrusion occurs in the basaltic lava group, and one of the ordinary dolerite sills is shown lower down. The triple composite dyke which has probably fed the laccolite does not appear in this section, but some later basic dykes of simple habit are shown, and these in some cases have failed to penetrate the thick mass.

*(Figure 44) Section across Allt an 't-Sithean and through Cnoc an 't-Sithean, about 1¼ mile N.N.W. of Sligachan, to show the relations of the basalt (black) and granophyre (white) in the quintuple composite laccolite. The intrusion occurs in the basaltic lava group, and one of the ordinary dolerite sills is shown lower down. The triple composite dyke which has probably fed the laccolite does not appear in this section, but some later basic dykes of simple habit are shown, and these in some cases have failed to penetrate the thick mass.*