Chapter 6 Peridotites (earlier group)

The plutonic phase of igneous activity in the Skye area was initiated by the intrusion of a magma of ultrabasic composition, which consolidated to form rocks rich in olivine. The intrusion assumed the laccolitic habit, and was effected at several places within what is now the south-western part of the Cuillin Hills, and also at one place in the neighbouring Isle of Soay. Except in the last case, the horizon was in the basaltic lavas, and not far from the base of that group. The geological relations of the peridotite laccolites of the Cuillins are, however, obscured in some measure by the gabbro which, in the form of one great complex laccolite, builds the greater part of this group of mountains. The gabbro magma, intruded immediately after the peridotic, has enveloped and invaded the ultrabasic rocks in a very remarkable manner. Some advantage of description might be gained by treating the gabbros before the peridotites, but the chronological order seems on the whole to be the more convenient.

The principal mass of ultrabasic rocks is that which we shall designate the *Sgùrr Dubh laccolite.* It forms the whole of the western peak of the ridge of that name, known to climbers as Sgùrr Dubh na Dabheinn, and attains there its greatest thickness. In the col between this peak and the higher one to the east (Sgùrr Dubh Mhòr) the peridotite mass passes under the gabbro of the latter mountain, the irregular surface of junction having a steep dip to N.E. or E.N.E. (Figure 10). On the Coir' a' Ghrunnda side it extends down into the corrie, the boundary which corresponds with the under side of the laccolite passing through the middle of the tarn. The inclination here, judged by the dip of the flow-banding in the peridotite, is much less, not exceeding 30°. From Sgùrr Dubh na Dabheinn the outcrop of the laccolitic mass may be traced both eastward and northward, though with diminished thickness. In the former direction the peridotites form the floor of An Garbh-choire, and extend nearly as far as to the shore of Loch Scavaig. The trend corresponds roughly with the line of the valley, and the inclination, as indicated by fluxion-banding, is to some point of north, usually at a high angle. The thickness of the laccolite, which at its maximum reaches more than 1500 feet, is here reduced to 500 or 600 feet. Farther east, in consequence of the form of the ground and the varying inclination of the mass, the belt of ground occupied by the peridotite expands, and extends for some distance southward up Coire Beag. Beyond this the mass is so much invaded and broken up by gabbro that its continuity is lost. The northward prolongation of the laccolitic body from Sgùrr Dubh na Dabheinn crosses the col connecting the two mountains known as Sgùrr Mhic Choinnich and Sgùrr a' Coir' an Lochain, and extends down Coireachan Ruadha towards the head of the Coruisk valley. In this latter part of its course it is deeply cut into by the gabbro and divided into tongue-like strips. The whole outcrop has a roughly semicircular form, extending from Allt a' Chaoich, near Loch Scavaig, to the foot of Coireachan Ruadha, a distance of three miles. The concave boundary, representing the upper surface of the mass, is presented to the north-east; the convex boundary, representing the lower surface, to the south-west. The irregular form of the outcrop arises partly from original departure from the ideal lenticular shape of a laccolite, partly from subsequent tilting and flexure, but chiefly from the partial destruction of the mass by the later intrusions of gabbro, in which it was completely involved.

The *partial destruction of the peridotite laccolite by the gabbro magma is* most marked along the upper or concave side, and especially towards the terminations eastward and northward. The best place for observing the phenomena is near the eastern end, about Allt a' Chaoich (the "Mad Burn") and the stream immediately south of it. Here the whole mass of the peridotite is intersected by offshoots from the neighbouring gabbro. These are partly in the form of straight dykes, partly a network of irregular veins; and the dykes often serve as the origin of veins, which branch out from them and connect them (Figure 11). In places the gabbro within the peridotite area swells into larger masses, which enclose detached blocks of peridotite (Figure 12). By increase in the amount of gabbro as compared with peridotite, we pass insensibly from peridotite full of ramifying veins of gabbro to gabbro crowded with blocks of peridotite, the boundary'being one which defies mapping. Outside the main area of peridotite there are still isolated portions of considerable size seen along the side of Allt a' Chaoich and on the flanks of Meall na Cuilce. Farther east and north these become more broken up, but blocks of peridotite several feet in diameter are still found embedded in the gabbro as far as the shores of Loch Scavaig and Loch Coruisk and even on some of the islets of the latter. A similar destructive action of the gabbro upon the peridotite laccolite, though in a less marked degree, may be seen in Coireachan Ruadha. On the south-western or under side of the laccolite these extreme effects are not perceived; but the fact that the peridotite is often traversed by gabbro veins, while the reverse relation is never found, is sufficient to prove that the gabbro on this side also is newer than the ultrabasic rocks.

As regards the relative ages of the peridotites and the gabbros, it is proper to observe that the great gabbro mass of the Cuillins is the product of a number of successive intrusions, and only those portions which come into juxtaposition with the peridotite laccolite can be positively proved to be younger than it. The component parts of the gabbro mass seem, however, to be so intimately bound up together that nothing less than direct evidence could make it reasonable to regard them as partly earlier and partly later than the very distinct intrusion of ultrabasic magma. For this reason we consider the peridotites in question to have preceded all other plutonic intrusions in the district. To be sharply distinguished from these *older* peridotites of plutonic habit are certain *younger* peridotites, mostly in the form of dykes, which belong to a very much later epoch, and will be considered in a subsequent chapter (22).

Besides the large Sgùrr Dubh laccolite already noticed, we refer to the earlier or plutonic set of peridotites now under discussion certain *smaller laccolitic masses* which will now be enumerated. With a single exception, they occur within, or in one case on the actual edge of, the gabbro of the Cuillins. One thin laccolite or sheet of small dimensions is seen in the dip between Sgùrr Dubh Mhòr and Sgùrr Dubh Bheag, the lower peak to the east (Figure 10). This Sgùrr Dubh Bheag intrusion is the only one occurring at a higher horizon (having regard to the inclination of both peridotites and gabbros) than the large mass. It dips rather steeply to the east or north-east. Another small laccolitic mass, about 250 feet thick but rapidly tapering, crops out along the face of the buttress from Sgùrr na Banachdich which divides the upper part of Coire-achan Ruadha into two smaller corries. Its rusty orange tint, contrasting with the darker gabbro above and below, makes it a conspicuous object as seen from Coruisk. A still smaller mass is intersected by the stream which drains the northerly branch of the same corrie. There are two small masses of irregular laccolitic form on the southern slope of Gars-bheinn, at altitudes of about 1500 and 1000 feet respectively. The lower of these, though partly enveloped by gabbro, rests upon the metamorphosed basaltic lavas below. Finally, a small mass of irregularly laccolitic habit occurs at An Dubh-sgeire on the east coast of the Isle of Soay, about two miles south of the last-mentioned locality. This, the most outlying intrusion of the group, occurs in the Torridonian grits, and therefore occupies a position below, but not necessarily much below, the base of the basalts. The distribution of these older peridotites is shown on a sketch-map in a later chapter (Figure 75).

These various laccolitic intrusions, large and small, have been supplied, like other laccolites, *through fissures,* in which the magma finally consolidated to form *dykes.* It might be expected that all trace of these dykes would be destroyed by the later invasion of gabbro magma which enveloped the whole; but this is not always the case. Portions of some of the dykes are preserved, and in more than one case their actual connection with the laccolites which they fed is demonstrated. These dykes are seen to the east and south of Gars-bheinn in several places. They have a N.N.W.–S.S.E. direction and may be traced for considerable distances through the gabbro and the wedge-like portions of the basaltic lavas which here dove-tail with the gabbro. In the lavas the dykes are of course continuous; in the gabbro they are liable to be interrupted, and so occur in detached lengths. In places they are abundantly veined by the surrounding gabbro. They range in width up to as much as 40 or 50 feet; but usually they are less, partly perhaps in consequence of their being attacked by the gabbro magma.

One place where the actual connection of one of these dykes with the largest peridotite laccolite may be observed is in the lower part of Coire Beag, on the south-eastern side of the valley. The dyke can be traced at intervals for nearly 1000 yards in a S.S.E. direction from this place. It is doubtless a feeder of the large mass, but it is not to be supposed that it is the only one. Indeed there are at least two other places along the southern boundary of the laccolite where tongues project into the gabbro, which are probably of a similar nature, though they cannot be followed for more than a short distance. A more interesting case is presented by the two small Gars-bheinn intrusions. The lower of the two is in visible continuity with a dyke below, which runs S.S.E., cutting the basaltic lavas and the underlying Torridon Sandstone; but the mass is also prolonged upward into another dyke, having the same direction and nearly on the same line. This latter dyke runs up the hill-side, with breaches of continuity where it has been destroyed by the gabbro, and terminates at the upper and smaller laccolite, of which it is evidently the feeder. It appears then that we have here two laccolitic intrusions of ultrabasic rock, at different levels, supplied from the same source; the relations being still clearly indicated despite the interference of the subsequent and much more voluminous intrusion of gabbro.

To avoid possible confusion, before proceeding to the petrographical description of these various laccolites and their dyke-feeders, we will specify those younger ultrabasic rocks which are excluded from this place for later consideration. They are, as stated, mostly dykes, and dykes which are not the feeders of larger masses but independent intrusions.

Sill-formed intrusions also occur, at least in the Isle of Soay. In addition there is an abrupt boss-like body of considerable size forming the hill An Sgùman on the south-western edge of the gabbro of the Cuillins. The reasons for assigning this to the later group of peridotites are that it clearly breaks through the gabbro, and is connected with dykes referable to the later group, while its petrographical characters also point to the same conclusion. Finally there are a small mass near the summit of Glamaig and an isolated intrusion of irregular form, partaking of the nature both of a dyke and of a sheet, in the Lias near Suishnish Point, between Lochs Slapin and Eishort. All these younger rocks will be described in a later chapter.

Of the rocks now under discussion we have no chemical analyses, but it is very evident without such aid that they are all of ultra-basic composition. We have spoken of them collectively as peridot-ites, using that term in a broad sense. The commonest type is a picrite, in which augite and felspar are fairly well represented in addition to the dominant olivine; but there are other varieties of frequent occurrence, including very typical peridotites, in which the characteristic mineral occurs almost to the exclusion of all others.

The *constituent minerals* of these ultrabasic rocks are not many, and the various well-marked petrographical types arise from different associations of these minerals or associations of them in different proportions. Most important of all is olivine, which is found in all the rocks, and, except in the rare "norite", is the principal constituent, making up from one-half to practically the whole of the bulk in different types. Owing to this abundance of olivine, which is of a highly ferriferous variety, all the rocks assume on an exposed surface an orange to reddish-brown colour which at once arrests the eye. When augite or diallage is present, the small lustrous faces are visible here and there upon the rusty surface or upon a fractured specimen, where the olivine appears as a very dark or almost black crystalline aggregate. In the "troctolites" the white felspar interrupting the rusty film on the surface of the rock gives it a paler aspect. The rocks are of medium grain and of extreme hardness and toughness, giving a ringing metallic sound under the hammer. A certain heterogeneity in the composition of the rocks on a small scale, and the frequency of xenoliths which weather out more or less freely than their matrix, impart to exposed surfaces of the rocks a remarkably rough and often pitted character. Owing to this and to the soundness and toughness of the rocks, they lend themselves in an eminent degree to climbing, even on very steep faces.

The *olivine* occurs in crystals or crystals-grains varying from 1/20 to ■ inch in diameter. They are the earliest product of crystallisation, with the exception of the spinellids, and are thus idiomorphic, except when in the form of a granular aggregate they make up almost the whole bulk of the rock. They do not, however, usually show good crystal outlines. The mineral almost constantly contains inclusions of the type which Professor Judd has described, viz. flat rectangular cavities partly occupied by magnetite in branching or dendritic forms. When these are largest they vary from 1/500 to 1/300 inch in length (*cf.* (Plate 25), Fig. 4, B), but usually they are much smaller, and then impart a peculiar dusty appearance to the thin slices. The little cavities are much more abundant here than in the olivine-gabbros to be described below, and often the magnetite occupies a larger space in each cavity, or almost fills it in some instances. We may infer that the olivine (including its minute interpositions) is in these ultrabasic rocks of a variety richer in iron than that in the gabbros.<ref>In olivine from a peridotite in the Isle of Rum Heddle found Fe_2O_3 2.933 and FeO 18.703: Min. *Mag.* (1884), vol. v., p. 16.</ref> The mineral is nevertheless sensibly without colour in thin slices.

The *augite,* which always forms allotriomorphic grains and patches, is sometimes colourless, sometimes light brown with a diallage structure (Figure 14). In some cases again it shows in thin slices a faint green tint, perhaps due to the presence of chromium. There is then no diallage-structure, but only occasional bands of inclusions, the rule being apparently that the bands are parallel to one of the prismatic cleavages and the inclusions themselves to the other.

A rhombic pyroxene is an occasional accessory in the true peridotites and in some few examples predominates over the monoclinic species, while in the exceptional rock which we shall refer to as norite it constitutes fully one-half of the mass. Being sensibly colourless and without pleochroism in thin slices, it may perhaps be termed *enstatite,* but this criterion is of doubtful value when, as in this case, much of the contained iron is concentrated in the form of minute "schiller" inclusions. The mineral occurs in idiomorphic crystals, giving rectangular sections 1/20 to 1/10 inch long, with a marked schiller-structure parallel to the macropinacoid. Inter-growths with the monoclinic pyroxene are found.

When felspar occurs in the rocks, it is always *anorthite.* Only exceptionally does it tend to idiomorphism, with rectangular sections: usually it has an interstitial arrangement. It shows carlsbad and albite twinning, and less frequently a few lamellas according to the pericline law.

The minerals of the iron-ore and spinel group, which are never wanting and sometimes abundant, belong to more than one variety. The most common is opaque in ordinary thin slices, and forms small octahedral crystals, invariably the earliest product of crystallisation and usually enclosed in the olivine. It has the appearance of magnetite, and is probably a *chrome-magnetite* or chromite, but has not been tested chemically. In some rocks we find, accompanying or replacing the opaque crystals, a translucent mineral of deep brown colour, usually in irregular grains, and this we may set down as *picotite.* At one place such a mineral occurs in relatively large crystals, which have been isolated and analysed. This is in the banded dunite to be described below, where the picotite is found in unusual abundance, making in some places narrow seams of practically pure material. It forms here well-shaped octahedra, black and lustrous, usually between 1/100 and 1/20 inch in diameter, and is distinguished from either magnetite or chromite by the fact that it scratches quartz. In thin slices it becomes transparent with a strong brown or greenish brown colour [S9229, etc.]. A carefully conducted analysis by Dr Pollard gave the result shown in column I. There is a fair correspondence with the picotite of Lake Lherz (column A.), though the Skye mineral is notably richer in chromium. The only analysed mineral from the Western Isles which can be quoted for comparison is from near the summit of Askival in the Isle of Rum. The analysis is by the late Dr Heddle, and is confessedly imperfect, the investigation of minerals of this group presenting peculiar difficulties. The figures (B.) are, however, sufficient to show that the mineral is rather a chromite than a picotite, the alumina being much lower and the iron higher than in the first column.

	I	A	B	I a	I b
SiO_2	1.19	2.00	6.543	0.0197	
TiO2	0.34			0.0042	
Al_2O_3	46.54	56.00	17.957	0.4554	
Cr_2O_3	17.55	8.00	26.304	0.1153	0.6083
Fe_2O_3	6.01		not det.	0.0376	
FeO	10.10	24:90	34.239	0.1403	
NiO, CoO	0.24			0.0032	
MnO	trace		0.869		0.6059
MgO	18.35	10.30	13.913	0.4547	
CaO	0.43		6.573	0.0077	
	l00.75	101.20	106.398		
Spec. grav.	(3.78)	4.08	4.163		

I. Picotite, from seam in banded dunite, glen south of Allt a' Chaoich, Loch Scavaig: anal. W. Pollard. (The specific gravity was taken on a hand-specimen, including a little olivine and serpentine, and is therefore too low.)

A. Picotite, Lake Lherz, Ariège: anal. A. Damour, *Bull. soc. géol. Fra.* (2), vol. xix., p. 414: 1862.

B. Chromite, seam in peridotite near summit of Askival, Isle of Rum: anal. M. F. Heddle, *Trans. Roy. Soc. Edin* vol. xxx., p. 461: 1882. "The iron is *conjectured* to be in the ferrous state"

Ia. and Ib. Molecular ratios from analysis I. These give very closely the formula RO, R_2O_3, where RO stands for MgO and FeO with a little CaO, NiO, etc., while R_2O_3 stands for Al_2O_3 and Cr_2O_3 with some Fe_2O_3.

It seems probable that the brown translucent mineral in our other rocks is not essentially different from that analysed, and we may name it picotite without fear of error; but the nature of the opaque octahedra is not certainly determined. It must be admitted that the rough test of transparency or opacity in thin slices is not a very satisfactory criterion; but it also appears that the distinction between picotite and chromite is a rather arbitrary one, and has not been clearly defined. It is at least established that some picotites contain ferric as well as ferrous iron, while of the large number of published analyses of chromite (terrestrial) only two do not show alumina and magnesia.<ref>Pratt, *Amer. Journ. Sci.* (4), vol. vii., p. 284: 1899. A large number of analyses are collected by Wadsworth in his *Lithological Studies* (Cambridge, Mass., 1884).</ref> The facts suggest that the spinels and the magnetites constitute not two but one group of isomorphous compounds of the general type RO, R_2O_3. If, as practical requirements may demand, we distinguish two sub-groups according to the predominance of alumina or ferric oxide among the sesquioxides, the varieties rich in chromic oxide occupy an ambiguous position, since Cr_2O_3 may be regarded as replacing either Al_2O_3 or Fe_2O_3. This is perhaps an argument for placing the highly chromiferous varieties in a third sub-group with some collective name. Here would be included most of the minerals which have been named chromite and some of those styled picotite, *e.g.* that from the original dunite of New Zealand with 56.54 per cent. of chromic oxide.

At a place very near to that which furnished the picotite analysed, the dunite contains instead another mineral of the spinel group. Unlike the picotite close by, but like the picotite in many of our rocks, it forms grains of irregular shape with little indication of crystal form. In thin slices it is transparent with a deep green colour, and it may be referred to *pleonaste.* It makes up in this place from one-third to one-half of the rock, but we have not observed it elsewhere.

The only other constituents of the rocks are rare scraps of brown *hornblende* and red-brown *biotite,* found occasionally in close association with the augite. Sometimes the biotite is intergrown with diallagic augite, its basal plane being parallel to the orthopinacoid of that mineral (S9234) [NG 458 203].

The rocks consisting of various associations of the minerals enumerated present a considerable range of petrographical characters. As might be anticipated, they have much in common with the peridotites of Rum and the Shiant Isles, as described by Prof. Judd.<ref>*Quart. Journ. Geol. Soc.,* vol. xli., pp. 354–416. Pl. X.-XIII.</ref>

Coming to the description of the rocks themselves, we may distinguish as the principal types peridotite in the narrower sense, picrite, and troctolite, and as an exceptional type norite.

Under the head of *peridotite* in the strict sense we include those rocks in which olivine predominates very decisively over all other constituents. Such rocks occur in considerable force in the large Sgùrr Dubh laccolite, especially in the eastern part of it. The type *dunite,* consisting wholly of olivine except for a usually very subordinate proportion of a spinellid mineral, is well represented. Locally, and especially in the small nameless glen a little south of Allt a' Chaoich, the spinellid mineral becomes a more prominent constituent; though it does not, except in particular bands of rock, equal in amount the olivine (Figure 13). As the little octahedra of picotite become more numerous, they become transparent in the thin slices, and this presumably indicates a more chromiferous variety than the usual opaque mineral. In certain bands green pleonaste occurs richly instead of picotite. Specific gravity determinations of three specimens of dunites gave:

(S8726) [NG 470 192]	Lower part of Coire Beag	3.21
(S9231) [NG 467 200]	Below An Garbh-choire	3.29
(S9229) [NG 480 195]	Glen south of Allt a' Chaoich	3.32

The last is from a band rich in picotite. A specimen very rich in pleonaste, from the same neighbourhood, gave 3.435.

In the other peridotites, while the mineral which plays the title-role still makes up considerably more than half of the rock, it is acompanied by augite or felspar, or both, in addition to the usual small amount of magnetite, chromiferous magnetite, or picotite. The augite is usually a brown diallage (Figure 14). The felspar, which is often quite as important a constituent, is always anorthite. Both minerals occur in little interstitial patches. These augite- or diallage-peridotites and anorthite-peridotites are connecting links with the picrites and troctolites, into which they graduate by diminution of the excessive proportion of olivine. An average peridotite from near the mouth of Coireachan Ruadha gave the specific gravity 3.26. An enstatite-peridotite, with only a small amount of diallage, seems to be of restricted occurrence.

The *picrite,* which is on the whole the prevalent type in the large laccolite, and is the essential rock of the smaller masses, differs from the peridotites proper in having a less marked preponderance of olivine, implying therefore a less extreme basic composition. Olivine still makes up fully one-half of the rock, and sometimes as much as three-fourths, the other principal minerals being augite and anorthite. As regards structural characters, there is little variety. The augite is in interstitial patches, or it may form spreading plates, each enclosing numerous grains of olivine, thus giving the "poecilitic" structure of Williams. Where felspar and augite come together, the former mineral is idiomorphic towards the latter. The specific gravity of these rocks ranges up to 3.15, but, with increase in the proportion of felspar relatively to augite, may fall to 3.00 or less.

The third chief type, composed essentially of olivine and anorthite, will, in default of a more precise name, be spoken of as *troctolite.* It is to be observed, however, that this term (with its German equivalent Forellenstein) is currently applied to two very distinct rock-types, which are varietal forms of gabbro and peridotite respectively. The one has labradorite as its felspathic element (*e.g.* Coverack in Cornwall and Volpersdorf in Silesia), while the other, besides being usually richer in olivine, has anorthite (*e.g.* Allival in Rum). The former type is found, though rarely, among the Skye gabbros; but the rocks with which we are now concerned, intimately associated with true peridotites, belong to the second type. The felspar, by its optical properties as tested in the thin slices, seems to be always anorthite. In confirmation of this, Prof. Sollas has kindly determined the specific gravity of the felspar from one of our troctolites (S9237) [NG 470 194] by means of his diffusion-column. The figures found were 2.735 to 2.74, with a mean of 2.737, and cleavage-flakes of specific gravity 2.74 gave extinction-angles of 36° and 37°. The rocks are always rich in olivine, and their petrographical as well as geological affinities are clearly with the peridotites, not the gabbros.

Troctolites of this kind occur in some force in Coire Beag and near the foot of An Garbh-choire, and the same type is rather widely distributed in the form of enclosed patches and lumps in the picrites and peridotites and also as streaks and veins traversing those rocks. Anorthite makes up from 40 to 60 *per cent.* of the mass, or sometimes less. The remainder is chiefly fresh olivine, but there may be in addition augite or diallage in quite subordinate quantity. Brown translucent picotite is sometimes a rather conspicuous element. The only noticeable variety among the troctolites arises from a difference — more apparent than real — in the mutual relations of the two principal constituents. In the common type the olivine forms crystals and grains 1/10 to ¼ inch in diameter, set in a framework of felspar (S9236) [NG 470 194]. Sometimes, on the other hand, it is the latter mineral that forms conspicuous crystal-grains, often with partly rounded outlines, up to ¼ inch in diameter. The microscope shows, however, that here also the olivine is of prior crystallisation, for its grains encroach upon the edge of the felspars, and are occasionally enclosed in them (S9237) [NG 470 194], (S9238) [NG 470 200]. The peculiarity is most striking on a weathered face, where the felspars, always in relief, appear like white spherules in a black matrix. Under the microscope this appearance is lost (Plate 18), Fig. 2. An average specimen of the troctolites gave a specific gravity of 3.07. The somewhat similar rocks of Allival in the Isle of Rum are often more felspathic: one of these was found to have a specific gravity 2.88, corresponding with about 72 per cent. of anorthite to 28 of olivine.

In addition to rocks consisting essentially of anorthite and olivine in fairly equal proportion, we find varieties in which olivine preponderates, affording transitions to those peridotites (in the stricter sense) which we have termed anorthite-peridotites. On the other hand the coming in of augite offers connecting links with the picrites. Such variations may be found in what is apparently a single body of rock. This seems to be the case in the laccolite of An Dubh-sgeire on Soay, from which Mr Clough has collected a series of specimens. One from near the middle of the mass is a picrite with rather more felspar and less augite than usual (S9973) [NG 468 141]. Abundant xenoliths in this are of troctolite, composed simply of olivine and felspar in about equal parts (S9975) [NG 468 141]. Near the southern end of the intrusion the matrix of the mass, as Mr Clough remarks, nearly resembles the xenoliths at the other locality. It is indeed an olivine-felspar-rock with only accessory augite (S9976) [NG 467 140], and, while petrographically a troctolite, is presumably a variety of the picrite. Again a specimen from the east side of the mass has for its essential minerals (in order of importance) olivine, felspar, and augite (S9990) [NG 468 141]; and the preponderance of the first-named element brings this rock near to the typical peridotites. This intrusion, though of no great dimensions, thus illustrates the variability characteristic of the rocks of this group, as well as the close relationship existing between the xenoliths and their enclosing matrix.

The remaining rock-type to be noticed is one which for convenience we have termed *norite:* but we may make here a remark similar to that made in the case of the troctolites. The rock in question is not only closely connected with the peridotites as forming part of the Sgùrr Dubh laccolite, but also its mineralogical constitution links it with these rocks and severs it from the types of norite or hypersthenite which occur in some regions (but rarely in Skye) as associates of gabbro. In short, rocks composed essentially of a felspar and a rhombic pyroxene, like the felspar-olivine-rocks, seem to fall most naturally into two divisions, for which it would be useful to have two distinct names. The ultrabasic affinities of our rock are shown petrographically by the preponderance of the ferro-magnesian element, and presumable richness in magnesia, and by the extreme basic nature of the felspar, implying the absence of alkalies. In such a rock we may regard the rhombic pyroxene as substituted for olivine quite as much as for augite.

This type has been found in one locality only,<ref>Very beautiful rocks of this kind occur in Rum, occupying a considerable area to the north of Harris.</ref> on the northern slope of the prominent peak called by climbers Sgùrr a' Coir' an Lochain, which guards the corrie of that name on its western side. It consists essentially of enstatite and anorthite, the former preponderating; while olivine occurs only in subordinate quantity, and diallage, magnetite (or possibly chrome-magnetite), and picotite are minor accessories (Plate 18), Fig. 3. The rhombic pyroxene is colourless in thin slices, and its birefringence weak: it must be referred to enstatite rather than bronzite or hypersthene. The crystals, which are idiomorphic towards the felspar, have a longitudinal striation indicating something of the "schiller" structure, but this is not of a very pronounced kind. Parallel intergrowths of enstatite and diallage are found.

Having noticed the petrographical characters of the principal types met with, we must devote some attention to the fashion in which these types, and varieties of them, are associated together. The most striking feature of the outcrops as seen in the field is their *heterogeneity,* which is carried to such an extreme that in some places it is scarcely possible to take a large hand-specimen consisting of only a single variety of rock. The heterogeneous nature of the mass is displayed chiefly in three ways — viz., in the inter-banding of different kinds of rock, in the occurrence of debris of one kind enclosed in a matrix of another, and in the abundance of veins which are partly of the nature of segregation-veins.

A more or less noticeable *banding* affects the greater part of the rocks composing the several laccolitic masses; but it varies in the degree of its accentuation (Plate 2). Often the alternating bands are merely varieties of picrite differing somewhat in the relative proportions of the constituent minerals. The structure may in this case be almost imperceptible, except where it is revealed by a fluted appearance on a weathered face. The several bands are often not more than an inch or two in width, and are not very sharply divided from one another. It is quite clear that they are not separate injections, but that the structure is due to fluxion in a magma which was heterogeneous at the time of its intrusion. Elsewhere more pronounced differences in composition distinguish successive and alternate bands, more felspathic and more pyroxenic types, both rich in olivine, occurring in intimate association. At many places in An Garbh-choire, in the upper part of Coir' a' Ghrunnda, and elsewhere, bands of pale troctolite are thus associated with the darker picrite; and at other points, as in the vicinity of Allt a' Chaoich, more typical peridotites, *i.e.* rocks composed mainly of olivine, enter into the complex. The alternations occur on a rather large as well as on a small scale, so that in their general aspect on a weathered face the exposures may simulate the bedding as well as the lamination of stratified rocks. The narrower banding is undoubtedly a true flow-structure of the kind already indicated. It is not impossible, on the other hand, that the larger alternations are in part to be explained as distinct injections. Apart from the veins to be noticed below, however, we have found little or no evidence of one rock-type cutting transgressively into or across another; and we infer that, in so far as successive injections are responsible for the phenomena, they followed one another very closely, so that the earlier one was still fluid when the later was forced in beside it. Where an already consolidated rock was invaded by a new accession of molten magma, the former was apt to be broken up, and there resulted not banded but brecciated and xenolithic structures.

Among the most interesting phenomena of banding, and among those certainly due to segregation and fluxion, not to separate intrusions, are seams rich in minerals of the spinellid group. The best example of this, already referred to above, is the dunite in the small glen south of Allt a' Chaoich. Here, along some bands or streaks, picotite becomes a very prominent constituent of the rock; and certain black seams, following the general direction of the banding at this locality, consist simply of picotite in relatively large crystals, with only a very small proportion of interstitial olivine. These seams are really elongated lenticles, not being continued for any considerable distance. They are commonly from ½inch to 1 inch thick, exceptionally 2 or 3 inches. Seams very rich in a black mineral, probably chromite or chrome-magnetite, occur in the upper part of An Garbh-choire and near the head of Coir' a' Ghrunnda; but a spinellid mineral in an almost pure state has been found only in the glen first mentioned. One of the seams composed essentially of picotite (the mineral analysed above) gave the specific gravity 3.78.<ref>Prof. Judd has described an almost pure picotite-rock (sp. gr. 3.90), which is stated to occur as a dyke in a mass of serpentine at Bingera, in New South Wales (*Min. Mag.,* vol. xi., p. 63: 1895). This would imply that a rock-magma may exist with the composition of picotite. The circumstances, however, lead to a suspicion that this "dyke" may really be a contemporaneous seam in a peridotite, since serpentinised, and such suspicion is perhaps strengthened by the occurrence of another "dyke" composed of grossularite.</ref>

That phenomena of banding in the Tertiary peridotites of Britain are not confined to Skye, is evident from the accounts which have been published of some of these rocks in the neighbouring Isle of Rum. It appears even that seams consisting of spinellid minerals are not wanting in the latter island. Heddle describes his chromite from Askival, already referred to, as forming "a vein about one-quarter of an inch in thickness, embedded in a granular brown belt of rock, in augitic trap" He states that the brown belt was apparently chiefly olivine, and doubtless the "augitic trap" was in reality a peridotite, for such, as remarked by Professor Judd, is the nature of Macculloch's "augite rock" in Rum.

The banded arrangement of the peridotite group is not often accompanied by any very noticeable fluxional orientation of the crystals in the rocks themselves; but this is sometimes found, and in places near Allt a' Chaoich a decided parallelism of the crystals imparts a certain fissile character to the rocks. In the "troctolites" of Rum, mentioned above, this parallel orientation is sometimes much more highly developed.

The inclination of the banding varies considerably in different places, as is well seen in the Sgùrr Dubh laccolite. At the western border or base, as exposed near Loch Coir' a' Ghrunnda, the dip is easterly at 30° or less. Farther eastward the strike of the banding gradually changes, until along An Garbh-choire it is not very different from E.–W. The dips here are often at very high angles, or actually vertical, but lower angles are observed in some parts, always towards some point of north. In Coire Beag and near Allt a' Chaoich the banding dips northward at angles of 30° to 60°.

Everywhere the inclination of the structure corresponds in direction with that of the mass as a whole. Probably it corresponds approximately also as regards the angle of dip, though it is not necessary to suppose an accurate parallelism with the base of the laccolite at every place.<ref>It will be shown below that banding in the gabbro laccolite of the Cuillins may be inclined at a considerable angle to the base of the laccolite itself (see (Figure 18), below).</ref> The smaller laccolitic intrusions are much less disturbed than the large one, and here the banding has a low and regular inclination. In the two Gars-bheinn intrusions it dips northward at about 10°. The dyke-feeders do not show any noteworthy banding.

Equally important with the prevalent banding, as impressing on these plutonic rocks of the peridotite group a highly peculiar aspect in the field, is the *xenolithic*<ref>The term xenolith was first used by Sollas to denote a fragment of extraneous origin enclosed in an igneous rock. It corresponds with "enclave" as used by Lacroix and others.</ref>*structure.* This affects the great majority of the rocks, and is found in the dyke-feeders as well as in the laccolites themselves. The phenomenon consists simply in the occurrence of numerous, and sometimes crowded, inclusions of one rock in a matrix of a different rock, both inclusions and matrix being of types belonging to the peridotite group in the sense here understood. As in the case of the banding, the difference may be more or less pronounced. In some cases it is slight, xenoliths and matrix, *e.g.,* being of not very different varieties of picrite; and the heterogeneous nature of the mass may be betrayed only by the curiously pitted aspect of a weathered surface. In other cases the two rocks involved may differ widely, a common appearance on the weathered exposures being that of lumps of pale troctolite standing prominently out from a matrix of picrite or peridotite. Troctolite and picrite, the latter often banded, are the most frequent types occurring as xenoliths. They are of rounded to sub-angular shape, and commonly range in diameter from an inch to a foot. A place where the phenomena can be studied in rich variety is the lower part of An Garbh-choire (*see* (Plate 3) and (Plate 4).

Two explanations seem to be a *priori* possible. An earlier rock, already consolidated, may have been broken up prior to, or in connection with, the intrusion of a new accession of magma, which then penetrated the interstices and enveloped the fragments; or the xenoliths may represent the debris of a rock previously solidified at some lower level and carried up in the form of fragments in a magma derived from the same or a neighbouring source. The fact that the xenoliths are usually much inferior in bulk to the enclosing matrix would seem to point to the latter explanation, as would also the rounded form of the xenoliths, indicative of a certain amount of corrosion by the magma. In some cases, however, there are circumstances which are more easily understood on the former hypothesis. The occurrence of strong banding in the xenoliths in some places is one such point; for, while this structure is highly characteristic of these laccolitic intrusions, it is scarcely to be expected in rocks consolidated in some deep-seated reservoir. Again, although as a rule the xenoliths show no appearance of fitting together (having indeed more or less rounded outlines), and those which exhibit banding have not a common orientation, there are exceptions to this rule. In some places the xenoliths more than equal the matrix in bulk, and, although displaced and partly rotated, they present unmistakably the appearance of a rock broken up in place and injected in the interstices by a later magma (Plate 4). The relations are indeed not unlike those of the peridotite and gabbro near Allt a' Chaoich, as described above (p. 64).

The two suppositions which we have stated as alternatives are not mutually exclusive, and the difference between them is perhaps less absolute than appears from the terms in which they are enunciated. If we are at liberty to imagine that the magma which the xenoliths represent in a given case was in part intruded as a member of the laccolite and there consolidated, in part solidified in the parent-reservoir or in the connecting conduit, and that the later intrusion was derived from the same source, we find place for both suggested explanations. In any case we must believe that the two rocks involved were of closely cognate origin, and were divided by no considerable interval of time. A high temperature in the earlier consolidated rock at the time when the later magma came in contact with it would promote a certain amount of solution and absorption of the former by the latter, of which we have evidence in the rounded form of the xenoliths.

A feature less widely developed than the banded and xenolithic structures, but still very frequently observed among our peridotites, is the occurrence of *segregation-veins* traversing the dominant rock in a given place. They are commonly about an inch or two in width, with the ramifying and irregularly tapering form characteristic of such veins in plutonic rocks of all kinds. They have too the usual relation to the dominant rock as regards composition, being invariably less basic, and in particular more felspathic: in most places they are of the troctolite type. In texture they are somewhat coarser than the rock which they traverse. In these respects they compare with the common pegmatite veins in granites and corresponding veins in other plutonic rocks, usually regarded as representing the final injection of residual magma, always more acid in composition than the general body of the rock. They are to be distinguished from ordinary veins of intrusion, with more sharply defined edges, which are also common in some places, and do not hold the same relation to the rock which they traverse (Plate 4).

In their extreme variability and heterogeneity, in the prevalence of banded structures, in the occurrence of seams rich in chrome-bearing minerals, and in other respects, touching both their manner of occurrence and their petrographical characteristics, our rocks illustrate many of the observations of Vogt<ref>Beiträge zur genetischen Classification der… Erzvorkommen (first part), *Zeits. für prakt. Geol.,* vol. ii., pp. 381–399; 1894,</ref> in his study of peridotites and of the genesis of chrome-iron-ores; and the occurrences in the Cuillins present indeed a fairly close parallel to those of Hestmando-Feld, in the north of Norway, which that geologist has described as a type. We shall see that there are also many points of resemblance between the peridotites of the Cuillins and the gabbros of the same district, to be described next. These latter show considerable heterogeneity within a single intrusive body, but it is not so prevalent, nor is it carried to such extremes, as in the peridotites.

A point of some interest in connection with the ultrabasic intrusions relates to the *nature of their contact* with the rocks among which they were intruded. The several masses which occur in the Cuillins, enveloped as they are by_the later gabbro, afford no information under this head. The lower of the small laccolites on the slope of Gars-bheinn does indeed seem to impinge at its under surface upon the basaltic lavas, but no exposures of the junction have been observed. The intrusion of An Dubh-sgeire in Soay, however, occurring among Torridonian sandstones, presents in places visible contacts with the sedimentary rocks, and specimens have been examined. In one (S9974) [NG 468 141], taken from the upper surface, near the middle of the reef, the igneous rock, normally an average picrite, becomes fine-textured at the edge, and the dividing line between it and the metamorphosed gritty rock is not sharply defined to the eye. The modification of the picrite extends inward for about half an inch from what may be taken as the surface of junction; and the microscope shows that this modification is not of the nature of an ordinary chilled selvage, but is due to the igneous rock having, to that depth, enclosed foreign material, which has been also in some measure absorbed into the ultrabasic magma and has so affected the composition of the edge of the laccolite. Quartz-grains are present abundantly in this marginal band, and are always deeply corroded, as is evident from their irregular shapes and ill-defined boundaries. Between the derived grains of quartz and the minerals proper to the picrite there is always interposed a brownish substance with confused structure, often imperfectly spherulitic, due to mutual reactions between the ultrabasic magma and the foreign matter (quartz with some alkali-felspar). This substance encloses the quartz-grains, and penetrates to some small distance among the olivine, anorthite, and augite of the picrite. It. resembles in appearance some altered pitchstones, and has probably been in part vitreous, but later changes have obscured its true nature. Plentifully scattered through the brownish interstitial material are very slender felspar rods, about 1/100 inch long, which are not anorthite but some less basic variety. In places there are pseudomorphs of a yellow serpentinous substance replacing idiomorphic crystals of relatively large size — 1/10 inch or more in length. They have not the shape of olivine, but probably represent a rhombic pyroxene. This latter mineral is not one proper to the picrite, and the mode of occurrence of the pseudomorphs in the slice indicates that the mineral which they replace was connected with the special reactions in question. A mineral of the hypersthene group might indeed be expected from a peridotic magma locally acidified by absorbing extraneous silica.

In addition to the felspar-microlites, the brownish quasi-vitreous areas enclose others in the form of little dark rods, which seem to represent some ferro-magnesian mineral destroyed. These are better seen in slices of other contact-specimens. In these the brown substance is in places reduced in amount while the enclosed crystallitic growths become more abundant and closely packed. They also increase in size, being sometimes as much as 1/40 or 1/30 inch in length. They are mostly slender felspar crystals, tending to fan-like and sheaf-like groupings; and their constantly low extinction-angles prove that they are alkali-felspars, probably both orthoclase and oligoclase, the alkalies being doubtless derived from the abundant felspathic grains in the contiguous Torridonian rock (S10042) [NG 468 142]. With the felspar rods there occur abundantly others, green and pleochroic, which are probably to be regarded as pseudomorphs after hypersthene.

Finally, a few remarks should be made relative to the *alteration,* of the peridotites due to secondary changes. Incipient decomposition of the constituent minerals is found, as a rule, only in very slight degree, and most of the peridotites are entirely unchanged. In thin slices the felspar (when present) is perfectly clear, the pyroxene gives no clear evidence of secondary alteration, and even the olivine, one of the most susceptible of the rock-forming minerals, usually shows little or nothing of the familiar serpen-tinous transformation. The only rocks which are serpentinised in any important degree are those which have suffered crushing. This has given rise to a system of sub-parallel cracks, which are marked by narrow veinlets of colourless or yellowish serpentine (black in the hand-specimens) (S9232) [NG 461 202], (S9234) [NG 458 203]. There is a considerable amount of secondary magnetite-dust, mostly collected in the form of dense strings along the median line of each serpentine veinlet. It is evident that the earliest change in the olivine has been the separation of much of the iron in the form of oxide. At a later stage this may be in part reabsorbed into the serpentine, giving a yellowish colouration.

Equally interesting is the question of the *thermal metamorphism* of the peridotites by the later intrusions of gabbro, but on this point we have not gathered much information. A slice has been prepared, however, from one of the detached blocks of peridotite involved in the gabbro near the shore of Loch Scavaig, and this shows a micro-structure quite different from that of the normal rocks (S9239) [NG 488 193]. Mineralogically the rock may be termed a picrite, but it consists mainly of a granulitic aggregate of olivine and felspar, in which the former occurs as rounded granules and the latter with allotriomorphic habit. There are even little areas free, or almost free, from olivine, recalling the "ocellar" structure common in the "pyroxene-granulites" of German petrographers. It seems not improbable, though by no means proved, that this structure is connected with recrystallisation in the process of thermal metamorphism. The diallage, however, which is the third but subordinate constituent, presents the ordinary characters of that mineral. In view of the comparatively simple mineralogical constitution of the peridotites, it is not to be expected that thermal metamorphism will give rise to important recombinations.

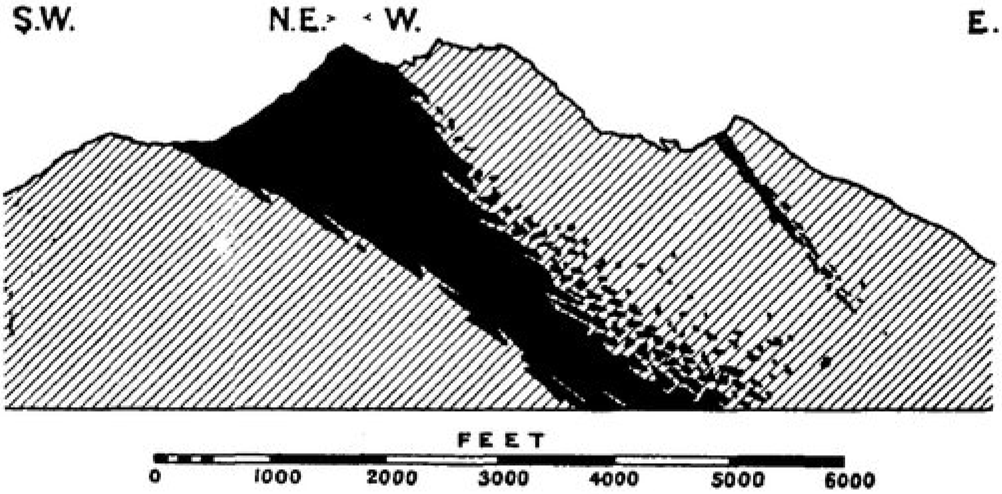

Fig. 10.—Section along the Sgùrr Dubh ridge, showing the principal laccolitic mass of peridotite and a smaller one to the east, and representing diagrammatically the partial destruction of the peridotite by the gabbro magma in which it became enveloped.

(Figure 10) Section along the Sgùrr Dubh ridge, showing the principal laccolitic mass of peridotite and a smaller one to the east, and representing diagrammatically the partial destruction of the peridotite by the gabbro magma in which it became enveloped.

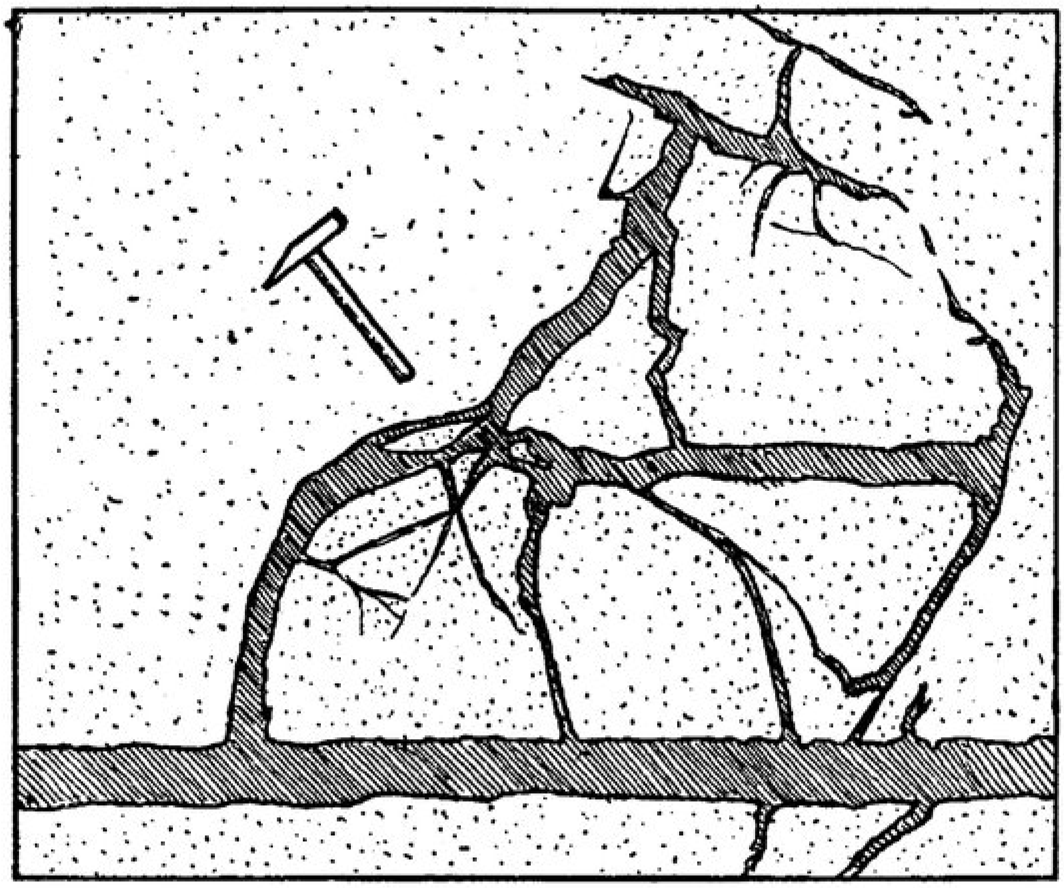

Fig. 11.—Dykes or veins of gabbro traversing the peridotite group, in glen south of Allt a' Chaoich, Loch Scavaig: seen in ground-plan.

(Figure 11) Dykes or veins of gabbro traversing the peridotite group, in glen south of Allt a' Chaoich, Loch Scavaig: seen in ground-plan.

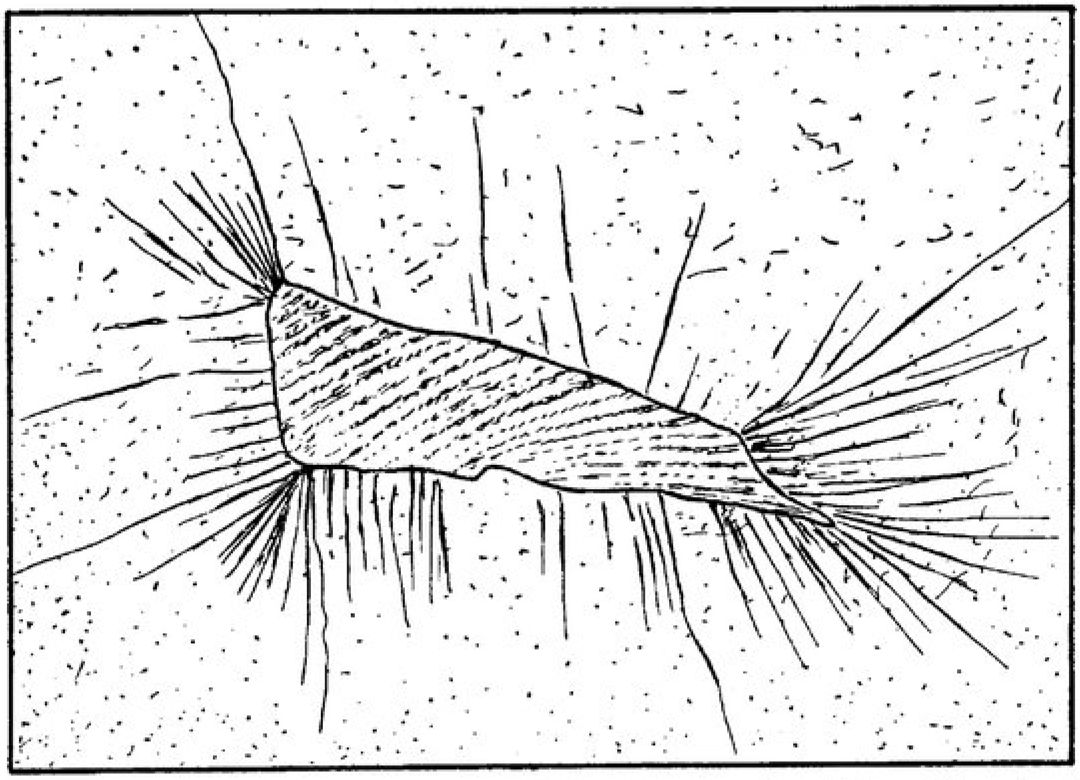

Fig. 12.—Block of banded peridotite, 7 feet long, enclosed in gabbro, in glen south of Allt a' Chaoich, Loch Scavaig: seen in ground-plan. The gabbro is traversed by numerous fissures radiating from the enclosed block.

(Figure 12) Block of banded peridotite, 7 feet long, enclosed in gabbro, in glen south of Allt a' Chaoich, Loch Scavaig: seen in ground-plan. The gabbro is traversed by numerous fissures radiating from the enclosed block.

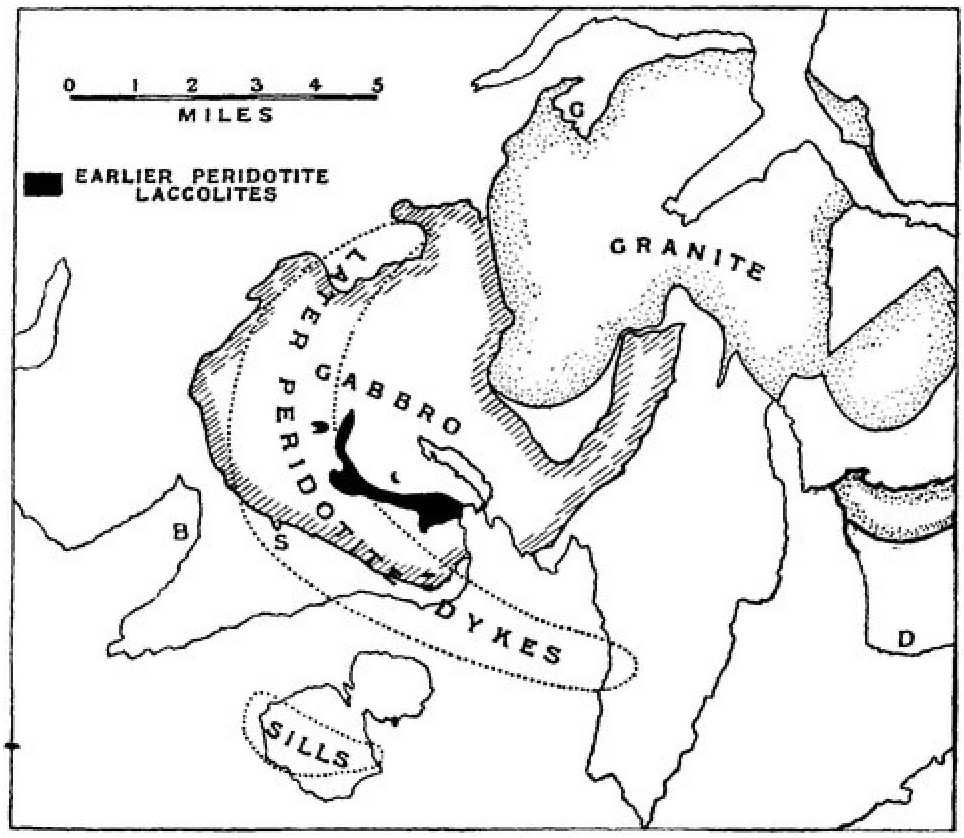

FIG. 75.—Sketch-Map to illustrate the distribution of the peridotites, older and younger. Scale, ¼ inch to a mile.

The older plutonic laccolites of the south-western Cuillins (with one in the Isle of Soay) are marked in black.

The large crescentic area enclosed by a dotted boundary embraces the younger peridotite dykes of the Cuillins and the Strathaird peninsula. The only peridotite dykes outside this area are a group on the coast of Loch Brittle at B, but peridotite sills occur in Soay as indicated. The boss of An Sgùman is situated at the point marked S, and the intrusions of Glamaig and Carn Dearg at G and D, on the prolongations of the two horns of the crescent.

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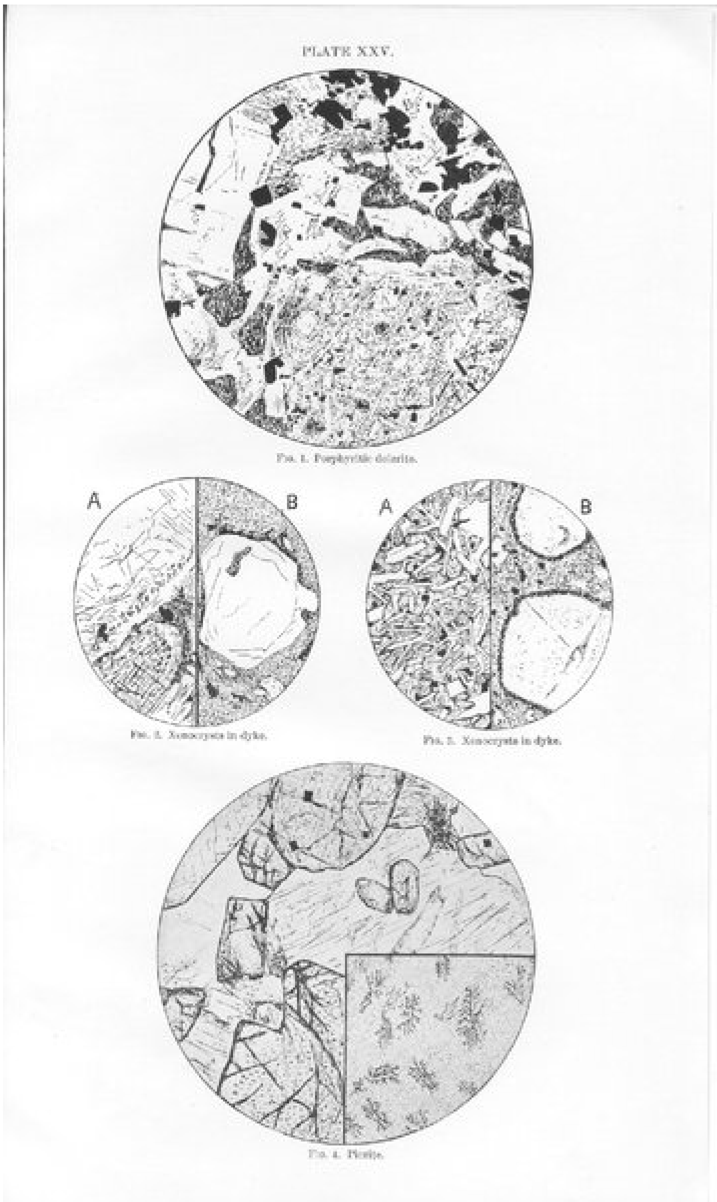


(Plate 25) Fig. 1. (S9372) [NG 628 285] × 30. Porphyritic Dolerite, dyke 400 yards N.W. by N. of Scalpay House. The lower part of the figure shows part of one of the circular felspathic areas which represent vesicles filled by the oozing in of the residual magma. See p. 331. Fig. 2; × 20. Xenoliths in basic dykes. A. (S7483) [NG 526 194]. Edge of ga,bbro xenolith in dyke in Abhuinn nan Leac, Strathaird; showing the earliest stage of breaking up by the formation of numerous fissures; also the development of secondary inclusions in both felspar and augite. See pp. 355, 361. B. (S6716) [NG 633 208]. Detached quartz-grain from granite xenolith in dyke on ridge N. of Ben Suardal, near Broadford; showing the earliest stage of breaking up by the formation of fissures, which here tend to run parallel to the outline; also incipient corrosion. See p. 356. FIG, 3. × 20. Basic dyke carrying granite xenoliths, on shore N.E. of Corry Lodge, Broadford. See p. 357. A. (S6719) [NG 644 243]. The normal dolerite, where free from foreign material. B. (S6720) [NG 644 243]. Portion enclosing abundant debris of granite, of which two detached quartz grains are shown, eack with its corrosion-border of granular augite. The matrix, partly obscured by alteration, is of fine texture and of much less basic composition than the normal dolerite. Fig. 4. (S8723) [NG 436 182]. Picrite, An Sgùman. A. (occupying three quadrants); × 30. Showing olivine, augite, anorthite, etc. The dendritic inclusions of magnetite in the olivine are conspicuous in the large crystal in the lower left-hand quadrant: in the crystal at the top of the figure they are cut at right angles to their plane, and so appear like rods. See p. 381. B. (lower right-hand quadrant); × 110. Showing the dendritic inclusions more highly magnified. See pp. 68, 69, 381.

FIG. 14.—[9234] × 20. Peridotite, S.E. slope of Sgùrr Dubh na Dabheinn: chiefly of olivine (showing incipientserpentinisation), with some diallage and felspar (to the right) and opaque octahedra probably of chrome-magnetite.

(Figure 14) (S9234) [NG 458 203] × 20. Peridotite, S.E. slope of Sgùrr Dubh na Dabheinn: chiefly of olivine (showing incipient serpentinisation), with some diallage and felspar (to the right) and opaque octahedra probably of chrome-magnetite.

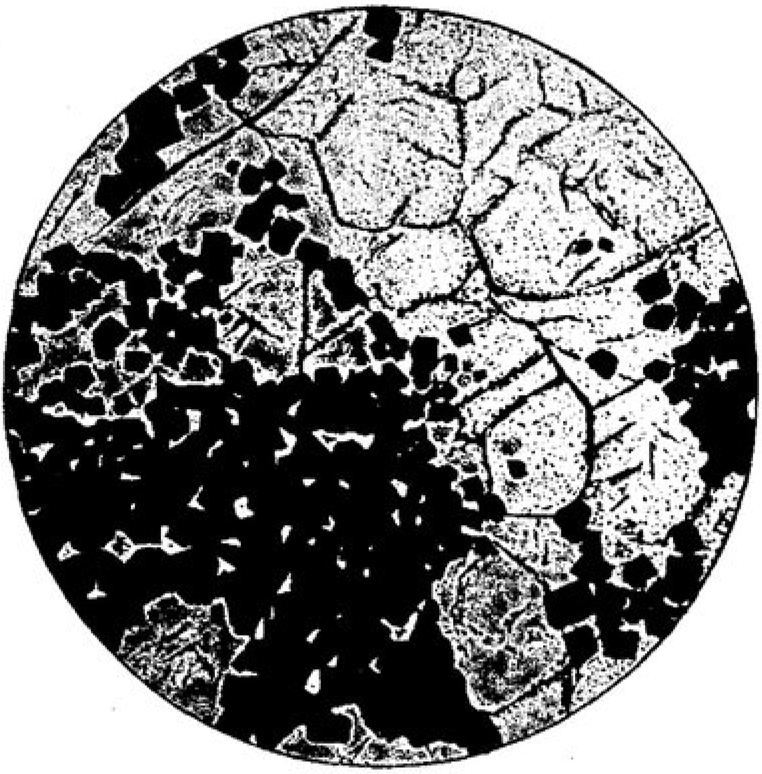
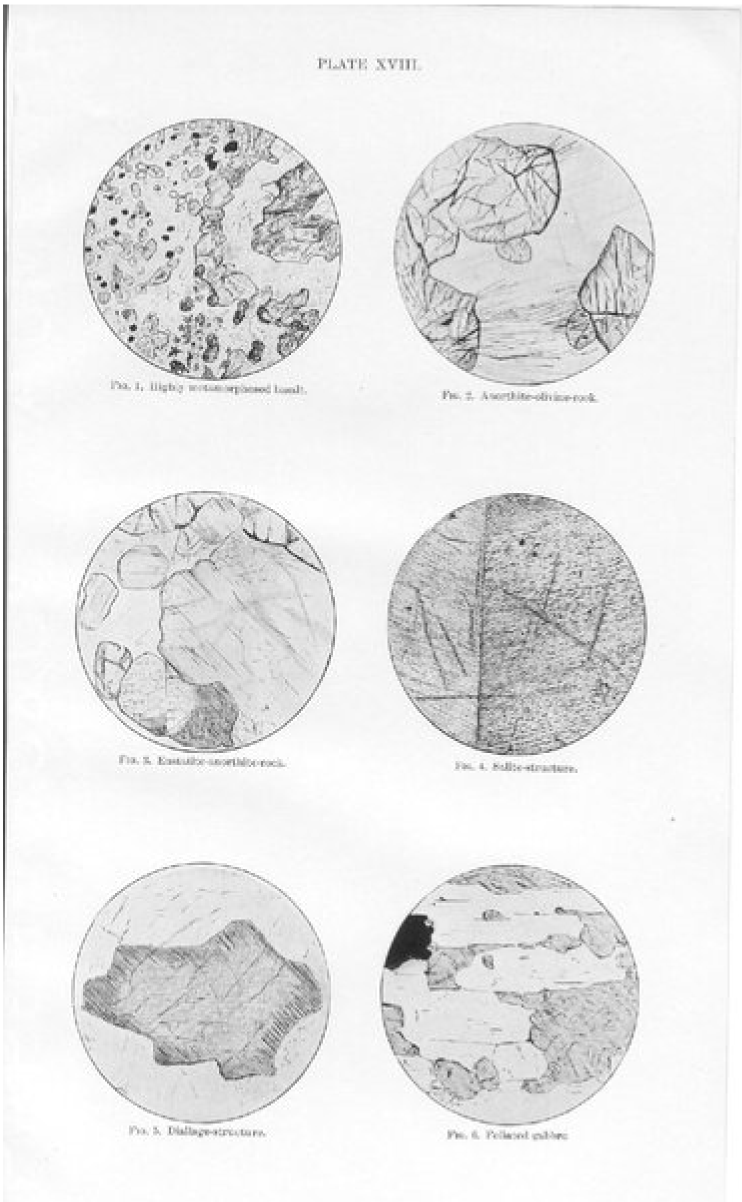
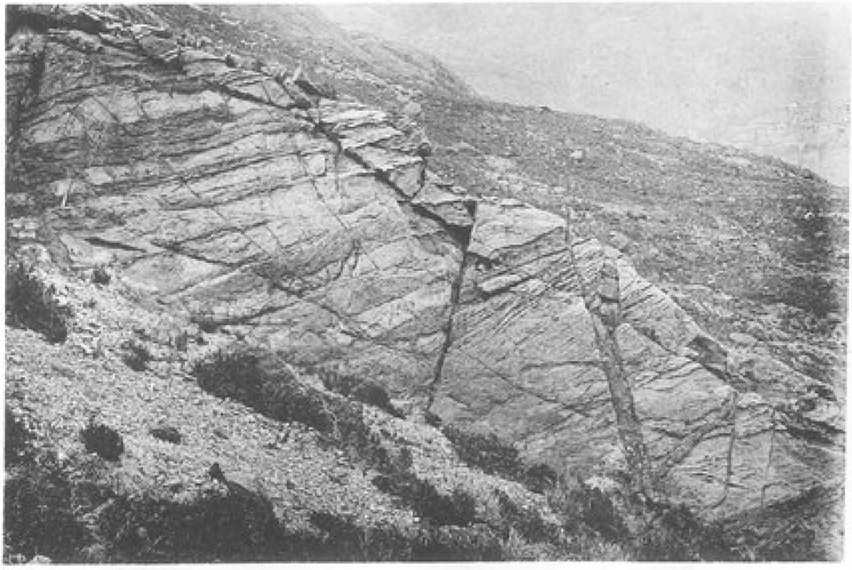


FIG. 13.—[9228] × 20. Dunite, rich in picotite, from the banded peridotites in the glen a little S. of Allt a' Chaoich, Loch Scavaig: consists wholly of fresh olivine and octahedra of picotite.

(Figure 13) (S9228) [NG 480 195] × 20. Dunite, rich in picotite, from the banded peridotites in the glen a little S. of Allt a' Chaoich, Loch Scavaig: consists wholly of fresh olivine and octahedra of picotite.



(Plate 18) Fig 1. (S8731) [NG 437 191] × 20. Highly metamorphosed amygdaloidal basalt, near gabbro, N.E. of An Sgùman. The rock is completely reconstituted, and presents the appearance of some so-called pyroxene-granulites. The figure shows part of an amygdule, now consisting of alternate zones of augite and felspar. See pp. 52, 53. Fig. 2. (S9238) [NG 470 200] × 20. A northite-olivine rock (troctolite) in the peridotite group, lower part of An Garbh-choire: consisting simply of olivine and anorthite, the latter often traversed by numerous fine fissures, which radiate from the olivine grains. See p. 73. Fig. 3. (S8705) [NG 456 219] × 20. Enstatite-anorthite-rock (norite) in the peridotite group, N. of Sgùrr a' Coir' an Lochain, near Coruisk. The chief constituents are enstatite and anorthite, the latter interstitial to the former. At the bottom of the figure is a crystal, half of enstatite, half of diallage, and immediately to the left of this a crystal-grain of olivine. See p. 74. Fig. 4. (S7462) [NG 520 214] × 100. Augite of gabbro on the W. slope of Blath-bheinn: showing the basal striation, accentuated by a fine "schiller" structure, and combined with the orthopinacoidal twin to give the "herring-bone" arrangement. See p. 109. Fig. 5. × 10. Augite of gabbro at head of Loch Scavaig: showing the prismatic cleavage and diallage - structure. The latter, parallel to the orthopinacoid, is developed only in the marginal portion of the crystal. See p. 109. Fig. 6. (S7849) [NG 49 22] × 10. Foliated gabbro in the banded part of the group, Druim an Eidhne: showing a parallel orientation of the component crystals. See p. 119.



Banded structure in the peridotite group, An Garbh-choire.

(Plate 2) Banded structure in the peridotite group, An Garbh-choire.

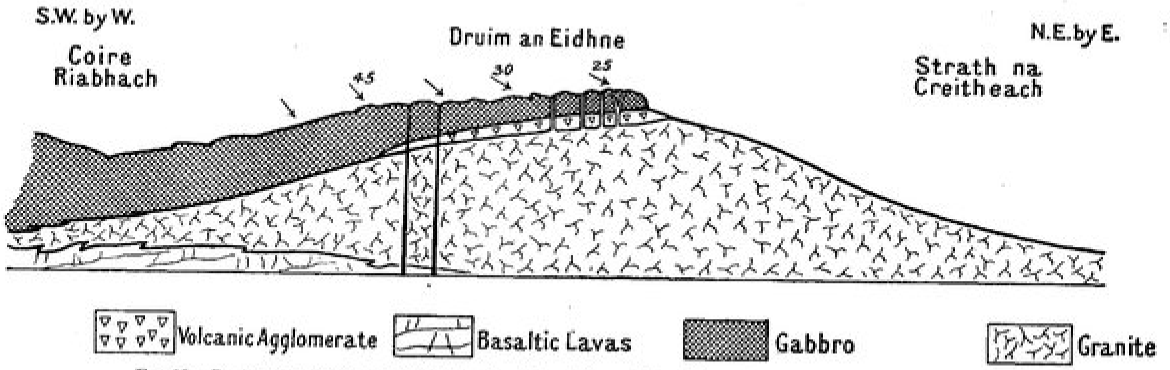
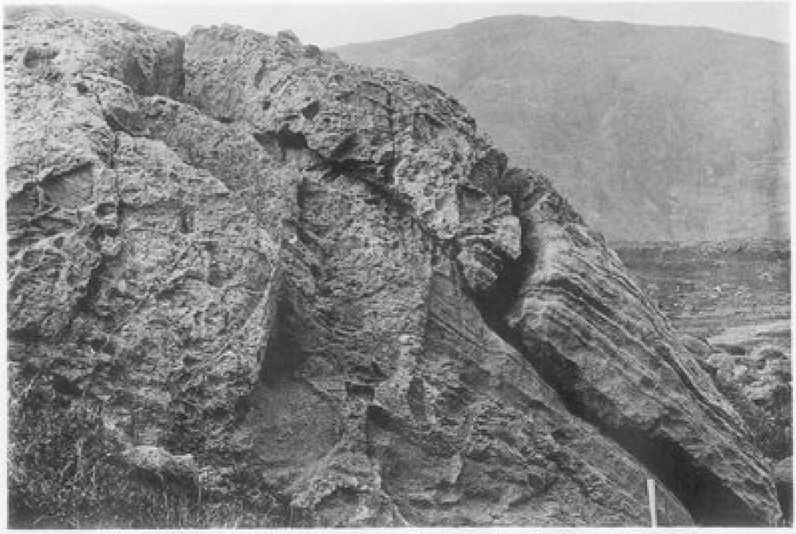


FIG. 18.—Section across Druim an Eidhne, to show the relations of the gabbro and granite: scale, 6 inches to a mile. The arrows mark the inclination of the banding in the gabbro at this place.

(Figure 18) Section across Druim an Eidhne, to show the relations of the gabbro and granite: scale, 6 inches to a mile. The arrows mark the inclination of the banding in the gabbro at this place.

PLATE III.



Brecciated appearance, due to xenolithic structure, in the peridotite group, An Garbh-choire.

(Plate 3) Brecciated appearance, due to xenolithic structure, in the peridotite group, An Garbh-choire.

PLATE IV.

Veined structure in the peridotite group, An Garbh-choire.

(Plate 4) Veined structure in the peridotite group, An Garhh-choire.