Chapter 18 Basic dykes: general petrography

Our petrographical account of the basic dykes of Skye will be based on the examination of hand-specimens (including determinations of specific gravity) and microscopical preparations. Knowledge of the chemical composition of the dykes is limited at present to four analyses: one (of a tachlytic selvage) quoted from Dr Heddle; another made for this memoir by Dr Pollard; and two by Mr T. Baker, communicated by Professor Lebour. Possibly more data from the chemical side might assist materially in classifying the rocks and ultimately in establishing their mutual relations to one another and to other basic intrusions in the form of sills and sheets.

The chief difficulty in the way of dividing the basic dykes into distinct groups belonging to different epochs arises from the fact that certain petrographical types, and these among the commonest, have recurred at more than one epoch. It is easy to show, for instance, that certain dykes are cut off by the granite, while others cut that rock; but some of the former are indistinguishable lithologically from some of the latter in the field, and offer no certain criteria for discrimination even on a microscopic examination. Hence in places not near the granite, and where no other sufficient test is applicable, it is often impossible to separate pre-granitic from post-granitic dykes. Such difficulties arise especially in the case of the non-porphyritic dolerites, rocks which are extremely common and widely distributed. The presence or absence of olivine, except in certain types where the mineral is very abundant, does not seem to be a character of much diagnostic value: many of the rocks hover on the line between "olivine-bearing" and "olivine-free".

The principal criteria for determining the relative ages of the dykes are their direct relations to one another where they come into juxtaposition, their relations to other igneous rocks of Tertiary age in the neighbourhood, and their relation to faults and other tectonic features of the district where they occur. Owing to the very general parallelism of direction of dykes of all ages in the country, actual intersections of one dyke by another are by no means often seen.<ref>Certain groups of dykes in the Cuillin district must be excepted from this statement for reasons already explained.</ref> When two or more different dykes run side by side, so as to constitute what we have called a double or a multiple dyke, the nature of the contacts will sometimes afford a clue to the relative ages of the several members; but such indications, from chilled margins, etc., are not always free from ambiguity.

The principal igneous intrusions, other than dykes, which serve as standards of reference, and afford where they occur a relative scale of time, are:

(i) the gabbros

(ii) the granites

(iii) the basic sills of the great group

(iv) the "inclined sheets" of basic rocks, intersecting the gabbro of the Cuillins, to be described in Chapter 21

Of these the third have the most extended distribution. It is to be remarked, however, that there are no dykes referable to the brief interval between the gabbros and the granites, and none are certainly known (with the probable exception of certain composite dykes) intervening between the granites and the great group of sills. Practically, therefore, the first three standard groups mentioned only enable us (where they are represented) to distinguish the dykes belonging to the volcanic phase of activity from those belonging to the phase of minor intrusions. To the former category belong the dyke-feeders of the fissure-eruptions; to the latter (apart from possible feeders of the basic sills) belong the majority of the dykes of the region, in general constituting independent intrusive bodies. Of these latter, the greater part are older than the inclined sheets included under (iv.), but some are younger.

The value of the four sets of intrusions just enumerated for our present purpose lies in the fact that the members of each set constitute a natural group belonging to one epoch. It is nevertheless necessary to remember that the members of such a group are not in the strict sense contemporaneous with another. Thus the fact that a given dyke is seen to cut one or more of the basic sills is not in itself sufficient to prove that the dyke is younger than the sill-epoch: it may be the feeder of a somewhat later sill at a higher level. A like remark applies to the inclined sheets, and also to the basic lavas.

One of the strongest reasons for considering the majority of the dykes younger than the basic sills is derived from the relation of these various intrusions to faults. It appears that the faults of Tertiary age in the island constantly affect the sills. On the other hand, few of the dykes are displaced or crushed by faults, and some of them have followed pre-existing fault-planes. In so far as the faulting can be referred to a definite epoch, this reasoning applies to dykes even at a distance from any basic sills. Allowance must of course be made for the fact that a small fault with nearly vertical 'displacement would occasion but little visible disturbance of a nearly vertical dyke.

In the basaltic country the general uniformity of lithological characters among the lavas, and also among the sills, makes faulting often difficult to verify. In the Broadford district and in Sleat, where the stratified formations afford well-marked geological horizons, the case is different. Mr Clough writes: "Most of the faults in the district appear to be older than the dykes; but the directions of many of them are not noticeably different from the general direction of the dykes, and so the existence of these has not tended to divert the dykes out of their ordinary paths. Many of the N.W. and N.N.W. dykes occur along faults which effect considerable displacements in the rocks at their sides. This is particularly noticeable along the junctions of the Secondary and Torridonian rocks, and of the Applecross and Kinloch divisions of these latter rocks. But both near these junctions and elsewhere it is quite rare to find dykes which are themselves crushed or faulted. It is perhaps desirable to mention a few exceptional instances. Rather more than three-quarters of a mile N.E. of Kinloch a N.E. fault breaks through a N.W. dyke and displaces it slightly: in the line of fault there is in one place another uncrushed dyke. About a mile slightly W. of N. of Kinloch a dyke running slightly W. of N. is partly crushed in a line parallel to its sides: the dyke is in a line of fault with considerable displacement, and in view of its somewhat unusual direction it appears probable that prior to the intrusion of the dyke there was a crush-band along this line of which the dyke took advantage. On the coast rather more than a quarter of a mile N.E. of Armadale Castle a N.N.W. dyke is much crushed and slicken-sided along various lines, some of which are nearly horizontal".

As already stated, we have not found that the hade of the dykes gives any trustworthy information as to whether they are older or younger than the tilting of the plateaux. The earliest dykes — those at least which were contemporaneous with the lavas — have presumably shared in the tilting; but the fact that some dykes with marked hade are certainly later than some which are vertical shows that some other factor has to be reckoned with.

In so far as the dykes can be divided into natural groups with distinctive petrographical characters, such that the members of the same group can be referred confidently to the same epoch, we are justified in collating the evidence derived from different members of such a group to deduce the relative age of the group as a whole. If, for instance, certain dykes in one place are demonstrably later than the basic sills, and other dykes of the same group in another place demonstrably earlier than the "inclined sheets", we may infer that the group belongs to some part of the interval between the epoch of the basic. sills and the epoch of the inclined sheets. The application of such reasoning is, however, limited in important cases by the impracticability of discriminating petrographically groups which belong to different epochs.

Although, for reasons sufficiently set forth, we cannot in our petrographical description of the basic dykes follow a chronological order, we may conveniently take first those which belong demonstrably to an early epoch. To this end we put together all the dykes which are clearly seen to be cut off by the granite intrusions; a considerable number of these have been examined, more especially in the district between Broadford and Torran. Dykes of the same general type are found in many other places, and some of these doubtless belong to the same epoch but others are clearly younger, and we accordingly confine ourselves here to the area specified, *i.e.* the neighbourhood of the eastern Red Hills and especially of Beinn an Dubhaich.

These *pre-granitic basic dykes* are decidedly less regular in their 'behaviour than the generality of the Skye dykes. They depart more frequently from the normal direction, and they never seem to be very persistent, often dying out in a short distance or leaping aside to resume a parallel course on another line. A noticeable hade from the vertical is much commoner here than in other groups of dykes. The width is usually small, though in some instances it reaches 20 feet or even 50 feet, but not for any great distance. Chilled edges seem to be characteristic of this set of dykes, though by no means confined to them: an amygdaloidal character, on the other hand, is rare.

Petrographically almost all these earlier dykes examined fall under one general head, though with variations in coarseness or fineness of texture, which are related to the size of the dyke and sometimes also to the distance of the specimen from the cooling surface. The rocks may be named diabase, dolerite, or basalt according to texture, but the micro-structure is usually the same for all, viz. the ophitic or occasionally the sub-ophitic. Although we have no chemical analyses, it is evident that the rocks are of thoroughly basic composition. The specific gravity is usually more than 3, ten specimens giving a mean of 3.03. These, however, include some which have been more or less metamorphosed by the granite, a process involving a slight increase of density in cases where it has been tested. There are certain dykes of less basic composition than the rest and with lower specific gravity. Some of these are apparently normal, but others have been modified by taking up xenolithic material, in a manner to be described in a later chapter.

The ordinary varieties consist of labradorite, augite, and magnetite, with a little apatite but not olivine. The labradorite varies somewhat in composition, and the crystals have sometimes zonary banding, but the dominant kind gives extinction-angles up to about 35° in symmetrically cut sections. The light brown ophitic augite is probably rich in iron, for it gives rise to clotted patches of magnetite when it becomes chloritised. Only in the coarsest variety of rock is a partial diallagic structure found (S7061) [NG 614 204]. Original magnetite is usually rather abundant in these rocks, and we may perhaps infer that they are rich in iron-oxides, but not in magnesia.

The *metamorphism of the early basic dykes* by the granite is well observed round the Beinn an Dubhaich mass. Interesting examples of this change may be seen near Kilchrist Old Manse,<ref> The locality most easily found is a little S.W. of the footpath to Boreraig, where it is crossed by a wall, south of the Glebe. Here a large dyke intersecting the limestone is cut off and metamorphosed by the granite. Specimens taken at 9 or 10 feet and at 2 feet from the granite show different grades of metamorphism.</ref> near the Marble Quarries, beside Allt an Inbhire, and at other places. The metamorphism is specially well marked where portions of the dykes have become detached and enveloped in the granite: this may be seen near the shore south of Torran, as noticed by Sir A. Geikie,<ref>*Quart. Journ. Geol. Soc.,* vol. lii., p. 382; 1896.</ref> and at one or two spots in the valley of Allt Leth Slighe.

The general character of the transformation is much like what has been described in the basic lavas, and a summary account will therefore be sufficient. The most conspicuous change is seen in the augite, which is converted usually into hornblende. This mineral is often in patchy, rather fibrous aggregates, but passes finally into crystal-grains and plates, the yellowish-green colour at the same time becoming deeper and browner. Some part of the hornblende must come from chloritic alteration-products of the augite, for it is sometimes found in little veins traversing the felspars.<ref>See Harker, *Petrology for Students,* 3rd ed., fig. 74; 1902.</ref> In the vicinity of the magnetite grains brown mica often takes the place of the hornblende. The felspar of the rock is not in general recrystallised, but it is partly freed from its inclusions, and so appears clearer and fresher. Whether the opaque iron-ore is to any extent recrystallised it is not easy to decide, but the little granules seem in some cases to have drawn together into more compact grains. In hand-specimens these metamorphosed dykes are dark, dense, crystalline rocks. Three specimens gave specific gravities 3.02, 3.05, 3.08. An exceptional specimen from a 50-ft dyke on the south side of the granite, east of Allt an Inbhire, gave a specific gravity 2.85; but this has evidently had its composition considerably modified (prior to metamorphism) by taking up foreign material: it encloses numerous grains of quartz. It shows, however, the same changes as the other examples. In addition, it has small amygdules, once doubtless lined with a chloritic mineral and filled with calcite. They now consist of granular pale-green hornblende with a patch of recrystallised calcite in the centre (S7060) [NG 616 199].

As might be anticipated, no changes comparable in degree with those just described are found where the basic dykes have been invaded by the later intrusions of small volume — dykes, sills, and sheets. The only noticeable change which seems probably due to the metamorphic effect of these minor intrusions is a partial epidotisation of earlier basic dykes intersected by them. Epidote is a mineral well known as a product of thermal metamorphism, especially in the less advanced stages, though of course it may also originate in quite different circumstances. Mr Clough has noted in several places a production of epidote in basic dykes and sills where they are intersected by later intrusions, and regarded it as a metamorphic effect. He has not found it in the Tertiary dykes to the east, south-east, or south of the Broadford and Beinn Suardal area.

We notice next the *solitary dykes of coarse diabase,* which occur only in small number, but are widely distributed. By the epithet "solitary" we mean to express that they occur singly, or sometimes in couples, but never in numerous groups like most of the other types. They attain considerable dimensions, the greatest width being usually more than 50 feet, but this is not maintained, and the dykes themselves are rarely traceable for more than 400 or 500 yards. Their place in the sequence of intrusions in Skye has not been ascertained very precisely; but they are later than the great group of basic sills, and in one or two cases have been observed to cut finer-textured dykes of dolerite. They belong therefore to the phase of minor intrusions, and have no close connection with the gabbro, for which they might easily be mistaken in hand-specimens.

Since these dykes are few, and usually make conspicuous features, it is worth enumerating the principal examples. Several have already been mentioned on account of their large size. Whether any occur in the north-western portion of the island, our survey does not enable us to say. The most northerly examples observed are two, about 50 ft and 24 ft wide respectively, on Meall na Gainmhich, about 6 miles S.S.E. of Portree, or 4½ miles N.W. of Sligachan. The largest one recorded is on the south-western slopes of Broc-bheinn, about 1¼ mile N.E. of Drynoch Lodge: this is 150 feet wide where it crosses the upper part of Allt na Coille, but dwindles in a south-easterly direction. A dyke of this set, 4½ feet wide, is seen in Bealach na Beinne Brice, 2½ miles W.S.W. of Sligachan. Farther south two occur near together on Meall a' Mhaìm. They are perhaps 30 or 40 feet wide, and one of them is seen very conspicuously at the large cairn at the head of Bealach a' Mhaìm, the pass between Sligachan and Glen Brittle. Some 1200 yards W. of the summit of Meall a' Mhaìm occurs another, 75 feet in width, remarkable for enclosing abundant xenoliths of gabbro up to as much as a foot in length. Another crosses Allt Dearg Beag near the northern boundary of the gabbro: this forms part of a multiple dyke. On the other side of the mountains a large dyke makes a prominent feature crossing the southerly ridge of Blath-bheinn at about 1100 feet altitude. Another is seen near the little tarn on Slat-bheinn, Strathaird: its greatest width is about 50 feet. Two dykes, 30 or 40 feet wide, a little east of Loch Coire Uaigneich, south-east of Blath-bheinn, are perhaps to be referred here, as well as a 60-ft dyke, perhaps the continuation of one of these, farther S.E.; but they have not been subjected to microscopic examination. There remain the conspicuous 50-ft dyke on the east face of Beinn na Caillach, and the 70-ft dyke at Harrabol. The latter is part of a double dyke, the other member, 30 ft wide, being of an intermediate rock of specific gravity 2.75. To these may perhaps be added one or two recorded by Mr Clough in the Sleat district, notably a dyke seen ¼ mile W. of Tormore, near the Point of Sleat, which is in places 120 feet across. We have not seen any specimen of this.

The rocks forming these large solitary dykes are of coarse texture and to the eye scarcely distinguishable from some of the gabbros. They usually contain olivine, but not as a constituent easily visible on the hand-specimens. Two examples gave specific gravities 3.02 and 3.08, while the Blath-bheinn dyke, which is free from olivine, gave 2.92. This last has been sliced (S7477) [NG 522 200], with two from the tract north of the Cuillins, both containing abundant olivine (S7555) [NG 443 274], (S7556) [NG 474 270].

The olivine may be either fresh or converted to green serpentine and magnetite. Both original magnetite and ilmenite are found, the latter in characteristic skeleton crystals, and the Blath-bheinn rock has also little cubes of pyrites, passing into hematite. The felspars contain rounded glass- and other inclusions, sometimes of comparatively large dimensions, collected in the central part of the crystal. They constantly show zonary banding between crossed nicols, and that in a much more marked degree than is occasionally seen in the gabbros. Extinction-angles for the central and chief portion of a crystal range in symmetrically cut sections up to 45°, indicating the most basic variety of labradorite. Carlsbad, albite, and pericline twinning are constantly found. The augite is moulded upon the idiomorphic crystals of felspar. It is of light brown colour in thin slices, with perhaps a rather deeper tint than is customary in the gabbros. It shows good prismatic cleavage, but no basal striation or diallagic structure. The rocks have thus under the microscope diagnostic characters which enable us to differentiate them from the gabbros, notwithstanding a strong general resemblance in some respects and a nearly identical appearance to the unaided eye. In the field these dykes are easily distinguished from most others, not only by their large size and coarse texture, but by their making more or less prominent features in relief against the country rock.

The remaining *non-porphyritic basic dykes* of Skye, excepting only some in the Cuillins to be referred to in a later chapter, we have not succeeded in dividing into natural groups referable to defined epochs. This is unfortunate, since they include the majority of the dykes seen in most parts of the island. The rocks present, as a rule, little that is remarkable, and do not call for any full description. The porphyritic dykes will be described subsequently.

We give below chemical analyses of two dykes which probably belong here, although their precise ages cannot be ascertained, since they are seen to cut the Torridonian only. The second, with 46.68 per cent. of silica and 16.69 per cent. of iron-oxides, belongs to a type which is very abundant and widely distributed. The rocks as a whole seem to be of decidedly basic character, though perhaps less so than the earlier dykes. Forty examples gave specific gravities ranging from 2.80 to 3.06; but most were nearer to the lower limit than to the upper, and the mean value was only 2.86. Only about half of these dykes were proved to intersect the gabbro, the granite, or the basic sills of the great group; and it is probable that some of the others belong to the pre-granitic set.

	I	II
SiO_2	48.30	46.68
Al_2O_3	20.06	18.89
Fe_2O_3	1.29	8.74
FeO	10.15	7.95
MgO	5.21	5.36
CaO	10.10	10.00
Na_2O K_2O	2.80	1.96
Ignition	2.00	0.40
	99.91	99.98
Specific gravity		2.90

I. Dolerite or basalt, dyke (passing into a sheet) on coast opposite Sgeir na Iasgaich, near Ob Allt an Daraich, 2½ miles W. by S. of Kyleakin: anal. T. Baker. Specimen not seen: this and the following rock were collected by Prof. G. A. Lebour, who has kindly communicated the analyses.

II. Dolerite, dyke at point E. of mouth of Allt na Nighinn, 2 miles W. of Kyleakin (S8951) [NG 724 263]: anal. T. Baker. The chief constituents are a rather acid labradorite in striated crystals about 1/20 inch long and a light brown augite in imperfect crystals, either mineral in places idiomorphic towards the other. There are pseudomorphs after olivine and little octahedra of magnetite: also a subordinate later felspar, not closely lamellated but with concentric zonary structure. The shapeless patches of this later felspar enclose very numerous needles of apatite (phosphoric acid not determined in the analysis). See (Plate 22), Fig. 2.

Here, as in some other cases, the presence or absence of olivine does not seem to us a character of primary classificatory value, since it does not evidently correlate itself with other points of difference. The innumerable non-porphyritic basic dykes of our area, other than those separately treated, fall conveniently under two heads according to their relative coarseness or fineness of texture. The ophitic structure prevails in the coarser rocks and the granulitic in the finer, and other differences may also be recognised between the two sets, though not always without exceptions.

The more coarse-textured dykes may be termed *dolerites and diabases.* Some contain olivine, while others, in most respects similar, do not. When that mineral is present, it forms as a rule rounded grains, often replaced by green or greenish yellow or brown serpentine and other secondary substances. Magnetite occurs in varying amount in little octahedra and granules. Any evidently titaniferous iron-ore seems to be rare, but chemical tests would be necessary to decide this question. Needles of apatite are often detected, but have a capricious distribution. The felspar is labradorite: it shows in slices the usual rectangular shapes with carlsbad and albite twinning and in some of the most coarse-textured rocks some pericline-lamellee in addition. The augite, crystallised subsequently to the felspar, is light brown in section without any special peculiarity. It is doubtless of an aluminous variety, and is often partially replaced by a chloritic mineral, sometimes with radiate-fibrous arrangement. It has invariably an ophitic or sub-ophitic habit, though the individual crystal-plates are not often of such size as completely to enclose the felspar (Figure 68). Rocks with these characters have a quite general distribution, and are found cutting the basalts of the plateaux, the gabbro of the Cuillins, and the stratified rocks of the south-eastern part of the island.

The finer-textured rocks we shall term *basalts.* These again may or may not contain olivine. Some of high specific gravity (about 3) and doubtless thoroughly basic composition are devoid of that mineral: these rocks are very rich in augite.

Magnetite occurs as before. The felspars are smaller and of narrower shape ("lath"-shape) in section, but all except the smallest show twin-striation. They are found to be labradorite whenever they can be tested. The augite, of quite pale tint in the slices, is in granules wedged in among the felspars or, if more abundant, aggregated in patches, and the varieties of micro-structure met with depend chiefly upon the amount and habit of the augitic constituent. One special type, seen in some rocks rich in augite (S7131) [NG 537 232], (S8191) [NG 472 253], exhibits the structure already noticed under the name "ocellar" as occurring in some of the basalt lavas (*see* (Plate 17)., Fig. 3, C), viz. a tendency of the augite to build imperfect prisms, or at least elongated elements, with a confused sheaf-like or partially radiate arrangement about certain points.

These basalt dykes differ from the augite-andesite dykes to be described in a later chapter in that they have as a rule no glassy base. Only exceptionally do we find any indication of a base, and then only in connection with a marginal modification of the rock. A small proportion only of the dykes have an extremely thin tachylytic edge, as we shall notice in the following chapter. Small scattered amygdules are occasionally found.

The basalt dykes have the same wide distribution as the dolerites, and, like them, belong undoubtedly to more than one epoch of injection. Some of them are among the latest intrusions of the Cuillins. In some parts of the gabbro mountains we find very numerous little dykes, or rather veins, of very 'compact-looking basalt, often only two or three inches wide. They sometimes have an irregular course, curving or bending abruptly aside, and in places ramifying, a peculiarity distinguishing them from other dyke-rocks in our area.

We pass on to the *porphyritic basic dykes.* Those basic dykes which exhibit conspicuous porphyritic elements seem referable, in most cases where evidence is available, to a rather late stage in the history of igneous activity in the region. An exception to this rule we have already noticed in the peculiar rocks, often containing quartz-grains, which sustain such remarkable relations towards associated acid intrusions. Apart from these, no noticeably porphyritic dykes have been observed which are clearly referable to an early stage. Both the basic lavas and the basic sills are, as has been remarked, in general non-porphyritic, and porphyritic dykes are not to be expected as common among their feeders. Of the dykes now to be described, some intersect the granite, and others cut minor intrusions themselves younger than the granites and in some cases of quite late age. Several distinct groups are to be recognised, but the data do not enable us to arrange them in chronological order.

Very noticeable are certain porphyritic dykes rich in olivine which traverse the granite in various parts of the Red Hills. They are from 2 to 15 feet in width, and vary in direction between N.W.–S.E. and W.N.W.–E.S.E. The conspicuous minerals in hand-specimens are rectangular felspars and golden yellow olivine, less frequently lustrous black augite. The felspars range up to ¼ inch in diameter and the olivines to about ■ inch, while the texture of the general mass of the rock shows some variation. Dykes of this kind are seen on Glamaig and the Beinn Dearg ridge near Glen Sligachan, on the slopes of Glas-bheinn Mhòr and Beinn na Cro, and on the western slope of Beinn Dearg Mhòr of Strath; and they may conveniently be styled the *Beinn Dearg type.* They occur scarcely, if at all, outside the granitic tract. Within that area they are the most usual type; though other dykes are also found, consisting of a rather dense and dark non-porphyritic rock, with a tendency to spheroidal weathering.

These olivine-bearing dykes of the Red Hills are of thoroughly basic composition. Seven specimens gave specific gravities from 2.86 to 2.96, with a mean 2.90. One example has been completely analysed by Dr Pollard, whose results are given in the accompanying table. The figures differ very notably from those for the more widely distributed types given above. In particular, the richness in magnesia, the comparative poverty in alumina, and the low silica-percentage are significant points. The Beinn Dearg dykes, again, have no close resemblance to the sills of the great group, being decidedly poorer in alumina and alkalies and richer in magnesia. Since these dykes are undoubtedly a *local* group, connected with the special focus of central Skye, we might perhaps more reasonably compare them with the gabbros; but they differ quite as decidedly from these, being much poorer in alumina and richer in iron and magnesia, as well as poorer in silica. In short, the Beinn Dearg type of dykes represents a highly specialised derivative from the hypothetical common stock. If there exists in the district a "complementary" product of the same differentiation, it must be represented by thoroughly acid rocks very poor in ferro-magnesian minerals. (See below, p. 427.)

SiO_2	44.01

TiO_2	1.66
Al_2O_3	12.69
Cr_2O_3	trace
Fe_2O_3	3.62
FeO	8.75
NiO & CoO	trace
MnO	0.21
MgO	12.86
CaO	10.57
Na_2O	1.68
K_2O	0.49
H_2O above 105°	2.73
H_2O at 105°	0.89
CO2	trace
P_2O_5	0.17
S	0.11
	100.44
Specific gravity	2.95

Porphyritic Olivine-Dolerite (S7862) [NG 515 261], dyke cutting granite, Ciche na Beinne Deirge: anal. W. Pollard, *Summary. of Progress* for 1899, p. 174. See (Plate 22)., fig. 4.

The porphyritic felspars are of a rather basic labradorite (with extinction-angles up to 40° in symmetrical sections), and show carlsbad and albite twinning. Their inclusions are mainly of glass. The olivine-grains, with but little approach to crystal-outline, are fresh or only slightly serpentinised, and occur in abundance. When augite figures among the phenocrysts, it is a variety very pale in thin slices, differing from that of the ground-mass. The opaque iron-ore is either in little octahedra or in more shapeless grains. The felspar of the ground-mass, in little striated prisms, the larger ones showing carlsbad as well as albite twinning, is labradorite of a less basic kind than the phenocrysts (extinction-angles up to 30°). The augite is light brown with more or less of a purplish tone and sensible pleochroism. It seems probable that part of the titanic acid has gone into this mineral, the iron-ore being chiefly magnetite. Apatite needles are sporadically distributed.

In micro-structure these rocks show some differences. There are porphyritic olivine-basalts, with a ground-mass composed of small felspar prisms and granules of augite and magnetite. There are porphyritic olivine-dolerites, in which the augite of the ground-mass varies from a partly idiomorphic to a sub-ophitic habit (Plate 22), Fig. 4. Here, in addition to the rectangular striated felspars of the ground, there are some of later crystallisation and shapeless habit, with strong zonary banding and no close twin-lamellations. Finally, there are ophitic olivine-dolerites, in which the porphyritic felspars are wanting: these, too, show the subordinate shapeless and zoned felspars in addition to the dominant set.

A very numerous set of porphyritic dykes is found in the Strath district, especially round Beinn Suardal, and may be distinguished as the *Suardal type.* Felspars are usually the only evident phenocrysts: if olivine occurs it is in smaller grains than in the Beinn Dearg dykes. .A striking feature is the great frequency of enclosed xenoliths, usually of gabbro or granite, and of xenocrysts derived from the disintegration of these. In most of the dykes something of this nature may be noticed; and exceptionally, as in a dyke to the west of Allt an 't-Suidhe near Loch Kilchrist, gabbro debris makes up locally quite half the bulk of the rock (S6718) [NG 602 213]. The dyke just mentioned, traversing the volcanic agglomerate, bears about N.N.E., and has a width of 50 feet: most of the dykes of this group, however, are only a very few feet wide, and the common direction is N.W.–S.E.

Twelve examples of the Beinn Suardal porphyritic dykes, free from xenoliths, gave specific gravities from 2.74 to 2.95, with a mean of 2.86. Their mineralogical composition, too, evinces a very considerable range of variation. This is certainly due in great part to the magma having often absorbed a considerable amount of material from foreign sources, and become modified in consequence. For this reason a summary notice of the petrography of the dykes will be sufficient: the phenomena of the xenoliths will be treated in another chapter (20).

The porphyritic felspars proper to the rocks are labradorite, containing glass-cavities. Augite phenocrysts are never abundant, and olivine may or may not occur. There is always plenty of magnetite, in small granules or minute octahedra. The usual ground-mass consists mainly of little felspars, in imperfect prisms and bundles, with augite in granules and sometimes in imperfectly-built crystals ((Plate 22)., Fig. 5). Other constituents, such as biotite, seem to be connected always with reactions between the basaltic magma and material of foreign origin. The felspars of the ground-mass are usually labradorite. Sometimes they are of a less basic kind, and the rock becomes rather an andesite than a basalt; but this modification, observed in association with enclosed granite debris, finds an explanation in the consideration already set forth.

To the Suardal group we may probably attach many of the dykes of porphyritic basalt found at numerous localities throughout the district of Sleat. Mr Clough has supplied some field-notes on these rocks, but they have not been examined more closely. The specific gravities of ten examples ranged from 2.78 to 2.94, with a mean of 2.85. The rocks contain conspicuous porphyritic felspars, and in some cases porphyritic augites: sometimes also they carry xenoliths of gabbro, etc. In the Moine Schists at Inver Dalavil, on the west coast of Sleat, occurs a dyke in which the porphyritic felspars are sometimes as much as 3 inches long, rivalling those near Tobermory in Mull. These felspars gave the specific gravity 2.69, indicating labradorite. Another of Mr Clough's observations relates to the unequal distribution of the felspar phenocrysts in a dyke. One of this group on the west side of Port na Long, near the Point of Sleat, shows bands roughly parallel to the walls of the dyke, some very rich in porphyritic felspars, others almost free from them. The edges of the severa. bands show no sign of chilling against one another, and the cross-joints in the dyke pass uninterruptedly through; so that the whole appears to belong to a single intrusion.

These porphyritic basalt dykes of Sleat have the normal direction. It is not possible to prove that they are of precisely the same age as the Suardal dykes which they resemble, but Mr Clough's observations would make us refer them, like the others, to a somewhat late epoch. They cut the ordinary basic sills of the district, as well as the granophyres and some of the non-porphyritic basic dykes. On the other hand, they are cut by some non-porphyritic dykes of thoroughly basic composition.

Other porphyritic dykes in the Sleat district present types quite different from the preceding. One from the neighbourhood of Kylerhea has phenocrysts of augite and olivine, the latter replaced by serpentine and carbonates, but not of felspar. The augite is pale in a thin slice, with a faint purplish tint towards the border of the crystal, and shows in polarised light a well-marked and regular "hour-glass structure" (S5419) [NG 788 223].

A group of porphyritic dykes intersecting the Torridon Sandstone on the shores of the Sound of Soay presents rather peculiar features. In hand-specimens the rocks show fresh glassy-looking felspars, with tabular habit and from ¼ to ½ inch in length, set in a fine-textured matrix of a rather light grey colour. A slice (S8714) [NG 496 185] shows these porphyritic felspars to be labradorite, with carlsbad, albite, and pericline twinning, the lamellae being rather unevenly distributed. Some of the crystals contain large inclusions generally resembling the ground-mass. Associated with the porphyritic felspars are imperfect crystals of magnetite and certain light green serpentinous pseudomorphs very suggestive of a rhombic pyroxene destroyed. Other light green patches, consisting mainly of fibrous hornblende, have the shape of olivine. The ground-mass consists of small felspar crystals, granular augite in quite subordinate amount, and rather abundant magnetite. The small felspars show narrow rectangular sections, often only once twinned, and constantly give nearly straight extinction. They must therefore be oligaclase, perhaps even with some orthoclase. In the inclusions within the porphyritic felspars the small felspars do not, so far as can be judged, give the very low extinction-angles. The abnormal composition of the specimen examined might be explicable on the supposition that the magma has been to some extent acidified after the crystallisation of the porphyritic elements. We are reminded in some respects of the dykes elsewhere to be described which have demonstrably been modified in this way by taking up granitic material. No undestroyed relics of an acid rock, however, were observed in the case now in question. The several dykes belonging to this group, so far as they have been examined, show no difference of an essential kind. A conspicuous dyke, 12 feet wide, just E. of Ulfhart Point, has a less fine texture than the specimen described above, but the felspars of the ground-mass, though of larger size, give the same nearly straight extinction as before. If we reject the supposition, for which no direct evidence can be adduced, that these rocks have been modified by absorption of extraneous matter, we may compare them with other dykes to be noticed at the end of this chapter as approximating in composition to the mugearite type. The nature of the dominant felspar and the subordination of augite to magnetite and olivine are significant in this connection, but the phenocrysts of labradorite make an important difference.

A different type is represented by numerous dykes of small width in the neighbourhood of Drynoch and Meadale, to the N.E. of Loch Harport. These are olivine-bearing rocks of finer texture than. the Beinn Dearg type and having phenocrysts of felspar only. An example at the sharp bend of the high-road about 6½ miles from Sligachan gave the specific gravity 2.80. A slice (S8715) [NG 405 318] shows that olivine occurs in small grains which are fairly abundant, some fresh, but others replaced by green serpentine. The porphyritic felspars, ¼ inch long or more, are fresh and glassy-looking: they are only scattered through the fine-textured matrix. This is chiefly of little striated felspar prisms, with a strong tendency to fluxional arrangement, while light brown augite occurs in ophitic plates and rather plentiful magnetite in small octahedra and granules. These rocks recall in some respects the porphyritic olivine-dolerite of the Roineval type of double sills (p. 262).

Here we may notice a conspicuous dyke seen on Roineval, east of the summit, and already alluded to as possibly one of the feeders of the peculiar double sills or laccolites there exhibited. It has a maximum width of 35 feet, with the normal direction. The rock shows a finely crystalline dark grey ground, enclosing very numerous fresh felspars about ■ inch long and little grains of olivine, and is a porphyritic olivine-dolerite with "granulitic" structure. In a thin slice (S8188) [NG 418 351] the felspar phenocrysts show carlsbad, albite, and pericline twinning, and the extinction-angles (up to 34° in symmetrically cut sections) indicate labradorite, but not of a very basic variety. They contain round inclusions of relatively large size, and these are chiefly confined to the interior portion of each crystal, which often shows definite crystallographic outlines more perfect than those of the crystal itself. This indeed is often moulded upon the augite-granules of the ground-mass, and there can be no doubt that the broad margin of the crystal represents a later growth of the phenocrysts continued during the crystallisation of the ground-mass (Plate 20)., Fig. 4. We have observed a similar appearance in the phenocrysts of some other dykes, and Professor Judd<ref>*Quart. Journ. Geol. Soc.,* vol. xlv., pp. 175–186, pl. VII.; 1889.</ref>has described it as a phenomenon of frequent occurrence. The olivine of the rock, in grains about 1/20 inch in diameter, is perfectly fresh. The ground-mass consists of granules of pale yellowish-brown augite, little striated felspars giving elongated sections, and small crystals of magnetite.

The next type to be noticed among these basic dykes may also be termed *porphyritic olivine-dolerite.* It does not seem to be very widely distributed, but within the areas where it occurs is numerously represented. The rocks are of thoroughly basic composition. Five examples gave specific gravities ranging from 2.84 to 2.93, with a mean of 2.88. The special feature as regards structure is the association of abundant porphyritic elements with an ophitic ground. These dykes may be called for distinction the *Gheal Gillean type.*

A number of dykes of this kind occur in the neighbourhood of Camasunary. Some larger ones, up to as much as 50 feet in width, are seen near the foot-path from there to Strathaird, and another large one about 400 yards N.E. of Kirkibost House. Their direction is the normal one, varying from N.W.–S.E. to N.N.W.–S.S.E. Specimens of these large dykes have quite a coarsely crystalline appearance, owing to the abundance of porphyritic crystals. These are of felspar, often from ¼ to ½ inch in length. Thin slices show that they are a somewhat basic labradorite. They have carlsbad, albite, and pericline twinning, and contain numerous rounded glass-inclusions, usually collected towards the centre of the crystal. These crystals are set in a matrix consisting mainly of augite and felspar with the ophitic relation. This felspar is quite subordinate in amount to the augite. It forms numerous little striated crystals, from 1/20 inch to as little as 1/100 inch in length in different specimens. Olivine is represented by pseudomorphs in yellowish-brown serpentine and pilitic amphibole, and there are ragged grains of black iron-ore.

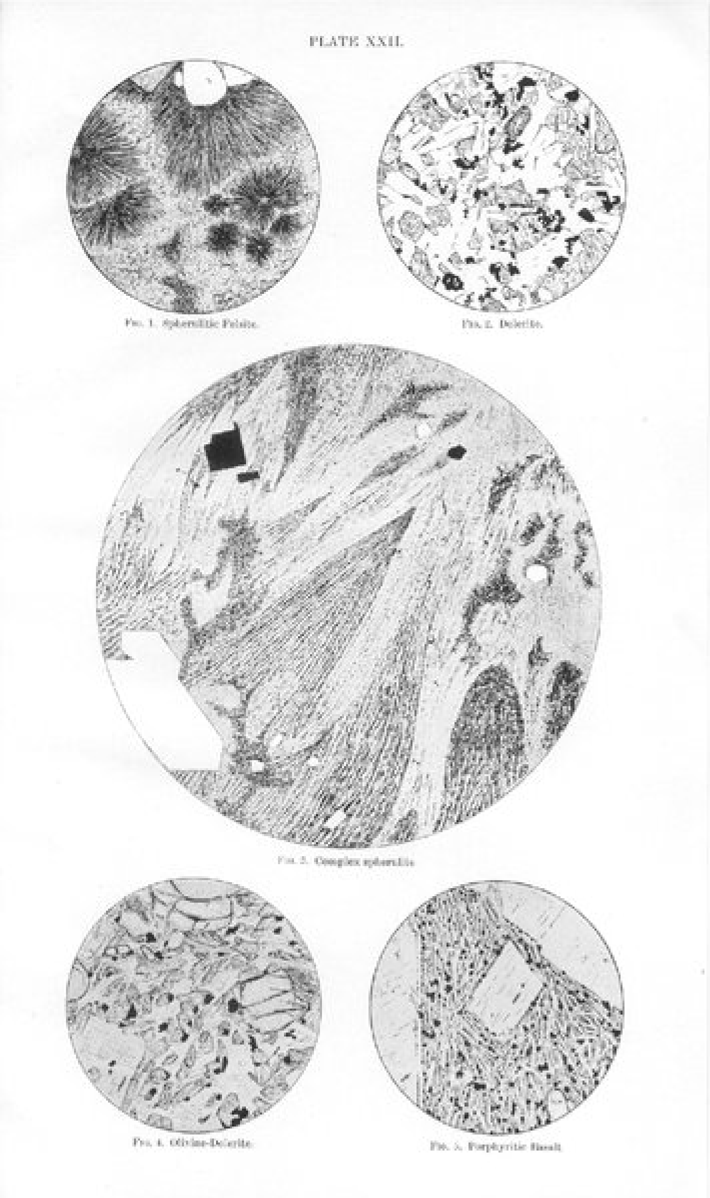
Dykes of rock comparable in many respects with the above occur about Tarskavaig, in the Sleat peninsula, where Mr Clough describes them as a common type. The porphyritic crystals are so crowded together in some specimens examined as almost to hide the ground-mass, giving the rock the general aspect of a gabbro. Three specimens sliced showed a close similarity to one another. Olivine is more plentiful than in the dykes of Gheal Gillean, etc., and is better preserved. It seems to occur sometimes in two generations (S7367) [NG 580 096]. The porphyritic felspars, which make up more than half the rock, are of a thoroughly basic kind: some appear from their optical properties to be anorthite. The felspar of the ground-mass, not a very abundant constituent, is a medium labradorite. These dykes are evidently of the same general type as those near Strathaird and Camasunary. They have the N.N.W. direction, and if prolonged on that line would pass near Strathaird. Mr Clough found similar dykes to be common farther south, towards the southern point of Sleat (S7366) [NG 595 038]. In several instances they cut porphyritic basalt dykes of more ordinary types, and this might perhaps lead us to assign this group to a rather late epoch. It is not clear, however, that all the dykes of this general type belong to one group. Some of them bear a very close resemblance to the large sill which runs at the base of the Mesozoic strata in the neighbourhood, but no direct evidence of any connection has been observed.

Among dykes of *porphyritic dolerite without olivine,* but still of basic composition, we may notice a group intersecting the Torridonian strata in the Isle of Scalpay. A specimen selected from a dyke about 400 yards N.W. by N. of Scalpay House is a grey, finely but evidently crystalline rock, enclosing porphyritic felspars up to ½ inch in length. Its specific gravity is 2.904. In a slice (S9372) [NG 628 285] the porphyritic crystals are seen to be labradorite, with carlsbad and albite twinning. The felspars of the general ground-mass, judged by their extinction-angles, are of a somewhat more acid variety. The light brown augite is in irregular grains wedged in between the felspars, but the two minerals seem to have crystallised simultaneously, and in places they are associated in a rudely micrographic intergrowth. Magnetite is abundant, and there are also occasional patches of pyrites, which are very evident on the hand-specimen. This is the character of the general mass of the rock; but enclosed in it are numerous little patches of a different kind, which appear in the slice as well-defined circular areas up to about ■ inch in diameter. These are almost wholly of felspar, which is partly lamellated, with very low extinction-angles, partly untwinned. Magnetite occurs very sparingly and in minute crystals; while augite is absent, and its place taken very inadequately by a few slender needles of pale green actinolitic hornblende and small flakes of brown mica, the latter grown round the magnetite (*see* (Plate 25)., Fig. 1). There is sometimes a little interstitial quartz. It is clear that these small round patches are of very decidedly more acid composition than the enclosing rock. They have not the characters which we look for in xenoliths; and their small and fairly uniform size, their equable distribution, and their spherical form lead us to regard them as vesicles which at a late stage, when the rock was far advanced towards complete consolidation, became occupied by the residual and relatively acid portion of the magma. A similar phenomenon has been recorded in andesitic rocks from more than one British locality,<ref>See, *e.g.,* Teall, *Geol. Mag.,* 1889, pp. 481–483, pl. XIV.</ref> and we shall have to notice it later among the andesitic dykes of Skye (See pp. 399–401.)

A very distinct type among our basic dykes, and one of very restricted occurrence, differs from the rest in the nature of the felspathic constituents and in other respects which lead us to attach it provisionally to the *mugearites* described in Chapter 15. The best example is a well-known dyke at Am Bile, about 1¼ mile E.N.E. of Portree, to which we shall have to refer in the following chapter. It has a glassy selvage, an analysis of which is quoted below (p. 338, II.). The interior of the dyke is not necessarily identical in composition with the selvage, but there is no reason to suppose that it differs in any very essential way. The silica-percentage is somewhat higher than in the ordinary basic dykes, while the lime and especially the magnesia are lower, and the alkalies higher, including a notable proportion of potash. All these points connect the rock with the mugearites.

The peculiar mineralogical composition of the rock bears out the comparison. The dominant constituent is striated oligoclase in imperfectly shaped crystals from 1/20 inch downward. Another felspar, in shapeless grains of later crystallisation, is untwinned, and must doubtless be referred to orthoclase. The coarser texture of the rock, as compared with the mugearites of Roineval and Druim na Crìche, enables the felspars to be identified more easily; and it is seen that the orthoclase is here rather more abundant, as might be expected from the relative proportions of the alkalies in the analysis. It makes up probably about one-fifth of the total felspar and more than one-eighth of the whole rock. Besides the interstitial grains mentioned, there are a few orthoclase phenocrysts, or perhaps xenocrysts, of larger size, with much-corroded border and abundant glass-inclusions. Augite plays only a subordinate part in this rock; but there has been an abundance of olivine, now represented by pseudomorphs of serpentine stained to a deep red-brown colour. Little octahedra of magnetite are fairly plentiful, and little slender needles of apatite are exceedingly numerous (S9373) [NG 5040 4457]. The finer-textured rock towards the edge of the dyke (not the glassy selvage) shows a micro-structure more closely comparable with that of the typical mugearites. The fel spars are of the same acid varieties as before, but the ferro-magnesian silicates are too completely destroyed to be identified. The magnetite and apatite occur abundantly, as before (S9374) [NG 5040 4457]. There is also an occasional corroded orthoclase, as much as A inch in diameter, quite honeycombed with glass-inclusions, and the same thing is seen in the actual glassy selvage of the rock (S9375) [NG 5040 4457].

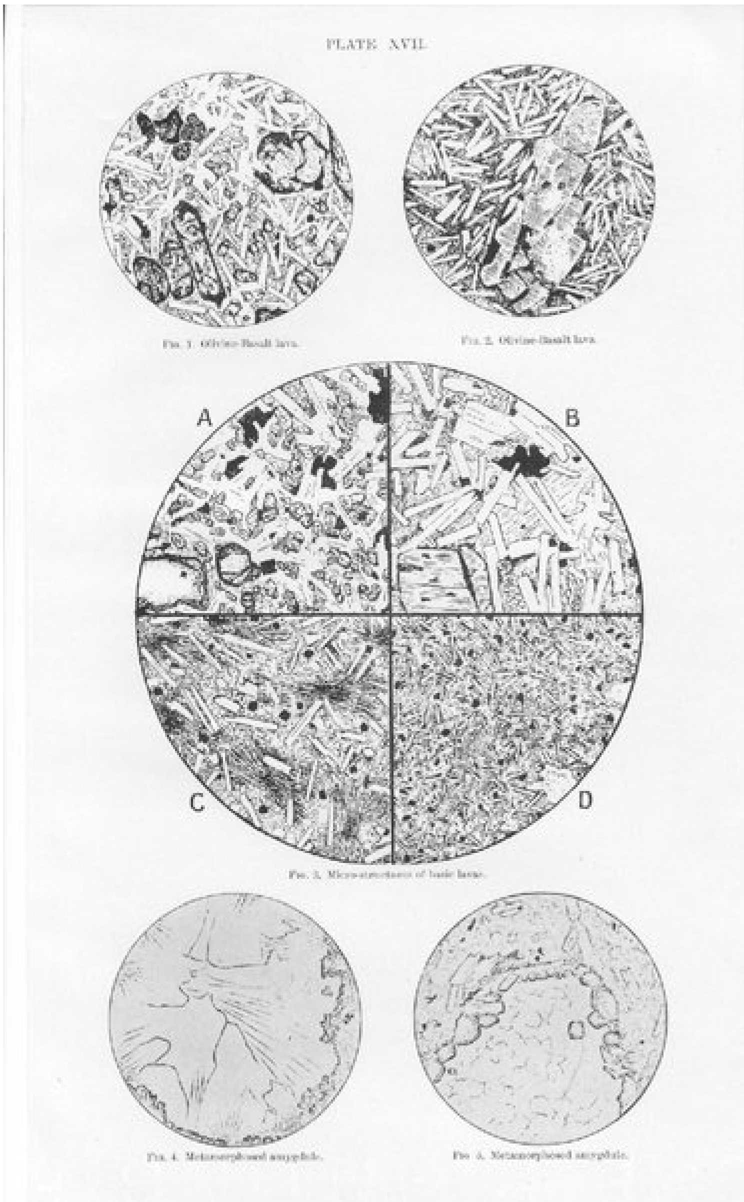
We shall notice in the next chapter certain small dykes seen S. of Loch Ashik, near Broadford, and at one or two places in the district of Sleat, which probably approach mugearite in compostion; but these, being thoroughly glassy rocks, do not lend themselves to a petrographical comparison.



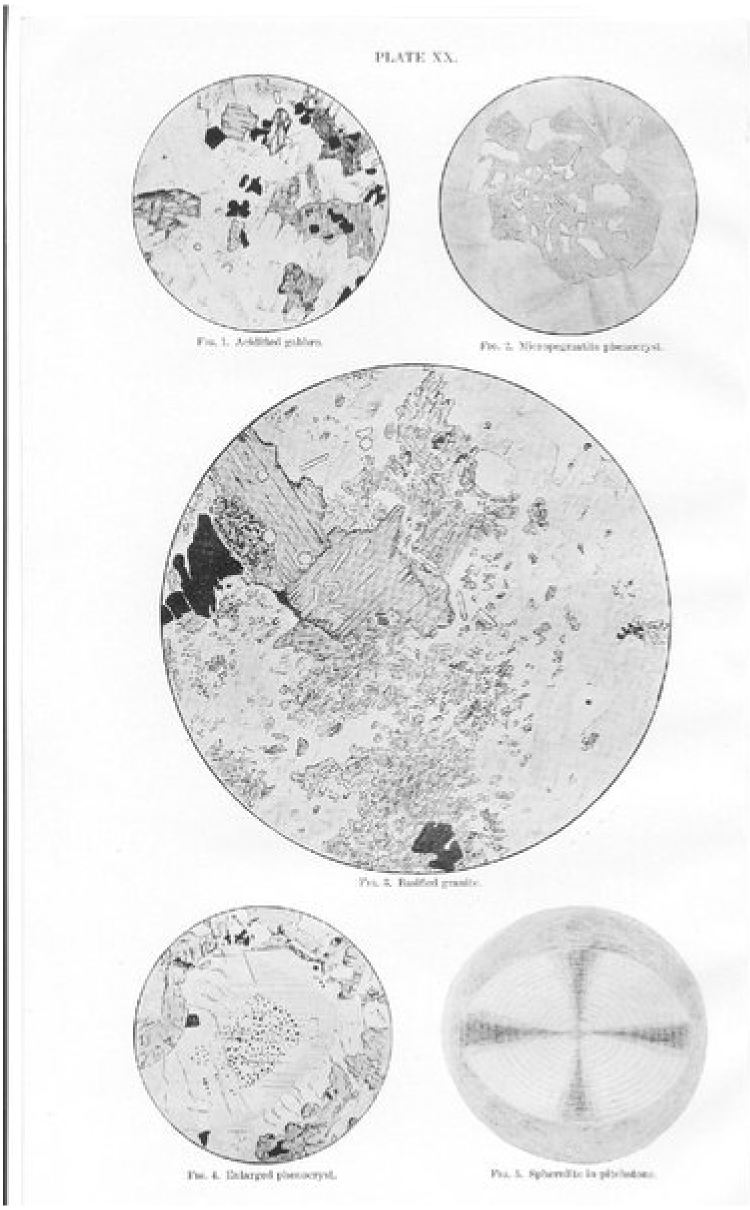
(Plate 22) Fig. I. (S3200) [NG 621 170] × 20. Spherulitic felsite, above Boreraig: showing dense radiate spherulites, sometimes grown round quartz crystals, with interspaces having a granular structure. See p. 281. Fig. 2. (S8951) [NG 724 263] × 20. Dolerite, dyke at point E. of the mouth of Allt na Nighinn, 2 miles W. of Kyleakin. At the top of the figure is one of the shapeless later felspar crystals, enclosing numerous needles of apatite. See p. 322. Fig. 3, (S5389) [NG 48 22] × 40. Part of a large composite spherulite from an acid dyke cutting the gabbro of Druim an Eidhne. The centre of the spherulite is outside the figure, above and to the right. There are minor centres of radiation, which serves as the apices of conical growths directed outward, the axes of the cones conforming with the principal radiate arrangement. One such cone, cut along its axis, occupies the central part of the figure; while below, to the right, are others cut at some distance from their axes so as to present parabolic sections. The clear crystals are quartz, the opaque ones pyrites. See p. 286. Fig. 4. (S7862) [NG 515 261] × 20. Porphyritic Olivine-Dolerite, dyke cutting the granite of Ciche na Beinne Deirge, 3 miles S.E. of Sligachan. This represents the Beinn Dearg type of dykes, and is the rock analysed. See p. 326. Fig. 5. (S6711) [NG 623 205] × 20. Porphyritic Basalt, dyke cutting Cambrian limestone ¼ mile S. by E. of Suardal, about 2 miles S.S.W. of Broadford. This rock illustrates one variety of the Suardal group of dykes, containing phenocrysts of labradorite and grains of olivine in a ground-mass of smaller felspars, abundant magnetite, and finely granular augite. See p. 327.

FIG. 68.—[5421] × 30. Diabase or coarse dolerite, dyke ½ mile E.S.E. of summit of Ben Aslak and 2 miles S.W. of Kylerhea. Typical ophitic structure. The felspar crystals in this and numerous similar rocks show between crossed nicols a strong zonary banding, which does not disappear with the albite-lamellation, and is therefore due to the marginal portion being of different composition from the interior.

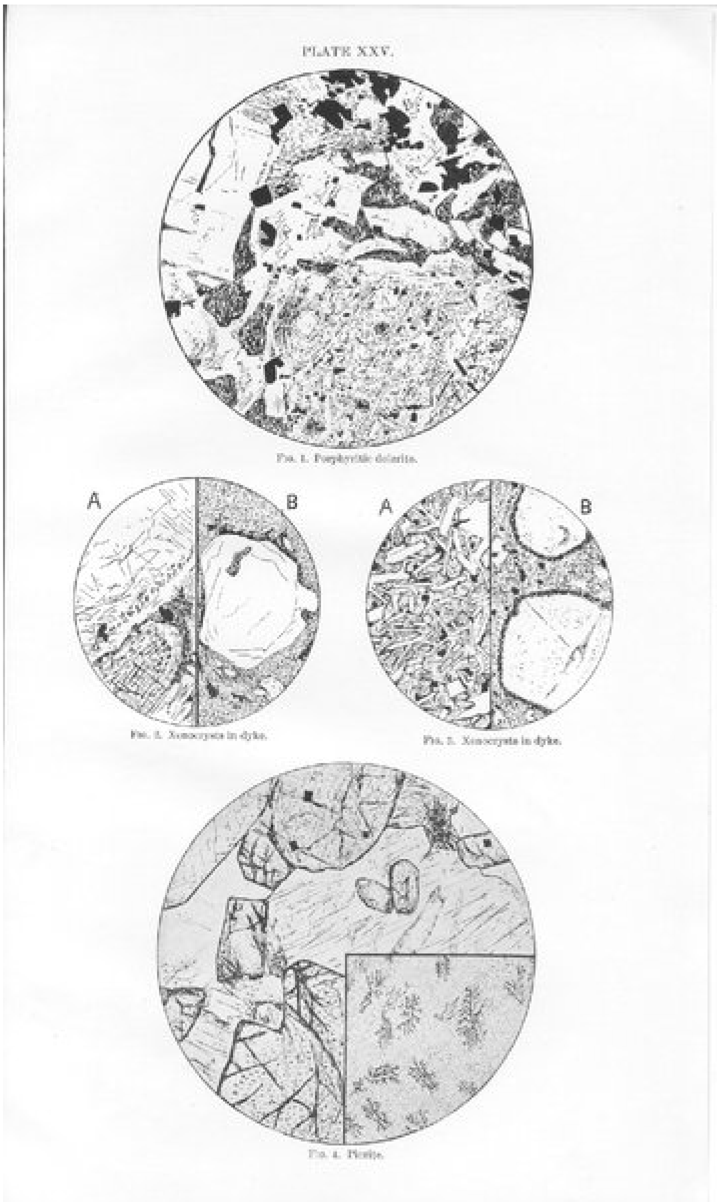
(Figure 68) (S6421) [NX 12 89] × 30. Diabase or coarse dolerite, dyke ½ mile E.S.E. of summit of Ben Aslak and 2 miles S.W. of Kylerhea. Typical ophitic structure. The felspar crystals in this and numerous similar rocks show between crossed nicols a strong zonary banding, which does not disappear with the albite-lamellation, and is therefore due to the marginal portion being of different composition from the interior.



(Plate 17) Fig. 1. × 20. Olivine-basalt lava, above schoolhouse, Braes, S. of Portree: showing olivine replaced by a mineral comparable with iddingsite. See p. 34. Fig 2. (S6772) [NG 520 363] × 20. Olivine-basalt lava, Rudha Buidhe, near Braes, S. of Portree: showing another type of pseudomorph after olivine. See p. 34. Fig 3. × 40. Microstructures of the basic lavas. A. (S8185) [NG 42 28] "Granulitic" structure in olivine-basalt, near bridge over Allt Fionnfhuachd, Drynoch; the rock analysed. See pp. 31, 36. B. (S9246) [NG 47 29] Ophitic structure in hypersthene-basalt, lower part of Allt Dearg Mòr, near Sligachan. A bastite pseudomorph after hypersthene appears in the lower left-hand corner. See pp. 36, 38. C. Ocellar structure in basalt at base of group, S. of Sgùrr nan Each: a type rich in augite and without olivine. See p. 37. D. (S9366) [NG 614 273] Microlitic structure in augite-andesite, S. coast of Scalpay: the augite is mostly chloritised. See p. 37. Fig. 4. (S7460) [NG 537 196] × 10. Metamorphosed amygdule in basalt, close to granite on E. side of Blath-bheinn; showing a crystalline aggregate of new plagioclase felspar, partly with radiate grouping, replacing zeolites. See p. 51. Fig. 5. (S2700) [NG 587 240] × 10. Metamorphosed amygdule in basalt, near granite, Creagan Dubha, N. of Beinn Dearg Mhòr (of Strath): showing a granular crystalline aggregate of new felspar, derived from zeolites, with a border of epidote grains. See pp. 51, 52.



(Plate 20) Fig. 1. (S8962) [NG 500 258] × 20. Gabbro partially fused and injected by the granite magma, gully on the N.W. face of Marsco. The minerals shown are felspar, partially destroyed augite, greenish brown hornblende, magnetite, apatite, and some interstitial quartz. Of the original constituents of the gabbro there remain relics of augite and some of the large crystals of labradorite. See p. 182. Fig. 2. (S5344) [NG 490 230] × 30. Phenocryst of micropegmatite in spherulitic dyke, Druim an Eidhne. It has served as the starting-place for subsequent spherulitic growths. See p. 284. Fig. 3. (S8694) [NG 513 249] × 40. Granite modified by absorption of gabbro material, S.E. ridge of Marsco. The figure shows aggregates composed of greenish brown hornblende with little scales of biotite, larger flakes of biotite enclosing apatite, and irregular grains of magnetite. The rest is of quartz, oligoclase, and orthoclase. See p. 184. Fig. 4. (S8188) [NG 418 351] × 20. Porphyritic Olivine-Dolerite, dyke on Roineval, two miles N of Drynoch: showing a felspar phenocryst enlarged by a later growth with crystalline continuity. See p. 329. Fig. 5. (S8733) [NG 50 30] × 50, crossed nicols. Spherulite in pitchstone, W. face of Glamaig: showing a concentric shell structure. See p. 404.



(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.