# Chapter 8 Gabbros: petrography

In describing the petrographical characters of the gabbro group we shall discuss first what may be regarded as the *normal types,* reserving for later notice the aberrant varieties which occur chiefly in the form of bands, seams, and veins. These normal gabbros are typical basic rocks, varying in texture from coarse to fine. That they also vary within certain limits as regards the relative proportions of their component minerals is evident to the eye, and the different specific gravities of specimens tested indicate in a general way this range of composition. Twenty-five examples from different parts of the area gave a mean specific gravity of 2.927, the extreme figures being 2.85 and 3.03.

To illustrate the *chemical composition* of the normal gabbros two specimens have been subjected to careful analysis by Dr Pollard, and the results are shown below in columns I. and II. To these we are able to add an already published analysis by the late Professor Haughton (III.). All three are from the laccolitic mass of the Cuillins, and they exhibit a rather close resemblance to one another. They present a general similarity also to the Tertiary gabbros of Carlingford, of which Haughton has given two analyses, showing 47.52 and 48.80 per cent. of silica respectively.<ref>*Quart. Journ. Geol. Soc.,* vol. xii., p. 197: 1856; *Journ. Roy. Geol. Soc. Irel.,* vol. iv., p. 99: 1876.</ref> We are also able to give an unpublished analysis of a gabbro from the Broadford boss (IV.) made by Mr T. Baker of the Durham College of Science and kindly communicated by Professor G. A. Lebour. This, as will be seen, is a rock of slightly more acid composition. Mr Player's analyses of the banded gabbros will be quoted in their proper place.

As compared with the average of gabbros from other regions, the Cuillin rocks analysed are rather poor in iron and magnesia and rich in lime.

Dr Pollard did not find metallic iron in the rocks examined, though it has been found in Skye gabbros by Mr Buchanan<ref>Judd, *Quart. Journ. Geol. Soc.,* vol. xli., p. 374: 1885.</ref> and by Professor Tilden.<ref>"On the Gases Enclosed in Crystalline Rocks and Minerals", *Proc. Roy. Soc.,* vol. lx., pp. 453–457: 1897.</ref> Another interesting observation by the latter relates to the gases enclosed in the minute cavities of the crystals of the rock. A gabbro from Loch Coruisk yielded 3½ times its own volume of mixed gases, of which 21.6 per cent. was found to be carbon dioxide and the rest chiefly hydrogen, with some carbon monoxide, nitrogen, and marsh gas. These figures are equivalent to about 0.02 in a percentage analysis of the rock. Helium was sought spectroscopically but not detected.

| | I | II | III | IV | V |
|---|---|---|---|---|---|
| $SiO_2$ | 46.39 | 47.28 | 48.12 | 50.78 | 47.18 |
| $TiO_2$ | 0.26 | 0.28 | | | |
| $Al_2O_3$ | 26.34 | 21.11 | 23.40 | 17.16 | |
| $Cr_2O_3$ | trace | | | | |
| $Fe_2O_3$ | 2.02 | 3.52 | | 3.15 | |
| FeO | 3.15 | 3.91 | 3.28 | 7.61 | |
| MnO | 0.14 | 0.15 | 1.68 | | |
| MgO | 4.82 | 8.06 | 5.31 | 7.16 | |
| CaO | 15.29 | 13.42 | 15.43 | 10.28 | 11.59 |
| $Na_2O$ | 1.63 | 1.52 | 1.86 | 2.61 | |
| $K_2O$ | 0.20 | 0.29 | 0.03 | | |
| $H_2O$ above 105° | 0.48 | 0.53 | 0.48 | 1.20 (ign.) | 0.10 |
| $H_2O$ at 105° | 0.10 | 0.13 | | | |
| $P_2O_5$ | trace | trace | | | |
| 100.82 | | 100.20 | 99.59 | 99.95 | |
| Specific gravity 2.85 | | 2.90 | | 2.82 | |

I. Olivine-Gabbro of Cuillin laccolite, west bank of Sligachan River, just below Allt Coire Riabhaich (S8043) [NG 481 232]: anal. W. Pollard, *Summary of Progress of Geol. Sur.* for 1899, p. 173. See Fig. 21, below.

II. Olivine-Gabbro of Cuillin laccolite, floor of Coir' Mhadaidh (S8194) [NG 449 242]: anal. W. Pollard, *ibid.,* p. 174.

III. Gabbro of Cuillin laccolite, Loch Scavaig [probably olivine-gabbro; specimen not seen]: anal. S. Naughton, *Dubl. Quart. Journ. Sci.,* vol. v., p. 94: 1865. Analyses of the felspar and augite of this rock are quoted below.

IV. Gabbro of Broadford boss, near mouth of Allt Mhic Leanain, 1½ mile N.W. of Broadford (S8950) [NG 620 260]: anal. T. Baker.

V. Gabbro of offshoot from Broadford boss, traversing the dolomitic limestone, west bank of Lochain Beinn na Caillich (S8692) [NG 612 241]: partial anal. by W. Pollard.

In Sir J. Norman Lockyer's spectra of our gabbros, I. and II., the chromium lines are very prominent, while vanadium and strontium are more faintly but distinctly indicated. The titanium lines are distinct, but not so strong as in some other rocks (especially the intrusive sills to be described later), in which a relatively high percentage of that element has been directly estimated. A comparison of the several photographs shows indeed that spectroscopic analysis under given conditions has a certain quantitative as well as qualitative value.

The first three columns in the Table show decided differences in some particulars; and a comparison of thin slices enables us to see how variation in chemical composition has given rise to variation in the relative proportions of the constituent minerals. The significant figures in this connection are those for alumina, magnesia, and alkalies; for the two chief minerals of the rocks, viz. labradorite and augite, do not differ much in their content of silica and of lime, and any excess of iron-oxides can be disposed of in the form of magnetite. Thus the first rock is more felspathic than the second. By the kindness of Professor Sollas we are able to give the results of a direct mineral analysis made by him with the apparatus and methods which he has devised.<ref>*Quart. Journ. Geol. Soc.,* vol. lviii., pp. 163–176: 1902. In the paper as published there are certain clerical errors, which are here corrected.</ref> The percentage mineral composition of the first rock (S8043) [NG 481 232] is as follows:

| | |
|---|---|
| Labradorite, sp. gr. 2.735 to 2.74 | 79.50 |
| Augite and olivine, 3.21 to 3.335 | 16.18 |
| Enstatite, 3.0 | 2.10 |
| Magnetite | 2.40 |
| | 100.18 |

It is worthy of remark that the occurrence of a second pyroxene, which had escaped detection in the microscopical examination, was first established by this direct isolation of the mineral. The second rock (S8194) [NG 449 242], owing to the presence of serpentine and other alteration-products, presented more difficulty in its mechanical analysis. Professor Sollas found:

| | |
|---|---|
| Labradorite, sp. gr. 2.737 | 65.96 |
| Augite, sp. gr. 3.280 | 32.43 |
| Magnetite | 1.61 |
| | 100.00 |

The Skye gabbros have a quite simple mineralogical composition. A plagioclase felspar, usually labradorite, and augite are the constant, and sometimes the only noteworthy constituents. Olivine and magnetite occur very frequently, but not often in any great abundance; while hypersthene, hornblende, biotite, sphene, apatite, ilmenite, pyrite, garnet, orthoclase, and quartz are only of exceptional occurrence. To these may be added the common alteration-products of the minerals named, although most of the rocks are in a good state of preservation.<ref>Good coloured plates of olivine-gabbros from Loch Coruisk are given in Teall's *British Petrography,* P1. XVIII., Fig. 1, and XXV.: 1888. A general account of the gabbros of the Western Isles of Scotland is contained in papers by Professor Judd (1885, 1886), and examples from Skye had previously been described by Professor Zirkel (1871).</ref>

Those petrologists who lay stress on the presence or absence of olivine would place the Skye gabbros under two heads accordingly, but such a subdivision does not appear to us to offer any advantages in this case. The presence or absence of olivine, except where it occurs in abundance, does not seem to be very closely connected with other petrographical characters in the rocks. In the very complex mass building the Cuillins and their branch ridges gabbros with and without olivine are intimately associated, the former, perhaps, predominating: the rock forming the smaller mass to the north-west of Broadford is, at least in the main, free from that mineral. In the description which follows we shall generally treat the rocks as a whole, whether they occur in laccolitic or sheet-like form, as in the Cuillins, or with boss-like habit as in the Broadford district. As regards the most common types, the same description will apply in general to all the occurrences. As regards varietal forms, however, there are differences which may be significant. The rocks are much more variable in the Cuillins (including the Blaven range) than elsewhere. Not only does the great laccolite consist of numerous distinct intrusive sheets which often differ from one another, but these also display in some cases considerable variation in the parts of one mass. The Broadford boss is much more uniform, and indeed shows very little variation except a transition to the diabasic type. Unlike the Cuillin mass, it is in general free from olivine. Of the smaller intrusions, it may be mentioned that the irregular sheets on Beinn na Cro have more variety of character than the boss just referred to, but without the extreme modifications met with in the great laccolite: olivine was found in one specimen only, a rock with "eyes" of coarser texture seen in the lowest exposure on the Strath Mòr side. The smaller intrusions of the district exhibit a general uniformity of petrographical characters.

We shall first describe severally the component minerals of the rocks.

In most of the gabbros the *felspar* has partially idiomorphic outlines with the usual crystal-habit. The carlsbad, albite, and pericline twin-laws are found, often in combination. In a large proportion of the more typical gabbros the crystals constantly show the albite-lamellation and very commonly the carlsbad twin in addition, while pericline lamellae occur less generally, usually in the larger and broader crystals, often affecting only a portion of the crystal or not passing completely across it. Many examples have been observed, however, in which only pericline, or pericline with carlsbad, twinning is present, or in which the albite-lamellation is subordinate to the other; and it is never safe to assume that a single set of lamellae in a crystal, or the more prominent and constant of two intersecting sets, is necessarily that corresponding with the albite-law. If the crystal is twinned on the carlsbad law, the albite and pericline lamellw are of course easily distinguished; in other cases the discrimination can often be made by reference to the optical orientation, using a quartz-wedge or a quarter-undulation plate. Neither the direction of elongation of the section nor the parallelism of twin-lamellas with cleavage-traces affords a criterion that can be trusted. It has been found necessary to bear this point constantly in mind in taking observations of extinction-angles in rock-slices with the view of identifying the various kinds of felspar.

The most usual inclusions in the felspars are merely of the earlier-crystallised minerals of the rock, but fluid-cavities are also found, sometimes with mobile bubbles.

| | I | II | III | A | B |
|---|---|---|---|---|---|
| $SiO_2$ | 53.60 | 49.155 | 50.811 | 47.90 | 45.87 |
| $Al_2O_3$ | 29.88 | 29.62 | 29.48 | 31.30 | 34.73 |
| $Fe_2O_3$ | | 1.152 | 0.252 | trace | |
| FeO | 0.20 | | | | |
| MgO | 0.07 | 0.911 | 0.124 | 1.16 | 1.55 |
| CaO | 11.02 | 15.309 | 12.69 | 11.22 | 17.10 |
| $Na_2O$ | 4.92 | 2.914 | 3.922 | 3 96 | |
| $K_2O$ | 0.80 | 0.695 | 0.552 | 0.98 | |
| $H_2O$ | 0.48 | 0.73 | 2.481 | 1.54 | |
| | 100.97 | 100.486 | 100.292 | 98.06 | 99.25 |
| Spec. grav. | | | 2.715 | | |

I. Labradorite, Loch Seavaig: anal. S. Haughton, *Dubl. Quart. Journ. Sci.,* vol. v., p. 94: 1865. From the gabbro of which a bulk-analysis is given above (p. 103).

II. "Labradorite", Harta Corrie: anal. M. F. Heddle, *Trans. Roy. Soc. Edin.,* vol. xxviii., p. 253: 1877. In the original the total is erroneously given as 100.386.

III. Labradorite, near head of Loch Scavaig: anal. M. F. Heddle, *ibid.*

A. Labradorite, Beinn Mar, Mull: anal. J. F. Brooks, *Quart. Journ. Geol. Soc.,* vol. xlii., p. 64: 1886.

B. Anorthite, Carlingford: anal. S. Haughton, *Quart. Journ. Geol. Soc.,* vol. xii., p. 196: 1856.

The common varieties of felspar in the Skye gabbros are, as a rule, labradorite. This is illustrated by the three analyses quoted, although the second one (evidently made on material not quite free from augite) falls rather between labradorite and bytownite.<ref>The three analyses correspond approximately with $Ab_8An_9$, $Ab_3$ $An_7$, and $Ab_3An_5$, respectively. For the felspar of a gabbro in the lower part of Allt Coire na Banachdich the specific gravity, carefully determined by Prof. Sollas, is 2.708, and the extinction-angle on the basal cleavage 21°, corresponding with bytownite of composition Ab </ref> The optical properties, however, are sufficient to show that there is, in different rocks, a considerable range of composition. In some of the more basic types bytownite and anorthite occur, though they are far less common than labradorite. On the other hand, the light-coloured veins which often traverse the more normal gabbros usually have more acid felspars. In some of them labradorite is accompanied by oligoclase or andesine, while in others oligoclase becomes the dominant constituent, and more basic felspars may be wanting. In these veins too, and not elsewhere among the gabbros, we sometimes find orthoclase.

Not infrequently the marginal portion of the crystal is of a somewhat different composition from the interior, and in that case always less basic. The difference is as a rule small, but in a few cases considerable — e.g., labradorite bordered by andesine, as shown by the extinction-angles. The zonary banding seen between crossed nicols does not on rotation disappear at the same time as the twin-lamellation, and therefore is not due merely to ultra-microscopic or molecular twinning.

We shall notice below that both albite and pericline lamellation have occasionally been brought about as secondary effects, due to the stresses which have operated on the rock-masses.

The common ferro-magnesian element of the Skye gabbros is *augite.* It is always present, and usually to the exclusion of rhombic pyroxenes, original hornblende, and biotite. Very often, and especially in the rocks of coarser texture, it is more or less affected by the so-called "schiller"-structures, and has in consequence a sub-metallic lustre. This peculiarity led Macculloch and other early writers to regard the mineral as hypersthene, and to style the rocks in question hypersthene-rocks or hypersthenites. Modern methods of optical examination have proved that the pyroxene is not a rhombic but a monoclinic one. Des Cloizeaux,<ref>*Manuel de minéralogie,* vol. i., p. 58.</ref> writing in 1862, says: "A specimen labelled hypersthene from the Isle of Skye, from the Museum at Paris, gave me all the characters of a [monoclinic] pyroxene, with cleavages parallel to the faces $m$, $h^1$, and $g^1$ [the prism and the two pinacoids], and obliquity of the system of rings as seen through $h^1$". Subsequently Zirkel and Judd found that this monoclinic pyroxene is the dominant one, the rhombic mineral being of exceptional occurrence. This indeed might be inferred from the content of lime. The analyses I. to VI., quoted below, show that the lime makes about 20 per cent., while the magnesia is 14 to 16 per cent., and the ferrous oxide ranges from 9 to 14: further, that the alumina is quite low. The dominant pyroxene of the gabbros is therefore a malacolite with a moderate amount of iron. The molecular ratios

FeO: MgO: CaO

range in the six analyses from

0.55: 1.05: 1.00 to 0.34: 1.11: 1.00,

and it is noticeable that they do not give

FeO + MgO = CaO,

as required by Tschermak's formula.<ref>Compare Teall's remarks on the augite of the Whin Sill, a rock presenting numerous analogies with the Skye gabbros. *Quart. Journ. Geol. Soc.,* vol. xl., pp. 648, 649: 1884.</ref>

| I. | | II | III | IV | V | VI | VII |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 51.30 | 50.80 | 53.046 | 51.362 | 51.936 | 49.268 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $TiO_2$ | | | | | 0.38 | | |
| $Al_2O_3$ | 0.76 | 3.00 | 4.816 | 1.662 | 1.322 | 0.222 | 11.45 |
| $Fe_2O_3$ | | | | | | 2.17 | |
| FeO | 13.92 | 9.61 | 11.389 | 8.968 | 13.9 | 12.15 | 14.17 |
| MnO | 0.25 | P08 | 0.078 | 0.332 | 0.25 | 0.381 | |
| MgO | 14.85 | . 15.06 | 11.576 | 16.471 | 13.85 | 14.812 | |
| CaO | 20.15 | 19.35 | 19.808 | 20.837 | 19.363 | 20.256 | |
| $Na_2O$ | | 0.44 | | | | | |
| $K_2O$ | | 0.22 | | | | | |
| $H_2O$ | 0.21 | 0.60 | 0.626 | 0.5.4 | 0.2 | 0.719 | |
| | 101.44 | 100.16 | 101.339 | 100.172 | 101.252 | 99.978 | |
| Sp. gr. | 3.34 | | 3.3293 | 3.329 | 3.335 | 3.321 | |

I. "Diallage, Skye": anal. G. vom Rath, *cit.* Rammelsberg, *Handbuch der Mineralchemie,* p. 465: 1860.

II. Augite, Loch Scavaig: anal. S. Haughton, *Dubl. Quart. Journ. Sci.,* vol. v., p. 95: 1865. From gabbro of which bulk-analysis is given, p. 103.

III. Augite, "in large lustrous greyish-green crystals", Coire na Creiche: anal. M. F. Heddle, *Trans. Roy. Soc. Edin.,* vol. xxviii., p. 479: 1879.

IV. Augite, "in large green crystals which weather pale, and assume on an outer film a lustre which is metallic and somewhat bronzy", Harta Corrie: anal. M. F. Heddle, *ibid.*

V. Augite, "slightly weathered, with a brownish-green colour, and a slightly bronzy lustre", Druim nan Ramh: anal. M. F. Heddle, *ibid.,* p. 480.

VI. Augite, "large, dark-green, cleavable masses", from near the shores of Loch Scavaig: anal. M. F. Heddle, *ibid.*

VII. "Diallage" Skye: anal. F. Herwig, *Programm desk. Gymnasium Saarbrücken,* 1884; *cit. Zeits. f Kryst.,* vol. xi., pp. 67, 68: 1886. [It is not stated that this mineral was from the gabbro.]

The augite crystals are as a rule all otriomorphic, and often tend to enwrap the felspars. Twinning parallel to the orthopinacoid is found, but not very frequently. The prismatic cleavage is occasionally supplemented by others, much less perfect, parallel to the two pinacoidal forms. Exceptionally a parting parallel to the ortho-pinacoid almost supersedes the ordinary augite-cleavage, and this is associated with a sub-metallic lustre on the planes of parting (diallage). Zirkel describes the examples collected and examined by him as for the most part diallagic. Professor Judd, speaking of the peridotites and gabbros of the Western Isles collectively, recognises both augite proper and diallage, and ascribes the peculiar nature of the latter to a system of "schiller "-inclusions arranged parallel to the orthopinacoid. He adds that in the central portion of the Skye gabbro the augite exhibits a still further modification. "In addition to the enclosures along the planes parallel with the ortho-pinacoid, other enclosures make their appearance in planes cutting these at an angle of 87½° [? 90°], or parallel with the clinopinacoid… . Frequently another set of enclosures may be detected as making their appearance along a third set of planes, which appear to be parallel to the basal plane".<ref>*Quart. Journ. Geol. Soc.,* vol. xli., p. 379: 1885.</ref> For this variety he adopts Dana's term pseudo-hypersthene. It does not appear from our study of the Skye gabbros that the diallage-structure, though it is often found (Plate 18)., Fig. 5, is the most usual modification of the augitic constituent. Much more common is what may be called the salite-structure, which appears in thin slices as a delicate striation parallel to the basal plane (Plate 18), Fig. 4. The same remark applies to some other British gabbros, including those of Carrock Fell and St David's Head. The basal striation is described by Mr Teall in the Whin Sill, and has been noted in other rocks by many observers. The structure has been variously explained as due to a minute parallel intergrowth of two different minerals, to exceedingly fine twin-lamellation, or to a system of minute parallel inclusions. A large number of slices of the Skye gabbros have not enabled us to establish any conclusion as regards the true nature of the structure. A parallel intergrowth of augite and hypersthene would accord well with the chemical composition of the mineral, which shows a striking deficiency in lime as compared with the ideal formula of a malacolite; but the perfectly normal optical orientation of the crystals seems to negative such a supposition. In many of our rocks the basal striation is accompanied by a set of microscopic inclusions, also parallel to the basal plane; but in other cases such inclusions, if they exist, are so minute as to evade observation, and there is nothing to suggest that the striation is necessarily dependent upon them. Professor Judd's view<ref>*Min. Mag.,* vol. ix., pp. 192–196: 1890.</ref> seems to be that a fine lamellar twinning is first produced, parallel to the basal plane, and that this direction thereupon becomes a "solution-plane" or plane of chemical weakness, along which "schillerisation" is subsequently set up.

The geologist just named holds the schiller-inclusions to be of secondary origin. Without entering into a complete discussion of this question, we may briefly express our opinion that the arguments advanced in support of this theory by no means carry conviction. The fact that the peculiarity in question often affects only a portion of a crystal, sometimes with a capricious distribution, does not seem to be inconsistent with the primary origin of the phenomenon. Again, although it is true that the alteration of augite along cleavage- and other cracks sometimes gives rise to minute inclusions, these are not, in the examples which we have examined, of a kind comparable with those under discussion. The bronzy lustre sometimes seen in the field is, however, due to a surface-tarnish.

The augite of the gabbros proper (as distinguished from diabasic varieties) usually has a more or less evident striation, either basal, or less frequently orthopinacoidal, or sometimes both. The structure is most pronounced in the coarser-textured rocks, and especially in the interior of the great gabbro mass, though it is not invariably very marked there. This, as Professor Judd remarks, implies that it is, in some measure and in some manner, connected with the depth at which the rocks were originally situated. When either the salite-structure or the diallage-structure is strongly developed, the mineral exhibits in hand-specimens a sub-metallic lustre, often with a bronzy colour. Otherwise it has the ordinary appearance of augite, black, or dark green, or with a rusty tinge.

We have observed nothing which seems to prove a secondary origin for either salite- or diallage-structure, or for the schil-lerisation which may accompany them: on the other hand, there are various circumstances which lead us to regard them as original. One point only may be noticed here. Crystals of augite picked up from the gabbro by a granitic magma, and thereby converted into hornblende, are found exhibiting the traces of basal striation, marked out by a schiller-structure.<ref>*Quart. Journ. Geol. Soc.,* vol. lii., p. 324; Pl. XIII , Fig. 3: 1896.</ref> Since the intrusion of the granite, according to all the evidence, followed the gabbro after only a short interval, this goes far towards establishing the structures in question as of primary origin.

In thin slices the augite is pale brown to nearly colourless, without sensible pleochroism. The extinction-angle *c c* is 39° or 40°. Herwig found for a "diallage" from Skye the abnormally high angle 51° 25′, but the specimen, if from the gabbro, was evidently an exceptional one, as appears from the partial analysis quoted above (VII.). In a large number of cases tested the axis of elasticity nearest to the vertical axis has always been found to be c, not a [old German lettering].

The augite is not often chloritised or serpentinised. Magnetite-dust or some other finely divided opaque matter disseminated through the crystals, or through parts of them, is sometimes found, and is probably a result of alteration. The most common change in the mineral, however, is a partial or even total conversion to hornblende, green, or greenish-yellow, or greenish-brown. Whether fibrous or compact, this is always formed in the usual crystallographic relation to the augite, viz. with the *b* and c axes common and the basal planes (as usually taken) inclined in opposite directions. Thus in a clinopinacoidal section the extinction-angles, 39° or 40° for the augite and 14° to 16° for the hornblende, are on the same side of the vertical. A brown hornblende, which seems to be original, is occasionally found in small patches intergrown with the augite according to the same law. Biotite seems to be wholly wanting among the normal rocks, though it is found near contacts with basalt, etc., and in some of the metamorphosed gabbros.

Although Macculloch and others, working without the advantage of modern methods of precision, erred in regarding the dominant pyroxene of the Cuillins as *hypersthene,* they were not without warrant in recording the occurrence of that mineral. This is proved by the analysis quoted below, which is clearly that of a hypersthene belonging to the highly ferriferous variety for which Professor Judd has revived vom Rath's name amblystegite. Professor Judd. has himself recorded this mineral from the gabbros of Loch Coruisk.<ref>*Quart. Journ. Geol. Soc.,* vol. xli., pp. 380, 413; P1. XI., Figs. 7, 8: 1885.</ref>

| | |
|---|---|
| $SiO_2$ | 51.348 |
| FeO | 33.924 |
| MgO | 11.092 |
| CaO | 1.836 |
| $H_2O$ | 0.500 |
| | 98.700 |
| Specific gravity | 3.338 |

Hypersthene (amblystegite), Cuillins: anal. Thos. Muir, Thomson's *Outlines of Mineralogy,* vol. i., p. 202: 1836. [In the paper by von Oeynhausen and von Dechen (Karsten's *Archiv für Mineralogie, etc.,* vol. i., p. 74: 1829) this analysis is wrongly ascribed to Thomson. Further, the item $Al_2O_3$ 1.300 is inserted, apparently in order to make up the 100 per cent., although the total is still given as 98.700.]

The molecular ratio FeO : MgO + CaO given by this analysis is about 1.52 : 1.00.

The rhombic pyroxene seems to be rather rare in the Skye gabbros. In some other parts of the Western Isles it appears, according to Professor Judd, to be more widely distributed, though it is perhaps more frequently associated, with ultrabasic than with basic rocks. Only one of our specimens, from Coire na Banachdich (S2637) [NG 44 22], has hypersthene as the dominant pyroxenic constituent. The crystals are idiomorphic, though not perfectly bounded. Two varieties occur side by side; the one clear and showing pale tints in thin slices; the other deeply coloured, with a strong "schiller" structure parallel to the orthopinacoid, and also densely charged at the margin and along cracks with finely-divided magnetite, evidently due to secondary alteration. The pleochroism-scheme, so far as it can be made out, is:

| | **Pale crystals** | **Deeply coloured** |
|---|---|---|
| a = *a* | Pale rose | Deep brown (with a greyish tone) |
| b = *b* | Very pale | Reddish brown |
| c = c | Very pale apple-green | ? |

[old German letters a,b,c in above]

A rhombic pyroxene occurs as a subordinate accessory mineral in some other gabbros examined from the Cuillins. In the analysed rock (S8043) [NG 481 232], where it forms 2 *per cent.,* it is an enstatite, as appears clearly from its low specific gravity (3.0).

*Olivine is* a very frequent constituent of the Skye gabbros, though less constant than might be expected from the accounts given by Zirkel and Judd.<ref>These writers, it must be noted, deal with a wider region than the Isle of Skye, and both appear to have paid special attention to the rocks of Mull. Zirkel states that the Skye rocks are poorer in olivine than those of Mull. Prof. Judd, however, believes that "all the gabbros in their unaltered condition contained olivine, though in very varying proportions". (*Quart Journ. Geol. Soc.,* vol. xlii., p. 62: 1886.)</ref> As usual, it is strictly idiomorphic, but with a strong tendency to rounded outlines. There is rarely any appearance of regular cleavage-cracks. The commonest inclusions are minute flat rectangular cavities containing dendritic growths of magnetite.<ref>See Judd, *Quart. Awn. Geol. Soc.,* vol. xli., Pl. XII., Fig. 5: 1885. </ref> There is often also a copious separation of magnetite dust in cracks and at the margin of a crystal, this being evidently a secondary phenomenon (Figure 21). It may be taken as indicating that the olivine is a variety rich in iron, and, although there are no published analyses of Skye olivines, this is borne out by the high density of the mineral in our gabbros. The olivine of the analysed rock (S8043) [NG 481 232] sinks in a liquid of specific gravity 3.44. An olivine analysed by Heddle<ref>*Min. Mag.,* vol. v., p. 16: 1884.</ref> from the neighbouring island of Rum, with 18.7 per cent. of ferrous oxide and 2.9 of ferric, gave the specific gravity 3.327: this was from the peridotite group.

The olivine is often fresh, and then sensibly colourless in thin slices. The commonest change is the separation of iron-oxide already mentioned. Complete destruction of the mineral sometimes gives rise to pseudomorphs of green or yellow or brown serpentine, the secondary magnetite being largely reabsorbed. In other rocks round pseudomorphs of fibrous (pilitic) hornblende seem to represent vanished grains of olivine. A third kind of transformation is of rarer occurrence: *e.g.* slide (S2636) [NG 44 22] from Coire na Banachdich. This results in pseudomorphs of which the chief element is a mica-like mineral of yellowish-brown colour with one strong cleavage and sensibly straight extinction. The pleochroism is strong, vibrations parallel to the cleavage giving the deeper absorption. Embedded in this substance are rounded patches with a more confused structure: these too are pleochroic, but the stronger absorption is for transverse vibrations. These pseudomorphs recall some described from the olivine-diabases of Derbyshire,<ref>Arnold-Bemrose, *Quart. Journ. Geol. Soc.,* vol. 1., pp. 613 *et seq.:* 1894.</ref> and are in some respects comparable with the iddingsite of Lawson.

Original *iron-ores* are present in most of the gabbros, though never abundant in the normal rocks and often wanting. They occur usually in irregular shapeless grains, often moulded upon the felspar crystals and sometimes on the augite, proving that they are not very early products of consolidation. When there is anything of crystal-outline to indicate the nature of the mineral the forms are almost always those of magnetite, and this may be inferred to be the common iron-ore in this group of rocks. The characteristic skeleton crystals of ilmenite are rarely observed *e.g.* (S2635), but the discrimination of the two minerals in rock-slices leaves much to be desired. Petrologists are not agreed as to the existence of "titaniferous magnetite", as distinct from a mixture of magnetite and ilmenite, and some have suggested the possibility of ultra-microscopic intergrowths. We have not observed any appearance of visible intergrowth, and the iron-ore of the highly ferriferous seams on Druim an Eidhne, which analysis shows to have the composition of a mixture of the two minerals, behaved as a homogeneous substance when etched by hydrochloric acid, the solution obtained containing titanic acid.<ref>Geikie and Teall, *Quart. Journ. Geol. Soc.,* vol. L, p. 652: 1894.</ref> Chromite has not been detected in the microscopic examination of the rocks.

It is a curious fact that the gabbros, even when they do not usually contain any large proportion of iron-ore minerals, are capable of becoming highly magnetised. This may be verified on almost any prominent peak or ridge of the Cuillins, and accounts for the fact that the indications of the compass are in such situations wholly untrustworthy. The effects observed must be ascribed to atmospheric electricity, but the peculiar distribution of permanent magnetism in the rocks is not easily accounted for. It may be roughly described as equivalent to a number of magnetic poles of both kinds scattered through the mass of the rock without appearance of order or regularity, usually only a few inches or at most a few feet apart.<ref>Harker, *Proc. Camb. Phil. Soc.,* vol. x., pp. 268–278, Pl. XL, XII.: 1900.</ref>

In this connection it may be remarked that Sir A. Rücker<ref>*Proc. Roy. Soc.,* vol. xlviii., p. 521: 1890.</ref> has determined in his laboratory the magnetic susceptibility of a number of Skye gabbros. Eleven specimens from Loch Coruisk gave from .00049 to .00684, with a mean of .00237. Four other Skye gabbros gave from .00246 to .00747, the mean for the fifteen being .00323. The Skye basalts were not tested, but thirteen from Mull gave a mean of .00163: it is not clear whether these rocks were lavas or sills.

*Apatite* is never an abundant mineral in the Skye gabbros, and does not occur in most of the slides. Specially remarkable is its absence from such highly basic modifications as the seams rich in iron-ore, just referred to; while it is found frequently, though locally and in no great amount, in more acid members of the group, including the felspathic gabbro veins which traverse the seams in question.

One or two exceptional rocks, probably segregation-veins, contain *quartz* (S2635) [NG 44 22]. As usual in quartz-gabbros, this mineral occurs as a constituent of micropegmatite, intergrown with felspar which, in part at least, is orthoclase.

Macculloch recorded the occurrence of abundant *garnet* in one locality.<ref>*Description of the Western Islands of Scotland,* vol. i., p. 419: 1819. The text says "in the hill Scuir na Streigh", but Macculloch included under that name not only the Sgürr na Stri of the *Ordnance* Survey, but also Sgùrr an Eidhne and Druim an Eidhne.</ref> Although Zirkel throws doubt on the statement, and we have not succeeded in verifying it on the ground, it is doubtless correct. Cohen<ref>*Sammlung* von *Mikrophotographien der* Inikroskopischen *Structur von Mineralien and Gesteinen,* 3rd ed., Pl. V., Fig. 4; 1899.</ref> has given a photograph of a garnet, enclosing other small garnets, from a "granulite" in Skye, doubtless one of the "granulitic gabbros" of the Cuillins, and probably from Druim an Eidhne. We shall see reasons, however, for doubting whether these rocks really form part of the gabbro group.

The *special mineralogical variations* met with among the rocks require only a few remarks. Among the Skye gabbros varieties departing very notably from the average as regards mineralogical constitution are of quite rare occurrence, except in connection with the banded structure to which we have adverted. A few of these exceptional occurrences are worthy of mention. One variety is so rich in olivine as to be petrographically almost a peridotite. Such a rock, with specific gravity 2.925, occurs on the right bank of the Scavaig River. A thin slice shows that more than half of it consists of fresh olivine. The next abundant constituent is labradorite (not anorthite as in the troctolites in the peridotite group).

Augite, of light brown colour and with some diallagic structure, is in rather subordinate amount, forming spreading crystal-plates which enclose the olivine in pcecilitic fashion. There are a few little octahedra of opaque black iron-ore, apparently magnetite. Next, a rock from Coire na Banachdich, already mentioned, is a norite, consisting of felspar, idiomorphic crystals of hypersthene, some strongly schillerised and others quite clear, and a small amount of interstitial augite (S2637) [NG 44 22]. It is noticeable again that the felspar is labradorite, as in the normal gabbros: the norites belonging to the peridotite group have anorthite.

The *texture and micro-structure* of the rocks exhibit considerable variations. Among the normal gabbros a large number of examples have crystals measuring about 1/10 inch, or ranging from 1/20 to 3/20 inch, but much coarser rocks also occur, especially in the heart of the mountains, the individual crystals being sometimes as much as an inch in length, or exceptionally two inches. In the pegmatoid veins and lenticles occasionally intercalated in the normal massive gabbbros crystals of augite sometimes attain a length of six or eight inches. The mutual relations of the two principal constituents of the gabbros are not always the same. As a rule the felspar tends to be idiomorphic towards the augite, and may be said to be of earlier crystallisation (Figure 21). It may be remarked, however, that the "order of crystallisation" should properly signify the order in which the several minerals *began* to separate from the molten magma, while the manner in which the crystals fit together can only indicate the order in which they *ceased* to form. The fact that the relations vary sometimes in one and the same thin slice leads to the conclusion that the periods of crystallisation of the several minerals (including the magnetite) overlapped considerably. In some of the coarser rocks the augite is very distinctly idiomorphic towards the felspar, and this is notably the case in many of the pegmatoid veins and streaks. In some of the coarse and most of the finer-textured rocks, on the other hand, the augite tends to wrap round the felspar, and there are diabasic varieties in which the structure is frankly *ophitic.* These are found in general only in the marginal portions of the complex. Taken apart from their associations, such rocks would be styled diabases, but from the point of view adopted they are regarded as modified forms of the gabbros.

Sharply distinguished from gabbros proper and diabases are the *"granulitic* gabbros" or, as Continental petrographers would name them, "pyroxene-granulites". They are dark, dense, rather fine-grained rocks, the individual crystals having diameters up to about th inch only, consisting of labradorite and augite (with basal striation), with little octahedra of magnetite. The micro-structure is of the granulitic kind, and, when either of the principal constituents shows an approach to idiomorphism, it is the augite, not the felspar (Figure 22). The true nature of these rocks is a matter of some uncertainty, and it is not improbable that they are highly altered representatives of basic lavas entangled in the gabbro complex. The occurrence of oval spots like much-changed amygdules lends colour to this idea. Sir A. Geikie and Mr Teall<ref>*Quart. Journ. Geol. Soc.,* vol. 1., p. 647: 1894.</ref> were disposed to discard this opinion in view of the micro-structure of the rocks; but the occurrences since examined and mapped in the western Cuillins prove that very radical transformations are possible in the metamorphism of the basaltic lavas by the gabbros. In no case have the granulitic rocks in question been observed to intersect the gabbros proper, though the converse relation is frequently verified. It may be that two distinct rocks have been confused together, viz, a granulitic variety of the gabbro and metamorphosed lava closely simulating it. Only those rocks have been mapped as metamorphosed basalts which afforded some positive evidence of that origin, the rest being thrown in with the gabbro. Rosenbusch's suggestion<ref>*Mikroskopische Physiographie der Massigen Gesteine,* 3rd ed., p. 492: 1896.</ref> that Judd's granulitic gabbros correspond with the "beerbachite" of Chelius (an aplitic rock occurring as small dykes and veins in gabbro) seems to be based on a misunderstanding. We have not observed any rock comparable with beerbachite in Skye, the veins which traverse the gabbro being of quite other types.

The gabbro contains in many places irregular veins and streaks of coarse texture, which we may term *pegmatoid gabbro.* They are not very sharply bounded against the normal rock, and are doubtless to be regarded as quasi-contemporaneous segregation-veins. Unlike most of the gabbro, they have augite idiomorphic towards felspar, sometimes in imperfectly-built crystals six or eight inches long. These pegmatoid streaks have been observed chiefly in the heart of the gabbro laccolite. A specimen was examined from Coire na Banachdich; a coarse rock with augite crystals two inches long. In a thin slice (S2635) [NG 44 22] this augite is pale brown, with basal striation, and there are in addition psendomorphs after a rhombic pyroxene. The felspar seems to be a somewhat acid labradorite. The iron-ore is titaniferous, and there are also a few little crystals of light brown sphene. The rest of the interspaces between the felspar and augite crystals is occupied by a delicate micropegmatite. A point of some interest is the presence of rather numerous little needles of apatite, a mineral comparatively rare in our gabbros, though it is found generally in the granites and granophyres of the district.

In many parts of the mountains the gabbro is traversed by pale veins of finer texture, which cut it sharply (*see* (Plate 6)). They cut all varieties of the gabbro, but never any of the many dykes and sheets of various later ages by which the gabbro is intersected. This may be taken to indicate that the veins are closely bound up with the gabbros, and belong to the close of the gabbro-epoch, their magma being presumably a highly specialised derivative from the gabbro-magma, or representing its residual portion. They are very considerably more acid, and have in consequence a very different mineralogical constitution. Two types of veins are to be recognised, both to be distinguished from the true acid veins (granite and granophyre), which belong to the succeeding epoch, and to which they sometimes bear a resemblance at first sight.

There are firstly *veins of felspathic gabbro,* found in some places traversing the darker and more pyroxenic normal rocks. Besides a paler colour, they have a somewhat finer texture, though not so fine as the other kind of veins to be mentioned. They are less common, and are usually seen to be in connection with rather larger sheet-like bodies of similar rock, from which they are offshoots. Veins of this kind on Druim an Eidhne have been described by Sir A. Geikie and Mr Teall.<ref>*Quart. Journ. Geol. Soc.,* vol. 1., pp. 650, 654: 1894.</ref> Petrographically they are gabbros of a type poor in the ferro-magnesian silicates and iron-oxides. Further, they have oligoclase in some abundance, in addition to labradorite. The scanty augite seems to be in part proper to the rock, in part picked up from the normal gabbros. Apatite is a very noticeable constituent.

Secondly, there are *white felspathic veins,* which are more widely distributed than the preceding. Their width is often about an inch, but they range up to a foot or more in places, and also sink to very minute dimensions. They frequently ramify and anastomose; and exceptionally, when this is carried to an extreme, the gabbro looks like a breccia of angular fragments set in a matrix of the white felspathic rock. The veins are white or cream-coloured and of relatively fine texture, having often a saccharoid appearance. In some cases there are also little crystals up to ■ inch. One specimen gave the specific gravity 2.58, indicating a composition very different from that of a gabbro. Slices show that the rocks consist essentially of oligoclase and orthoclase, in about equal quantity or the latter predominating (S7847) [NG 495 264]. Quartz is never present. A little augite or uralitic hornblende and magnetite may occur, but these are, at least mostly, derived from the country rock. The felspars are often more turbid than is usual in the felspars of the gabbro. Epidote is occasionally found in granules, or again in little crystals about $_{\text{T}}$y, inch long (S8046) [NG 484 241].

These light-coloured veins are not equally common in different parts of the area. They are especially characteristic of the eastern half of the Cuillin mass, including the Blaven range.

We have already alluded to the heterogeneous appearance not infrequently observed in the Cuillins in what must still be regarded as a geological unit, a sheet-like mass of gabbro the product of a single intrusion. The heterogeneity may show itself in two ways, by a patchy, or more frequently a banded, structure and by the occurrence of true xenoliths. The distribution and arrangement of the banded structure in the gabbros of the Cuillins have already been pointed out: we have now to consider briefly the *petrographical character of these banded rocks.* In this there is not much to be added to the description given by Sir A. Geikie and Mr Teall of the typical examples on Druim an Eidhne.

As seen in the field, the appearance is simply that of alternating layers and seams differing in texture and in the relative proportions of the component minerals. The latter difference, when noteworthy, is made evident by difference of shade, lighter and darker bands corresponding with a preponderance of the felspathic and the pyroxenic constituents respectively (*see* (Plate 5) and (Plate 6), above). The differences may be slight or very considerable, and the width of the individual bands may vary within rather wide limits. When this is so, the greatest contrasts in petrographical constitution are found in connection with the narrowest bands, and the extreme variation, resulting in a nearly black variety very rich in augite and iron-ores, is found in thin seams only. In these respects the rocks are comparable with the banded peridotites already described.

Conspicuous banding in the gabbros is not confined to the sheet-formed intrusions which compose the great laccolitic mass: it is found also in some of the dyke-formed offshoots from the gabbro, which intersect the earlier peridotite group as already described. The phenomena are well seen in the glen immediately to the south of Allt a' Chaoich, near Loch Scavaig. The apophyses of the gabbro at that place are partly in the form of straight vertical dykes, partly a system of irregular ramifying veins, and it is the former only that display banding. These *dykes of banded gabbro* (Figure 23) are instructive for comparison with the banded sheets. A single dyke shows considerable differences of composition in successive bands parallel to the bounding walls. Further, it may show considerable differences of texture, becoming more fine-grained towards the edge, and presenting a thoroughly close-textured selvage indicative of comparatively rapid chilling. This character, however, is not always found, and it may occur on one side of the dyke only: such an asymmetric dyke is illustrated in the figure (A). Since the dyke is not insinuated between two different members of the peridotite group, but cuts across the banded ultrabasic complex at a high angle, it is clear that a single intrusion of the gabbro magma would have cooled evenly at its two edges; and we are led to the conclusion that this dyke is the result of more than one injection, the right (eastern) portion being somewhat younger than the left (western), though following it so closely that no very well defined division is to be perceived between them.

It is worthy of note that in this dyke the banded structure is more sharply marked in the earlier (left-hand) half. The left and right portions do not perhaps differ greatly in average composition; but the former presents a generally pale ground, in which occur several very conspicuous dark seams, not much more than ¼ inch in width. That the earlier and more rapidly cooled portion is the more heterogeneous cannot, however, be ascribed to differentiation in place, for the banding does not stand in any evident relation to the surface of cooling. One dark basic seam does indeed form the actual margin, but others no less marked occur in the interior.

A good idea of the actual range of variety in the banded gabbros is given by the following chemical analyses by Mr J. H. Player<ref>*Quart.* Journ. *Geol. Soc.,* vol. 1., p. 653: 1894.</ref> of bands occurring in close association with one another on Druim-an-Eidhne (p. 120).

The third specimen is especially interesting. It is ultrabasic in the fashion, not of the peridotites, but of the eruptive iron-ore rocks described by Vogt from Norway and elsewhere. The base which increases rapidly as the silica falls off is not magnesia but iron-oxide. Hence we find that olivine is present only sporadically and in trifling amount, while iron-ores make up about one third of the rock. If it is to be regarded as a mixture of true magnetite and ilmenite, these are present in about equal proportions, a small quantity of pyrites being also indicated by the analysis. It is very noteworthy that both the augite and the felspar in this highly basic seam are identical with those of the ordinary gabbros. The felspar is a labradorite, while in one slide (S5376) [NG 49 22] andesine and even oligoclase are recognised by their extinction-angles. Very remarkable is the absence of anatite.

The bands contain different proportions of the constituent minerals, and narrow dark seams of *very* basic composition are especially conspicuous. There are also considerable differences in texture. In A the gabbro is coarse towards the right (eastern) side of the dyke, and becomes progressively finer towards the left. It is in the fine-textured part that the dark seams are most distinct and most regular. In B the rock is coarsest in the middle of the dyke, and becomes finer towards the sides, presenting evidently chilled margins to the peridotite.

These dykes bear nearly N.N.E.–S.S.W., cutting the banding of the peridotite at a high angle, and each has a width of about 1 ft 6 ins.

That the various bands crystallised simultaneously, and must therefore have existed side by side in the fluid state, is shown by the fashion in which their crystals interlock at the common surface of two contiguous bands. It also appears that flowing movement had in most places practically ceased prior to the beginning of crystallisation, for, as a rule, there is no parallel arrangement of the constituent crystals. To this statement there are only a few exceptions. One rock from Druim-an-Eidhne has a very decided fissile character, owing to parallelism of the felspar crystals, which here have a pronounced tabular habit (Plate 18), Fig. 6. Something similar occurs at the head of Loch Coruisk, but in general there is no special orientation noticeable. The several partial magmas seem to have been intruded while still completely molten and mobile, and their not mingling implies a high mutual surface-tension.

| | I | II | III | A |
|---|---|---|---|---|
| $SiO_2$ | 52.8 | 40.2 | 29.5 | 40.2 |
| $TiO_2$ | 0.5 | 4.7 | 9.2 | 5.2 |
| $Al_2O_3$ | 17.8 | 9.5 | 3.8 | 10.2 |
| $Fe_2O_3$ | 1.2 | 9.7 | 17.8 | 10.2 |
| FeO | 4.8 | 12.2 | 18.2 | 12.1 |
| FeS2 | | 0.4 | 0.4 | 0.2 |
| MnO | | 0.4 | 0.3 | 0.2 |
| MgO | 4.8 | 8.0 | 8.7 | 6.9 |
| CaO | 12.9 | 13.1 | 10.0 | 11.4 |
| $Na_2O$ | 3.0 | 0.8 | 0.2 | 1.5 |
| $K_2O$ | 0.5 | 0.2 | 0.1 | 0.3 |
| Ignition - | 1.2 | 0.5 | 0.5 | 1.1 |
| | 99.5 | 99.7 | 99.2 | 99.6 |
| Specific gravity | 2.91 | 3.36 | 3.87 | 3.43 |

I. (S5373) [NG 49 22]. A light-coloured band mainly composed of labradorite. The other constituents are augite, uralitic hornblende, and magnetite.

II. (S5377) [NG 49 22]. A dark band composed of augite, magnetite, and labradorite.

III. (S5376) [NG 49 22]. A thin ultrabasic "schliere", mainly composed of augite and magnetite.

A. Calculated mixture of 45.9 parts of I. with 54.1 parts of III., for comparison with II.

The mutual relations of the several rock-types associated together in the banded gabbros compel us to the conclusion that they were intruded simultaneously, and were derived from some common source, which may be pictured as a subterranean reservoir where the several fluid magmas existed together without commingling. If the distinct but closely associated magmas were the results of a "differentiation" of a common parent magma having more of the composition of a normal gabbro, the differentiating process was the result of causes which at present can be only a matter of speculation, and the question is not one to be discussed in this place. We may observe, however, that the governing conditions were probably of no very simple kind, for the process has evidently not followed always the same lines. The thin seam very rich in iron-ores analysed by Mr Player and described by Mr Teall appears to have had but little olivine; but in other similar seams from the same locality that mineral has been formed in abundance. It is represented mainly by pseudomorphs, sometimes serpentinous, sometimes "pilitic", and always containing much secondary magnetite.

It may be noticed that the variation indicated by the three analyses quoted is very closely of the "linear" type,<ref>Harker, *Journ. of Geol.,* vol. viii.,p. 391: 1900. </ref> *i.e.* the composition of the second rock could be very nearly reproduced by a mixture in proper proportions of the first and third, as shown in column A above, and as illustrated graphically in one of Professor Vogt's papers.<ref>*Zeits. prakt. Geol.,* vol. ix., p. 186: 1901.</ref>

A. striking feature in some parts of the Cuillins is the frequent occurrence of small *fragments or xenoliths of gabbro enclosed in gabbro of a somewhat different kind.* Sometimes the difference is not great, and the xenoliths are not seen distinctly except on a weathered face. Where, as sometimes happens, they are decidedly less durable than their matrix, they weather into little hollows, and, if numerous, give a curious pitted appearance to the surface of the rock. This is well seen at several places on the floor of Tairneilear and on the rocky platform just west of the mouth of that corrie. These xenolithic gabbros are no doubt to be attributed in general to the fact that the gabbro mass consists of numerous distinct intrusions, the later of which have often broken through the earlier. Possibly the phenomenon arises also in a rather different way. In numerous localities the xenoliths are found in the vicinity of enclosed patches of volcanic agglomerate, which contain abundant fragments of gabbro, derived, as we have pointed out above, from some older and wholly concealed mass of that rock. The agglomerates are greatly metamorphosed, and in some cases the actual boundaries of the patches are such as to suggest that portions have been incorporated in the gabbro magma. This points to a possible source of some of the xenoliths, but such an explanation cannot be extended to include all the occurrences. A third possibility, already suggested in the case of the peridotites, is that the xenoliths may have been brought up in the magma from a much lower level, being the result of local crystallisation in the magma-reservoir itself.

An instructive comparison may be made between the gabbros and the peridotites of the Cuillins, and some heads of such a comparison are set forth below in parallel columns. It will be observed that the peridotites are much more prone to variation than the gabbros, both in different intrusions and in the parts of a single intrusive body. The variations, however, follow very similar lines in the two groups of rocks, though with certain exceptions. Especially noteworthy is the difference between the extreme basic products of "concentration", chromium being the characteristic element in the ultrabasic and titanium in the basic rocks. This appears to be a general principle in the chemistry of igneous rock-magmas, and has been specially emphasised by Vogt.

In conclusion we shall briefly refer to the changes which' the Skye gabbros have undergone in some places since they first became solid rocks. It will not be necessary to say much in this place relative to the *thermal metamorphism* of the rocks, often very marked, in the neighbourhood of the subsequently intruded granite.

| **Ultrabasic Group** | **Basic Group** |
|---|---|
| (i) Rocks composed of predominant olivine and generally augite as the two principal constituents, often with little or no felspar (anorthite); variety characterised by a rhombic pyroxene not rare. | (i) Rocks composed of felspar (labradorite) and augite as the two principal constituents, with or without olivine; variety characterised by a rhombic pyroxene rare. |
| (ii) The several intrusions differing widely in average composition. | (ii) The several intrusions differing little in average composition. |
| (iii) Banding generally prevalent and usually strongly marked; bands of felspathic peridotite and troctolite alternating with others of picrite and peridotite very rich in olivine. | (iii) Banding in part of the rocks and locally strongly marked; bands of more felspathic gabbro alternating with others of more augitic gabbro and olivine-gabbro. |
| (iv) The more basic bands include seams rich in, or almost wholly composed of, spinels or iron-ores, highly chromiferous, | (iv) The more basic bands include seams containing a large per-tentage of iron-ores, highly titaniferous. |
| (v) A xenolithic character generally prevalent and often very conspicuous; xenoliths and matrix being sometimes varieties of one type, but frequently quite different types. | (v) A xenolithic character locally prevalent, though not often very conspicuous; xenoliths' and matrix being alike of gabbro, but of somewhat different varieties. |
| (vi) The picrite and peridotite often traversed by coarser segregation-veins of troctolite. | (vi) The gabbro often traversed by coarser segregation-veins of more felspathic gabbro. |

When the effects are merely metamorphic (not also metasomatic) they present no peculiarity. The most frequent change observed in this connection is a partial or total uralitisation of the augite of the rock, such as is seen in the metamorphosed gabbros in other regions. The much more remarkable changes which have been set up where there has been actual interchange of substance between the gabbro and the granite magma will receive full attention in their proper place. It is not always possible, however, to be quite sure to what extent this latter condition has contributed to some of the transformations observed. The formation of biotite in the rocks is a case in point. On the western slope of Beinn na Cro, for example, which is one of the best places for studying thermal metamorphism in the gabbros, little flakes of bronzy mica are often conspicuous on a hand-specimen. In a thin slice this mineral shows the usual deep-brown colour, with intense pleochroism, and seems to have been developed mainly at the expense of augite (partly also of magnetite). Certain peculiarities of the felspars, however, and the occasional presence of a little interstitial quartz (S8966) [NG 566 245] may be taken to indicate that there has been some small amount of impregnation of the gabbro by the granite magma, and it is not improbable that the formation of the mica also is due to something more than simple metamorphism.

The slow changes which affect igneous rocks independently of thermal and dynamic metamorphism, and apart also, as it seems, from atmospheric weathering, have left their mark in varying degree upon our gabbros. Here we may include the partial turbidity of much of the felspar, and here too the frequent passage of the augite into hornblende, which can by no means always be referred to any known "metamorphic" agent.

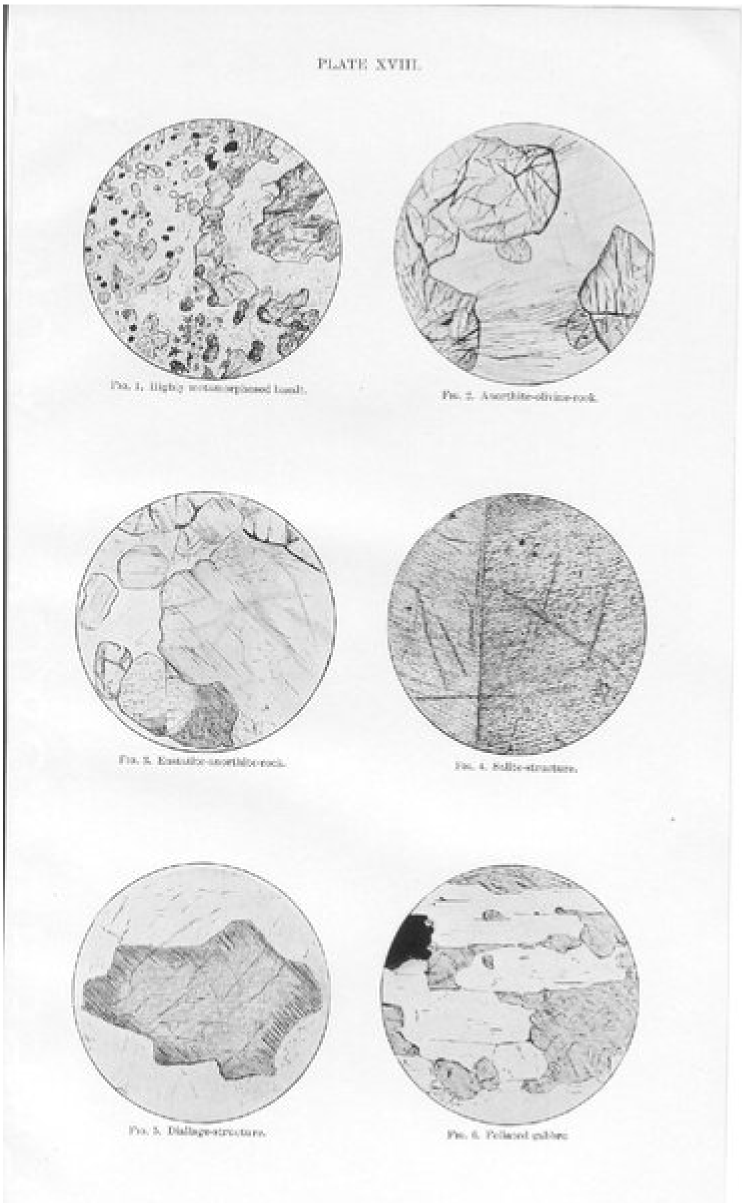
Concerning the *weathering* of the gabbro it is not possible to say much, for the reason that the rock is almost everywhere in a comparatively fresh condition. This is, of course, due to the scouring action of ice which has removed the superficial crust. The very few exceptions are of a kind to confirm the rule, for they are found in deep narrow gorges outside the actual mountain tract. The best instance is in the sides of Allt Coire na Banachdich below Eas Mòr, where the gabbro presents a very unusual appearance. Much of it is divided by plane joints into large blocks which, by the crumbling and scaling away of the surface, have taken on the form of giant spheroids. The rock is often so soft that it can be dug with a spade. The felspars remain when the other constituents have perished, and, breaking up, form a sand mingled with more or less of a rust-coloured clay, which represents the ferro-magnesian minerals of the gabbro. Another place where the gabbro is in a rotten condition is the gorge in which Allt a' Coire Ghreadaidh runs for nearly a mile of its lower course. Nothing of this kind is seen anywhere among the mountains and corries.

The other kind of decomposition which we distinguished in the basic lavas, viz. that connected with solfataric action, naturally finds no place in the gabbros, and no long list of alteration-products can be drawn up. Veins of chrysotile and of calcite are sometimes found, but they seem to be invariably connected with some degree of crushing and fracture of the rocks. Of recognisable new minerals the most frequent is perhaps greenish-yellow epidote, and this is sometimes found in good crystals. On Sgùrr Dearg, both on the S.W. ridge and. on the south-eastern slope, epidote crystals covered with radiating fibres of natrolite occur in cavities in the gabbro. Solid veins of white prehnite, with embedded crystals of epidote next the rock, occur on Druim nan Ramh. Rarely on the southern slope of Sgùrr nan Gillean there are veins containing doubly-terminating quartz-crystals sprinkled with mammilations of prehnite, and the latter mineral is also recorded in the gabbro of Coire Labain and of the west side of Sgùrr nan Gillean, just below Sgùrr a' Bhàsteir.<ref>See Heddle's *Mineralogy of Scotland.* pp. 65, 69, 104: 1901.</ref> Quartz-veins are found a little west of the summit of Sgùrr na Banachdich, but they seem to be in part connected with an enclosed patch of the basaltic lavas, and in the gabbro in general free silica is almost unknown.

The gabbro, at once a much more massive and a much stronger rock than the basalts, nevertheless shows sometimes *cataclastic effects* of an advanced kind. Such effects are confined, however, to the edge of the mass. They may be observed in specimens from various spots in Glen Sligachan and on Druim an Eidhne, and again from north of Garbh-bheinn and Belig, always near the boundary of the gabbro. As a rule the crushing has not been so directed as to set up a schistose structure, and often there is nothing in the appearance of a hand-specimen to indicate the crushing in its earlier stages. A more complete break-down of the rock, however, may be recognisable by an abnormally fine texture (though sometimes with uncrushed relics of the original rock), and in some cases by a dull aspect consequent upon chloritisation of the augitic constituent.

Thin slices of the more thoroughly crushed gabbros show various stages in the break-down of the original structure of the rock, culminating in what Törnebohm has styled "Mörtelstructur". The uncrushed remains of felspar and augite crystals are converted into round grains, embedded in a finely granular matrix. This may occur without any appearance of recrystallisation or of mineral change, the effects produced being purely mechanical (S7116) [NG 544 246], (S7120) [NG 532 240]. In other cases there is a partial uralitisation of the augite (S7462) [NG 520 214], or that mineral may be almost wholly replaced by a green hornblende (S2716) [NG 495 225]; but, as the specimens showing this come from the immediate neighbourhood of the granite, it may be an effect of thermal metamorphism.

Certain specimens examined, which have not been broken down in this way, exhibit strain-effects in the crystals of felspar, a peculiarity not found in connection with advanced cataclastic structures. Sometimes a crystal is bent, and where the curvature is sharpest there is a much closer twin-lamellation than elsewhere ((Figure 24), A). Again, we may see a crystal in which some of the twin-lamellae terminate abruptly against a crack ((Figure 24), B). Professor Judd<ref>*Quart. Journ. Geol. Soc.,* vol. xli., pp. 364–366; Pl. X., Fig. 1: 1885.</ref> has given an interesting discussion of the secondary twin-lamellation of the felspars in the peridotites and gabbros of the Western Isles, and is disposed to attach great importance to it. Phenomena such as we have referred to are found occasionally in many of the Skye gabbros, but we have seen nothing to suggest that the twinning is *in general* other than an original character.




*(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.*

FIG. 21.—[8043] × 20. Olivine-Gabbro, west bank of Sligachan River, just below Allt Coire Riabhach ; showing the ophitic structure. This is the rock analysed (I. above), and consists of labradorite, diallage, olivine with secondary magnetite, and a few small crystals of original magnetite.

*(Figure 21) [(S8043)](#) [NG 481 232] × 20. Olivine-Gabbro, west bank of Sligachan River, just below Allt Coire Riabhach; showing the ophitic structure. This is the rock analysed (I. above), and consists of labradorite, diallage, olivine with secondary magnetite, and a few small crystals of original magnetite.*

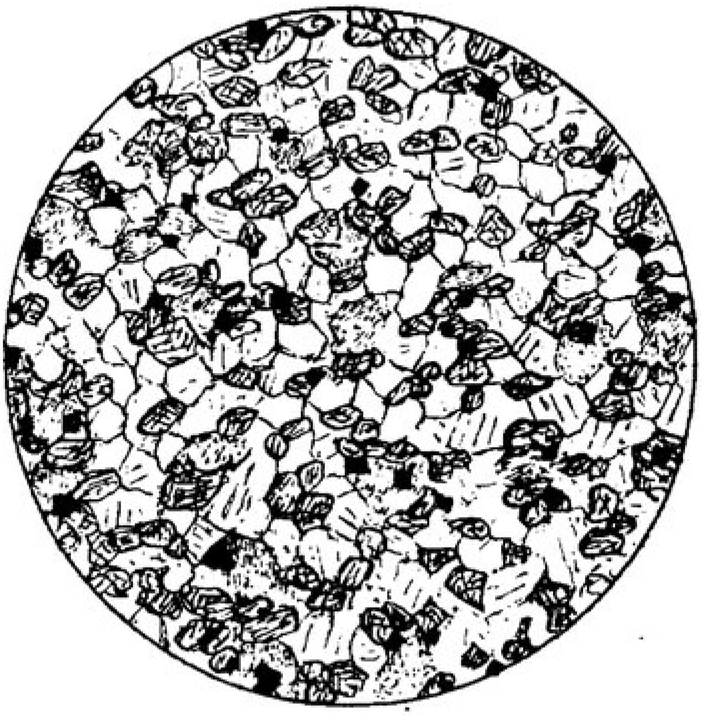
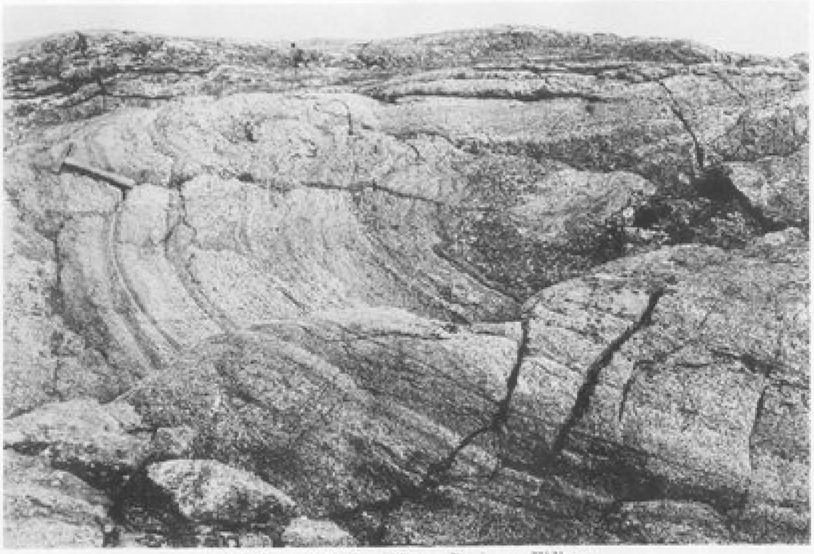


Fig. 22.—[5369] × 20. "Granulitic Gabbro," Druim an Eidhne; probably a highly metamorphosed basaltic lava. It consists essentially of a granulitic aggregate of labradorite and augite, with little octahedra of magnetite.

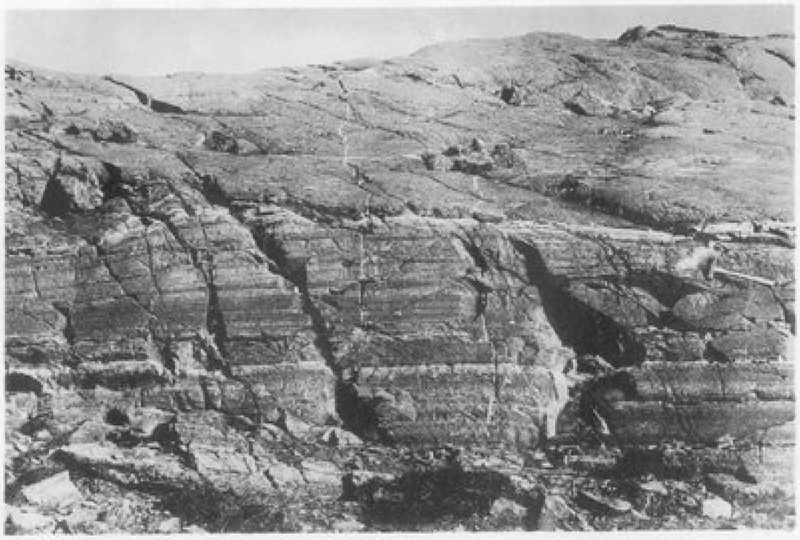
*(Figure 22) (S5369) [NG 49 22] × 20. "Granulitic Gabbro", Druim an Eidhne; probably a highly metamorphosed basaltic lava. It consists essentially of a granulitic aggregate of labradorite and augite, with little octahedra of magnetite.*



Banded structure in gabbro. Druim an Eidhne.

(Plate 6) Banded structure in gabbro, Druim an Eidhne.

PLATE V.



Strongly banded structure and felspathic veins in gabbro. Druim an Eidhne.

(Plate 5) Strongly banded structure and felspathic veins in gabbro, Druim an Eidhne.

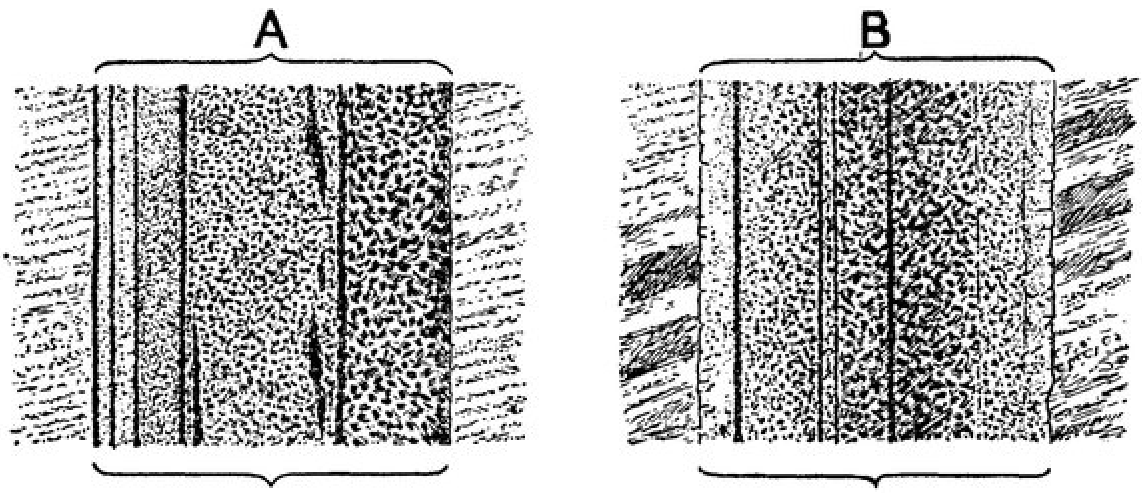



FIG. 23.—Dykes of banded gabbro cutting the banded peridotite group in glen south of Allt a' Chaoich, Loch Scavaig.

The bands contain different proportions of the constituent minerals, and narrow dark seams of very basic composition are especially conspicuous. There are also considerable differences in texture. In A the gabbro is coarse towards the right (eastern) side of the dyke, and becomes progressively finer towards the left. It is in the fine-textured part that the dark seams are most distinct and most regular. In B the rock is coarsest in the middle of the dyke, and becomes finer towards the sides, presenting evidently chilled margins to the peridotite.

These dykes bear nearly N.N.E.-S.S.W., cutting the banding of the peridotite at a high angle, and each has a width of about 1 ft 6 ins.

*(Figure 23) Dykes of banded gabbro cutting the banded peridotite group in glen south of Allt a' Chaoich, Loch Scavaig.*

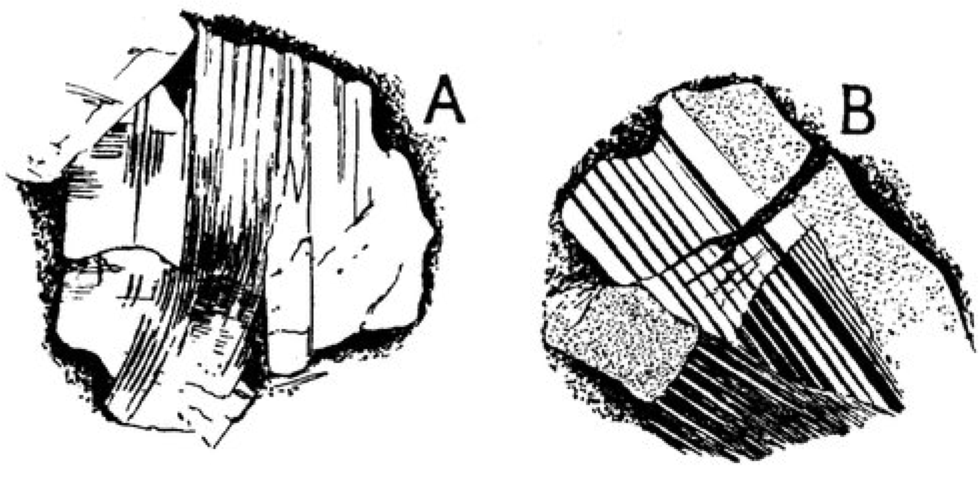



FIG. 24.—Secondary twin-lamellation, connected with strain, in the felspar of the gabbros : × 20, crossed nicols.

A [2637]. Coire na Banachdich.
B [5375]. Druim an Eidhne.

*None*