Chapter 10 Granites and granophyres: petrography

We proceed to describe in detail the acid rocks which build the large plutonic masses. Petrographically they vary from typical granites to varieties which Rosenbusch and others would designate granophyres. Sir A. Geikie, treating the large and small acid intrusions as a whole, has for convenience embraced them all under the general term granophyre. In our more detailed account it will conduce to clearness if we call the extensive masses which form the Red Hills granite, remembering, however, that in many places the rocks show some departure from the typical granitoid structure in the prevalence of micrographic intergrowths of felspar and quartz. The fine-textured spherulitic and other varieties, which in the Red Hills come in only in marginal modifications and apophyses, as well as the minor intrusions of granophyre and quartz-felsite of later date, which occur chiefly outside the tract of the Red Hills, will be reserved for description in a future chapter (Chapter 16).

The rocks of the Red Hills are of pale tint, usually yellowish on weathered faces. Little black lustrous crystals of augite or hornblende are usually visible. In many of the rocks these, with distinct crystals of felspar and irregular little grains of quartz, are embedded in a mass which has the rather dull confused appearance characteristic of fine micropegmatite. In the more granitoid rocks, on the other band, all the principal elements are apparent to the eye, or with a lens, and sometimes little flakes of dark mica are seen in addition to hornblende.

The *chemical composition* of the average type of the rocks is fairly represented by two complete analyses made by Dr. Pollard and quoted in columns I. and II. below. The rocks analysed are hornblende-bearing granophyres, the first from the large continuous area of the main Red Hills, the second from an independent laccolitic or sill-like intrusion, more than a mile across, forming Beinn a' Chaìrn, to the north of Loch Eishort. The latter rock belongs to a group of minor intrusions to be described in a later chapter (Chapter 13), but is introduced in this place to show its close resemblance to the large mass. Partial analyses of other specimens, selected for special purposes, are given under III. and IV., and for comparison with the Skye rocks we reproduce published analyses of similar Tertiary intrusions from Ireland and one of the Carrock Fell rock, which may also be of Tertiary age though the evidence is inconclusive. Of the Mull and Arran granites no analyses have yet been published.

It may be remarked that the British Tertiary granites (and granophyric granites) fall into two sub-groups, a more and a less acid. In the first sub-group the silica-percentage is about 75 to 77. The ferro-magnesian element is characteristically biotite, and is present only sparingly. This sub-group includes the granites of St Kilda, the Mourne Mountains, and the main mass of Arran, but is represented in Skye only by the Beinn an Dubhaich intrusion. In the second sub-group the silica-percentage is 70 to 72. The ferro-magnesian minerals are hornblende and augite, and are more abundant than before. Also there is a stronger tendency to micrographic intergrowth of felspar and quartz, so that many of the rocks are most typical granophyres. Here we include almost all the Skye rocks, with those of Mull and Carlingford, and the granophyre (of doubtful age) of Carrock Fell. We have not had the opportunity of studying specimens from the Isle of Rum. The rocks of the two sub-groups seem to occur always in separate areas, and we are not able to say whether there is any constant relation between them as regards relative age.

	I	II	III	IV	A	B	C	D
SiO_2	70.34	71.98	72.78	76.71	70.48	71.41	75.00	71.60
TiO_2	0.46	0.37						
Al_2O_3	13.18	13.13			l4.24	12.64	13.24	13:60
Fe_2O_3	2.66	1.33			3.72		2.52	2.40
FeO	2.24	1.64				4.76		not det.
MnO	0.19	0.14						
MgO	0.40	016			0.40	0.63		0:21
CaO	1.21	1.15		0:17	1.48	1.80	0.69	2.30
BaO	trace	trace						
Na_2O	3.61	2.98	4.08		3.66	3.03	3.07	5.55
Li2O	trace	not found	not found					

K_2O	4.90	4.93	5.18		4.26	5.47	4.33	3.53
H_2O above105°	0.76	1.38			1.59		0.80	0.70
H_2O at 105°			0:34	0122				
P_2O_5	0.10	0.19						
Cl	0.02	0.01						
	100.55	100.18			99.83	99.74	99.65	99.89
Spec. gravity	2.66	2.63	2.492	2.609	2.593	2.632	2.595	2.670

I. Hornblende Granophyre (S7124) [NG 526 246], Druim Eadar da Choire: anal. W. Pollard, *Summary of Progress* for 1899, p. 174. (The P_2O_5 and Cl here and the Cl in the next analysis have been inserted subsequently.)

II. Hornblende-Granophyre (S7064) [NG 630 172], Beinn a' Chàirnn, 3½ miles S. by W. of Broadford: anal. W. Pollard, *ibid.,* p. 173. Fluorine and sulphur sought but not found.

III. Riebeckite-Granophyre (S8856) [NG 495 227], between Meall Dearg and Druim an Eidhne: anal. W. Pollard.

IV. Granite (S8693) [NG 621 201] of Beinn an Dubhaich boss*,* in contact with limestone in Allt Cadha na Eglais: anal. *W.* Pollard.

A. Biotite-Granite, base of Slieve na Glogh, Carlingford; anal. S. Haughton, *Quart. Journ. Geol. Soc.,* vol. xii., p. 194: 1856.

B. Hornblende-Granite, Grange Irish, Carlingford: anal. S. Haughton, *ibid.,* p. 195.

C. Biotite-Granite, Slieve Corragh, Mourne Mountains: anal. S. Haughton, *ibid.,* p. 192.

D. Augite-Granophyre, Carrock Fell, Cumberland: anal. G. Barrow, *Quart. Journ. Geol. Soc.,* vol. li., p. 129: 1895.

The analyses show little that is out of the ordinary. It will be observed that soda and potash are about equally contained in these Skye rocks, when calculated to molecular proportions, one or other alkali slightly predominating. The molecular ratio Na_2O: K_2O is, for the first three analyses: 1.12, 0.92, 1.20.

The third rock, from Meall Dearg, is somewhat richer than the others in alkalies, and especially in soda; and this peculiarity shows itself in the formation of riebeckite as the ferro-magnesian element, while part of the felspar seems to be of the 'anorthoclase' type.

Some approximation to the percentage mineralogical composition of the rocks may be arrived at by comparison of the chemical and microscopical analyses. A rough calculation gives the results:

	I		II	
Quartz	27		29	
Orthoclase	33	55	29	59
Oligoclase	22		30	
Hornblende (with iron-ores)	17.5		11.5	
Apatite	0.5		0.5	
	100		100	

For the Carlingford granites Haughton, using a somewhat different method of calculation, found:

Quartz	20.70	17.16
Felspars	66.37	67.18
Mica	12.76	—
Hornblende	—	15.40

	99.83	99.74

Without actual analyses of the constituent minerals such calculations cannot, of course, give more than rough approximations but it appears that our rocks are richer in quartz and poorer in felspar than the Irish examples analysed.

A point of some interest as supplementing the ordinary chemical analyses relates to the nature and amount of the gaseous constituents contained in the rocks, chiefly if not wholly as inclusions in the crystallised minerals. Professor Tilden<ref>*Proc. Roy. Soc.,* vol. lx., pp. 453–457: 1897. *Chem. News,* vol. lxxv., pp. 169, 170 1897.</ref> found that two granites from Skye yielded respectively 1.6 and 2.8 times their own volume of mixed gases. The percentage composition of these gases was found in one case to be:

CO_2	23.60
CO	6.45
CH_4	3.02
N2	5.13
H2	61.68
	99.88

The important part played by hydrogen in this and other rocks and minerals investigated is a novel point. Spectroscopic examination failed to detect helium. The actual amount by weight of these gases in the rock is, of course, very small, being only about 0.04 and 0.07 per cent. in the two cases.

A large number of *specific gravity* determinations were made on the large acid intrusions. In some, as will be noticed later, the composition of the rock has been modified by absorption of gabbro or other basic material, and the density accordingly raised. Excluding these, we find for forty specimens of granites and relatively coarse granophyres from the large masses the mean value 2.59, the extreme figures being 2.51 and 2.65. Separating the rocks from different parts of the area, we obtain results as follows:

	mean sp. grav.
Creag Strollamus district	2.57
Beinn na Caillich district	2.57
Beinn an Dubhaich	2.59
E. and S. of Loch Ainort	2.60
N. and W. of Loch Ainort	2.64
E. of Blaven Range	2.61
W. of Blaven range	2.63

If these figures may be regarded as significant, they show that the rocks are somewhat denser (and presumably somewhat less acid) to the W. or S.W. than they are to the E. or N.E.

Grouping the specimens in another way, we find some apparent relation between the density of the rocks and their microstructure. For thoroughly granitoid examples the average specific gravity is found to be 2.61, but for typical granophyres 2.59, while the spherulitic modifications found locally on the margin of a mass and as apophyses give on the average only 2.53 or 2.54, resembling in their low density many of the minor acid intrusions of later date. Since all the rocks are holocrystalline, this would seem to indicate that the typically granitoid varieties are in general the richest in heavier minerals. It must be remembered, however, that the specific gravity of igneous rocks is considerably affected by secondary changes, and the differences indicated may be due, at least in part, to the varying freshness or alteration of the rocks.

The essential constituents of the Skye granites and granophyres are quartz, two felspars, and one or two minerals of the ferro-magnesian division. These latter include hornblende, augite, biotite, and exceptionally riebeckite. The common accessory minerals are magnetite, sphene, zircon, and apatite.

If we adopt the customary subdivision of the rocks according to the dominant ferro-magnesian element, we find that they fall under the heads hornblende-granite ("hornblende-granitite" of some authors, since there is often subordinate biotite) and augite-granite (often with hornblende in addition). We find further that the typically granitoid rocks mostly belong to the former category, while the latter is always characterised by more or less tendency to "granophyric", *i.e.* micrographic, structures, often taking the form of true micropegmatite. This constant association of micrographic structures with augite is not peculiar to Skye, but seems to embody some law of general application. The Carrock Fell rock is an example. Among the numerous acid intrusions of Caernarvonshire the typical granophyres always carry augite, to the exclusions of biotite; the ruder types of granophyre and the granite-porphyries contain the two minerals together; and the true granites have biotite alone. In Skye we find no biotite-granites (without hornblende), and original white mica never occurs. Petrographically, then, the majority of our rocks divide into hornblende-granites (with or usually without subordinate biotite) and augite-granophyres (very often with hornblende in addition), some hornblende-granophyres affording a connecting link between the two. Typical augite-granites are indeed found, as on parts of Marsco, but they are to be regarded as exceptional. Similarly a biotite-granophyre, though it is found in Am Fuar-choire and perhaps elsewhere, seems to be of comparatively rare occurrence.

Two felspars are constantly present, a plagioclase and an orthoclase. In many of the slides the latter seems, on a first impression, to predominate largely, but closer examination often reveals twin-lamellation *in* crystals which at a glance look like simple individuals. The difficulty of verifying this arises partly from the turbid aspect of many of the crystals, partly from their low extinction-angles reckoned from the twin-line. In symetrically-cut sections the angles are in a large number of cases not more than 3° or 4°. It is evident then that, besides the true monoclinic felspar, there is usually present a triclinic variety with very low extinction-angle. It must be an *oligoclase* of composition not very different from Ab_4An_1 or Ab_3 An_1, which, according to Michel Levy, give 1° and 5° respectively. In addition, many of the slides contain lamellated crystals with extinction-angles up to 16° or 18° in symmetrical sections. This third felspar is of a less acid variety, and its properties correspond with *oligoclase-andesine,* with a constitution represented approximately by Ab_5An_3.

The plagioclase felspars have formed before the orthoclase and quartz, and are idiomorphic, especially when enclosed by the orthoclase, as is sometimes the case. Carlsbad twinning is often seen in addition to the constant albite-lamellation, while peridine-lamellae come in in some of the broader crystals. Sometimes, and especially in the micrographic rocks, polarised light reveals a zonary banding which indicates that a crystal is not homogenous in composition. The interior, for instance, may be a basic oligoclase or oligoclase-andesine with positive extinction-angle, this being followed by an intermediate zone of oligoclase with sensibly straight extinction, while the margin is of albite-oligoclase with negative extinction-angle. In other cases a narrow border of orthoclase occurs: this is found in granophyres rather than true granites.

The *orthoclase* in these rocks is more readily affected by weathering than the plagioclase felspars, and is always more or less turbid, often almost opaque in thin slices. The change is of the kind often described as "kaolinisation", though whether the finely divided secondary product, is kaolinite or muscovite it is not possible to say. The crystals are allotriomorphic, and in the truly granitoid rocks tend to enclose quartz-grains as well as plagioclase and other minerals, while in the granophyric varieties the bulk of the orthoclase figures in the micrographic intergrowths. In other words, the orthoclase has crystallised slightly posterior to or simultaneously with the quartz.

In certain granophyres from Druim-an-Eidhne and Meall Dearg occurs a felspar which may be referred doubtfully to the *anorthoclase* or cryptoperthite group, the crystals being unfortunately not fresh enough for precise examination. Their shapes in sections are difficult to reconcile with the usual habits of either orthoclase or plagioclase, and compare rather with the peculiar felspar of the Norwegian rhomb-porphyries [S2667, B]. Usually without evident twinning, they present nevertheless between crossed nicols a curious mottled appearance, little patches of irregular form extinguishing at a slightly different angle from the rest. This recalls the "felderweise mikroperthitische structur" often described in anorthoclase. It is significant that this felspar is found only in rocks otherwise exceptional in containing riebeckite, and, as the analysis shows, relatively rich in soda.

The *quartz* in these rocks occurs either in rather rounded irregular grains, which are often embraced by or enclosed in the orthoclase, or in micrographic intergrowth with that mineral. It contains in most cases numerous minute fluid-pores with bubbles, and in some rocks Zirkel<ref>*Zeits. deuts. geol. Ges.,* vol. xxiii., p. 89: 1871.</ref> detected also cubes of salt

(Glamaig).

The *augite* always occurs in roughly idiomorphic crystals, though not very sharply bounded by good faces. In some of the granophyric rocks it is found in two rather different habits, which may perhaps indicate two distinct generations; viz., in columnar crystals, averaging about 1/30 inch in length, and in smaller and more slender crystals, forming groups enclosed in quartz or micro-pegmatite; *e.g.,* on Druim nan Cleochd [S2668, 3198]. Twinning has not been observed. The augite is of a green, as distinguished from a brown, variety, but varies in thin slices from bright green

to sensibly colourless. The extinction-angle c C is about the same for all tints, viz. 39° to 42°. There is no perceptible pleochroism. Very common is the conversion of the augite, whether green or colourless, to green hornblende. The latter is not fibrous, and differs in no respect from original hornblende in the same rocks. Partially altered crystals show the invariable crystallographic relation between the two minerals, as already noted in the gabbros. Other modes of alteration of the augite give rise to chlorite, limonite, less frequently epidote, and perhaps magnetite.

The original *hornblende* builds crystals which often show the prism and clinopinacoid faces and sometimes terminal planes. In some granophyric rocks there are two distinct habits similar to those remarked in the case of augite (S2668) [NG 540 296]. These are not derivative after augite, though in some other rocks in the collection doubt may arise on this point. The hornblende, like the augite, is always untwinned.

The mineral is always deeply coloured in thin slices, and often in some brownish tone of green. In the truly granitoid rocks, where we should expect a green hornblende, it is often brown or greenish brown, four examples giving the following pleochroism-scheme:

a, light yellowish brown

b, deep brown (with very little tone of green) or greenish brown

c, deep brownish green (almost opaque) to deep brown (with only a slight tone of green)

In the granophyric rocks the hornblende is constantly green, sometimes of a bright tint very like that of the augite. The extinction-angle cc is always about 16° to 18°.

The dark-blue soda-amphibole *riebeckite* is restricted, so far as our observations go, to Meall Dearg and the neighbouring part of Druim an Eidhne, where it was first detected by Mr Teall,<ref>*Quart. Journ. Geol. Soc.,* vol. 1., p. 219: 1894.</ref> and the only other record of its occurrence in the Inner Hebrides is at Ailsa Craig.<ref>Teall, *Min. Mag.,* vol. ix., pp. 219–221: 1891. Heddle, *Trans. Edin. Geol. Soc.,* vol. vii., pp. 265–267, P1. XV., XVI.: 1897.</ref> It presents in our specimens crystals of two different habits side by side, a feature noticeable in various other riebeckite-bearing rocks. The larger crystals are sometimes partly idiomorphic, sometimes allotriomorphic and, it may be, of a very irregular shape, showing a ragged sponge-like appearance in slices; while the smaller ones are idiomorphic, having the prism-faces and sometimes the clinopinacoid, with ragged terminations (Figure 34). The axis a is very near to the vertical crystallographic axis, the inclination being seemingly 3° or 4°, though the intense absorption prevents any very precise measurement. The pleochroism is:

a and b, deep indigo blue

c, greenish brown to brownish green

In one or two slides from Marsco occur idiomorphic crystals, about 1/40 inch in length, of a hornblende with a distinct blue-green tint, suggesting the presence of the riebeckite-molecule in small quantity.

The *biotite* of the Skye granites occurs in flakes of a deep brown colour, and is probably a haughtonite. For vibrations parallel to the cleavage the absorption is strong, almost to opacity. The extinction is sufficiently oblique in some flakes to verify a lamellar twinning parallel to the basal plane. Decomposition gives rise to chlorite and sometimes epidote.

The opaque iron-ore of these rocks seems to be always *magnetite,* and the grains usually show more or less of the octahedral form.

The mineral occurs only in quite subordinate quantity.<ref>In one place only, 50 yards S.E. of the old ruined Manse at Kilchrist, was found a lode of magnetic iron-ore, It cuts the granite vertically, bearing a little N. of W., and terminates at the junction of the granite with the Cambrian limestone.</ref>. It is often intimately associated with the augite. The *sphene,* on the other hand, is associated with hornblende, and belongs characteristically to the granitoid as distinguished from the granophyric varieties. It is in imperfect crystals or rounded grains, with a faint brownish tint in thin slices. The riebeckite-granophyre contains flakes of what appears to be *ilmenite,* opaque or rarely translucent and then deep brown.

Most of the rocks contain *apatite,* though its distribution in any given rock is often rather local. It builds little prisms of the usual habit, which penetrate or are enclosed by other minerals; and frequently a number of minute needles are clustered together, usually enclosed in quartz. In certain places on Marsco, where the granite encloses portions of gabbro and is often modified in composition thereby, apatite is unusually abundant, and there occurs in rather stouter prisms with the regular hexagonal cross-section. The fact that in Skye apatite is more abundant in the granites than in the gabbros is not in accord with what is usually found on comparison of acid with basic rocks, but it is evident in the large collection of slices which we have examined, and is confirmed by Dr Pollard's analyses. Another point of interest is that the acid rocks were found to contain chlorine but no fluorine. Here the halogen elements can belong only to the apatite, and we see that our rocks do not bear out the rule which would assign the chlor-apatites to the basic and the fluor-apatites to the acid rocks. The Skye granites do not stand alone in this respect.<ref> In five granites from the eastern Highlands of Scotland Dr Mackie found that the percentage of chlorine amounted on the average to 0.054. *Trans. Edin. Geol. Soc.,* vol. vii., p. 54: 1901.</ref>

Less frequent and less widely distributed in the granites is *zircon,* always in minute, well-shaped crystals. When enclosed in biotite, as is generally the case, it is always surrounded by the well-known "halo" of intense absorption and pleochroism.

In one slice, of a granophyre from Allt Foams, near Broadford, there occur small twinned crystals of a mineral which we identify as *allanite* (*see* (Figure 34), G and H). It is of an intense brown colour with strong pleochroism. The strongest absorption gives a very deep red-brown colour, approaching opacity, while for vibrations in a direction perpendicular to this the colour is a deep brown of a greyer or greener tone. The mean refringence is high, and the extinction-angles from the twin-line are wide; but the strong absorption precludes any accurate determination of these angles or of the birefringence. Another rock, a hornblende-granophyre from Druim nan Cleochd, also contains a strongly absorptive and pleochroic brown mineral, which is here intergrown with green hornblende ((Figure 34), E and F). The colours are like those of haughtonite, but the most intense absorption (practically opacity) is for transverse, not longtitudinal, vibrations. The extinction-angle is quite low, but cannot be determined with precision. There are no evident cleavage-traces, but a very marked striation making a high angle with the direction of elongation. These properties do not agree with those of any known amphibole mineral.

As regards *micro-structure,* the rocks which build the large intrusive masses of the Red Hills are, as has been said, sometimes granitoid, sometimes granophyric, with many varieties of micro-pegmatite. On the whole the latter predominate, and a strong tendency to graphic intergrowths of felspar and quartz may be regarded as the most striking petrographical feature of this assemblage of acid rocks. In the fine-textured marginal modifications, and in minor intrusions and apophyses of the large masses, this tendency is even more marked, and often assumes the form of spherulitic structures. It is clear, however, that no difference of an essential kind exists between "micropegmatite", "pseudo-spherulites", and some spherulites with fairly regular black cross, as developed in these rocks; and we may conveniently emphasise their essential identity by using the terms micrographic and cryptographic for the various types of intergrowth, according as they can or cannot be clearly resolved by the microscope. Graphic structures visible to the naked eye are not found.

The best examples of typical *granitoid* structure are afforded by the Beinn an Dubhaich boss, but such rocks occur also in many parts of the Red Hills tract, *e.g.* in Glen Sligachan. The quartz has tended to crystallise rather before than after the latest felspar (orthoclase), but often the two minerals have formed almost simultaneously. We include with the true granites those rocks in which a rude micrographic structure is locally developed, commonly of an irregular kind and on a relatively coarse scale.

As typical granophyres we include those rocks in which the chief bulk consists of a visibly *micrographic intergrowth, of felspar and quartz* (micropegmatite). These, with connecting links between them and the true granites, predominate over a very large part of the Red Hills. Distinct crystals of felspar, and sometimes grains of quartz, enclosed in the micropegmatite give the rocks an aspect which may be described as porphyritic; but this must not be taken to imply that consolidation has been effected in two distinct stages under different conditions: the characters to be described militate against such a supposition.

In different specimens, and in different parts of one specimen, the micropegmatite differs in composition, in scale of magnitude and degree of regularity, in manner of arrangement and relation to phenocrysts, etc. The component minerals are usually orthoclase and quartz: less commonly oligoclase takes the place of the former, but the intergrowth is then not usually of a very delicate or regular kind ((Plate 19)., Fig. 1, A). The felspar is almost everywhere in greater quantity than the associated quartz, but the proportion between them evidently varies, even in different parts of an area with common orientation throughout. The felspar in such an area is continuous, enclosing very numerous detached elements of quartz, which behave optically as parts of a single crystal. The little elements of quartz are in the less minute intergrowths of rather irregular outline, or very often wedge-shaped, so as to show in a thin slice as little triangles similarly oriented. With increasing fineness of scale the intergrowth approximates more and more to a lamellar structure, giving a parallel-linear arrangement in sections.

A large proportion of the micropegmatite is disposed in relation to the felspar phenocrysts, forming a broad border round each crystal. The intergrowth constantly tends, in the neighbourhood of a crystal, to assume a linear (probably a lamellar) arrangement at right angles to the faces of the crystal. It follows that, when most regularly developed, the border, as seen in a thin slice, consists of four portions, corresponding with the four sides of the rectangular section, adjacent portions being divided by a diagonal suture, as in a picture-frame. The intergrowth is most regular and most minute in contact with the phenocryst, while outwards the border usually passes by gradations into a coarser and less regular interstitial micropegmatite, or inosculates with contiguous borders belonging to other phenocrysts. Such borders surround crystals both of orthoclase and of oligoclase. In the former case it can often be verified that the felspar of the micropegmatite has the same orientation as the phenocryst, and is indeed an extension of it. This is probably not an occasional phenomenon but the general rule, though it is often obscured by the turbidity of the felspar. We have not observed a similar crystalline continuity in the case of oligoclase, and indeed the delicate intergrowth bordering the phenocrysts seems to be in general an orthoclase-micro-pegmatite. Oligoclase phenocrysts framed in such a border show a very narrow external shell of turbid felspar, which seems to be orthoclase, and the felspar of the border is probably continuous with this. Grains of quartz are sometimes surrounded by a zone of very irregular micropegmatite, the quartz of which is oriented like that of the grain, but this is a much less common occurrence ((Plate 19), Fig. 2).

We have observed nothing which affords any support to the view that these later outgrowths from phenocrysts belong to a time subsequent to the consolidation of the rock.<ref>* *Cf.* Judd, *Quart. Journ. Geol. Soc.,* vol. xlv., pp. 175–186: 1889.</ref> On the contrary, the phenomena become most intelligible on the supposition of no great break in time and no important discontinuity as regards physical conditions between the phenocryst stage and the micro-pegmatite stage of consolidation. It is possible indeed that no change of conditions is implied other than the progressive change in the composition of the residual magma which must result from the abstraction of the constituents of the felspar phenocrysts. We may conceive that the growing acidity of the residual fluid magma reaches a certain critical point, after which not pure felspar-substance but a minute intergrowth of felspar and quartz is deposited upon the faces of the crystals. It is not necessary to suppose, as Mr Teall has suggested,<ref>*British Petrography,* pp. 401, 402: 1888. See also Anniversary Address in *Quart Journ. Geol, Soc.,* vol. lvii., pp. lxxv, lxxvi,</ref> that micropegmatite in general is of the nature of a eutectic mixture of felspar and quartz, which would require that the two constituents should always occur in certain constant proportions. So far as can be judged by eye, the proportion of quartz in the micropegmdtite of our rocks seems to be smallest in that part of the border contiguous to the phenocryst, increasing slightly outwards and becoming largest in the irregular interstitial areas. It is these latter areas which we should rather expect to be of the nature of a eutectic mixture.

Since the felspar phenocrysts doubtless acquired and maintained crystallographic outlines from a very early stage of their growth, a change such as we have imagined, from the deposition of felspar-substance to the deposition of micropegmatite, would result in a sharply bounded felspar crystal fringed by a micropegmatite border. But exceptionally the change seems to have come on in a less abrupt manner, for we sometimes find little patches of quartz in micrographic intergrowth in the interior of a felspar phenocryst. This is more frequent in the spherulitic marginal modifications of the rock than in the typical micrographic varieties. These spherulitic rocks afford evidence also on another point, viz. that the phenocrysts of the principal minerals were formed almost, if not quite, wholly after the intrusion of the magma, and are therefore not comparable with the phenocrysts of extruded lavas. This appears from the fact that the phenocrysts become smaller and of different habit towards the border of an intrusion which gives evidence of rapid chilling. The augite, for instance, on Glas Bheinn Bheag and Druim an Eidhne often assumes the form of small rods or needles, which sometimes share the radiate arrangement of the spherulites. This seems to indicate that this mineral crystallised subsequently to the intrusion of the magma, and the same must be true, *a fortiori,* of the felspars and quartz. It is noteworthy too that the phenocrysts in our granophyres are never broken.

The spherulitic or cryptographic structure is not found in the large intrusive masses of the Red Hills except along certain portions of the boundary, and in a few places along what appear to have been the margins of the distinct intrusions of which the large masses are made up. This modification is identical with what is the normal structure of many of the minor acid intrusions (dykes and sheets) in Skye, some few of which are indeed offshoots from the large masses under consideration, but most of which belong probably to a later epoch. We shall postpone the description of this type of structure until we come to consider these minor intrusions (Chapter 16).

While the fine-textured modifications of our rocks take for the most part the granophyric character, this is not everywhere the case, the dominant type in some places being a fine-grained rock with a *microgranitic structure,* usually with a *porphyritic* aspect due to the occurrence of conspicuous felspar crystals in the finer ground-mass. This is found in places, *e.g.* on some parts of Marsco, forming the border of one of the distinct intrusions of granite; and in such a case bears the same relation to the typical granitoid rock as the spherulitic and allied varieties do to the coarse granophyre. But there are also areas of porphyritic felsite contiguous with granite but probably representing separate intrusions, which have this character throughout. Such an area occurs on the border, and as it would appear at the base, of the main Red Hills mass at Meall a' Mhaoil and Meall Buidhe, to the north of Loch Ainort. Much of the rock has a dark and often bluish tint owing to secondary changes, to which these felsitic rocks are rather prone. A specimen, of specific gravity 2.66, has dull white crystals of orthoclase up to ■ inch in length. A slice (S9571) [NG 55 30] shows in addition grains of augite, often of partly rounded form, and a felsitic ground-mass of ordinary appearance and rather fine texture. Another place where the porphyritic felsite modification may be studied is on Glamaig, but here the geology is complicated by other circumstances, and especially by the remarkable modification of the acid rocks in some parts by a profusion of basic xenoliths, a phenomenon which belongs to the next chapter. In most of the rocks of porphyritic habit the phenocrysts are of felspar only, but there are some with quartz in addition. A specimen from the foot-path on the N.W. side of the Moll River, and south of Meall a' Mhaoil, contains abundant crystals both of quartz and of orthoclase, up to 1/10 inch in diameter. The ground-mass is of the "microfelsitic" type, and has a fluxion-structure in places (S8970) [NG 551 302].

A very noticeable feature of the acid intrusive rocks of Skye, and indeed of the British Tertiary province generally, is the *drusy or miarolitic structure.* This is very widely found, but is especially characteristic of the common granophyres with micropegmatite, as distinguished from the granitoid rocks on the one hand and the spherulitic and felsitic modifications on the other. The dimensions of the little cavities vary from an inch downward, and they have highly irregular shapes owing to the crystals of the rock projecting into them. These crystals are quartz and felspars, occasionally also hornblende, and, where the vacant space has given them freedom of growth, they present perfect crystal-facets. We have not found in Skye druses so large as some of those in the granites of Arran and the Mourne Mountains, nor have we discovered in our druses any of the peculiar minerals which occur in those districts. It is well known that beryl, chrysoberyl, fluor, tourmaline, topaz, fayalite, etc., have been formed in the druses of the Mourne granite.*<ref> Mr Seymour has recently added cassiterite to the list.</ref> Their absence from the corresponding rocks in Skye may be ascribed to the want of certain essential conditions, the minerals in question being of species usually referred to the cooperation of special "mineralising agents". It is noteworthy that Dr Pollard found no fluorine in the rocks analysed.

Although the druses are a conspicuous feature in the rocks which contain them, they make up in reality but a small part of the whole volume. From specific gravity determinations of rocks, first in bulk and then in powder, it seems probable that the cavities do not often amount to so much as one two-hundredth of the total volume. In some cases the original druses have been reduced in size by the deposition of secondary minerals within them, usually quartz and epidote, or by a coating of ferric oxide.

The foregoing general description covers almost the whole of the granites, granophyres, etc., of the Red Hills, excluding only the spherulitic and other fine-textured margins and off-shoots to be described later. The special local variations, in composition and in micro-structure, which remain to be noticed in this place are few and, as regards their distribution, insignificant.

As compared with the gabbros, and still more as compared with the peridotites, these acid rocks have a remarkably uniform composition. In the absence of many chemical analyses, this is sufficiently proved by the mineral constitution of the rocks. The most interesting of what may be regarded as aberrant varieties is the *riebeckite-granophyre* of Meall Dearg, already described by Mr Teall.<ref>*Quart. Journ. Geol. Soc.,* vol. 1., p. 219: 1894.</ref> This rock consists chiefly of felspar and quartz in typical micrographic intergrowth, in which the crystals of the other constituent minerals are embedded. The crystals of felspar have in part the characters of "anorthoclase" (S2667B) [NG 50 24]. In addition to the riebeckite, there may be exceptionally a few grains of augite (S8856) [NG 495 227]. Iron-ore is rather more plentiful than is usual in this group of rocks, and seems to be always ilmenite, in idiomorphic flakes closely associated with the riebeckite. Zircon is an occasional accessory. In the field the rock appears as an ordinary drusy granophyre, with a yellowish brown tint due to ferruginous staining. The riebeckite cannot be certainly distinguished from common hornblende on a hand-specimen, except by the irregular shape of the crystals. Two specimens of the rock gave specific gravities 2.512 and 2.492. Making some allowance on account of the drusy cavities, it is still evident that this variety, unusually rich in alkali-felspars, is notably less dense than the ordinary granophyres.

Another rare modification arises from the disappearance of quartz as an essential constituent, giving a rock which is petrographically a *syenite* according to the modern nomenclature.<ref>Macculloch and other early writers, in applying the name syenite to this group of rocks as a whole, used it in its original sense for hornblendic granite (including granophyre). The identification of hornblende, before the introduction of the microscope into petrology, was necessarily uncertain in the finer textured rocks.</ref> Such a rock is exposed in isolated knolls below Creagan Dubha, to the north of Beinn Dearg Mhòr (of Strath), a locality where a considerable amount of crushing of the rocks has somewhat obscured their relations. It is mottled with dull greenish patches and veins, and was in fact mistaken at first for a volcanic agglomerate, but the peculiarity is due merely to breeciation. A specimen gave the specific gravity 2.66, which is rather higher than the specific gravities of the granites. A thin slice (S6843) [NG 586 247] shows that it is essentially a felspar-hornblende rock. The felspar is principally orthoclase, but partly a finely striated oligoclase with nearly straight extinction. The hornblende is for the most part chloritised. Quartz is scarcely represented, except as narrow irregular veins traversing the felspar, and these seem to be secondary and connected with the brecciation. The locality of this rock would permit us to regard it as a marginal modification of the granite, but its mode of occurrence is not displayed, and it is in any case quite exceptional.

Any special peculiarity is quite as rare in the structural and textural as in the mineralogical and chemical characters of the rocks. A coarse *pegmatoid* structure (usually without graphic intergrowth) is found in two or three places where the granite is in intimate relation with earlier basic intrusions, viz. of gabbro on Marsco, and of a more peculiar rock on Sròn a' Bhealain, near Sligachan. The phenomena will be described in the following chapter. At the same places there is sometimes a rather vague flow-structure imparting a *gneissic* appearance to the rock. A rude gneissic structure of a different nature, due to crushing, is seen in Allt na Teangaidh, a branch of Allt Strollamus.

In some places the large bodies of granite and granophyre, whether of boss-like or of laccolitic habit, are traversed by pale fine-textured *aplitic veins.* These are of small width, often less than an inch. Though sharply cutting the normal rock, they have not the magnitude nor the straight course of dykes, and are not infrequently found ramifying. We may probably regard them as closely related to the granite itself, although distinctly later than its consolidation. They are of somewhat more acid composition, at least in respect of the proportion of the ferro-magnesian minerals which they contain. A specimen was sliced of a vein traversing the biotite-granite of Druim na Ruaige near its junction with Beinn Dearg Mheadhonach. This has the specific gravity of 2.59. Under the microscope it is seen to be of much finer grain than the granite and of somewhat different micro-structure. It contains biotite, but in less amount than the granite which it intersects (S8708) [NG 505 283]. A good place for studying the fine-textured veins in the granite is the eastern part of the Beinn an Dubhaich mass. Here they sometimes reach a width of 3 or 4 inches, and narrower veins are abundant in places. At places in Coire na Laogh, on the north side of Marsco, where, as we shall see, the granite is crowded with partially digested debris of gabbro, aplitic veins traverse the dark modified rock as well as the normal type, and have the same pale appearance in both. This seems enough to prove that the veins are not merely excretions from the immediately contiguous granite, but distinct later injections, though doubtless from the same source.

The dark ovoid patches, representing relatively *basic secretions* from the magma, which are so common in the granites and granophyres of many regions, are not often met with in our rocks, and are never of large size. One place where they may be studied is at Am Fuar-choire, about 1½ mile S.E. of Sligachan. Here they are not more than an inch or two in diameter, always rounded in outline, and sharply defined. At the place where they were specially examined the rock itself is a biotite-granite with partial granophyric structure and of moderately coarse grain. The dark patches are of much finer texture, and they have also a different structure, the felspar being more generally idiomorphic and. the quartz enwrapping it in micropcecilitic fashion. The ferro-magnesian element is much more plentiful than in the normal rock. It is completely chloritised, but there has probably been some hornblende in addition to the biotite.

Such dark patches are to be distinguished from *xenoliths.* These, except in certain places where they occur in great profusion and with remarkable circumstances, are not very frequent. The exceptional occurrences will be described in the next chapter. Since the granite of the Red Hills, though a much less complex mass than the gabbro of the Cuillins, undoubtedly consists of a number of distinct intrusions, it may be expected that the later portions have sometimes caught up xenoliths of the earlier. This is occasionally to be verified. Possibly it escapes notice in other instances owing to the similarity between the enclosed and the enclosing rock. Such examples as we have noticed are inclusions of granite or relatively coarse granophyre in some finer-textured type, and they occur at no great distance from the junction of two distinct intrusive bodies. In two or three places in the valley of the Kinloch Ainort river (Abhuinn Ceann Loch Ainort) such xenoliths are abundant. They are never rounded or corroded.

The granites of Skye have not in general been invaded by later intrusive magmas of any considerable volume, and accordingly we do not find in them (apart from granite xenoliths enclosed in dykes) any indications of thermal metamorphism. Dynamic metamorphism, on the other hand, connected with subsequent crust-movements, has in numerous places left its impress on the rocks in *cataclastic phenomena* of various degrees and kinds. The granite is probably more often severely crushed than the gabbro, and certainly shows the results more frequently in the field; though the most marked effects still seem to be restricted chiefly to the vicinity of faulted boundaries. The most interesting and easily accessible locality is the shore about 2½ miles N.W. of Broadford. Here much of the rock is so completely brecciated as to be easily mistaken at first for a volcanic agglomerate. The resemblance is sometimes enhanced by a partial chloritisation of the more finely ground material, imparting a darkened colour against which the pale larger fragments show out prominently. The true nature of the rock can be made out by examining places where the process of crushing is less advanced. It is often seen, as is shown in the lower figure of the accompanying plate, that the granite tends at first to break into lenticular fragments with a parallel arrangement; but the more completely crushed rock has no schistose structure (Plate 7).

Besides this strip of coast-line and the neighbouring lower slopes of Creag Strollamus, there are other places where crushed granites simulate rather closely the volcanic agglomerates. The eastern slope of Beinn na Caillich, above Coirechatachan, is one such place. In Allt na Teangaidh, a branch of Allt Strollamus coming down from the col between Beinn na Caillich and Beinn Dearg Allier, the appearance of the crushed granite is rather different, a certain rude parallel structure imparting to it something of a gneissic aspect, as already remarked.

Thin slices of the rocks show various stages of the cataclastic process. In the earlier stages the fragments are angular, and it is still possible in places to see how they might be fitted together (S6835) [NG 612 226], (S6837) [NG 608 264]. With the progress of crushing, and perhaps some degree of rolling, there is a rounding of the fragments and an increase in the amount of matrix (S6840) [NG 592 244], (S6841) [NG 588 242], (S6842) [NG 588 242]. The quartz shows strain-shadows between crossed nicols even before any considerable brecciation is set up, and in the earlier stages this character is constantly well marked (S6834) [NG 613 264], (S6835) [NG 612 226]: in the more thoroughly crushed rocks it is sometimes less evident. We have not observed in the granites any clear evidence of secondary twinning in the plagioclase felspar, such as we have noticed in the gabbros. This is perhaps explained by the fact that the oligoclase of the granites has naturally a closer twin-lamellation than the labradorite of the gabbros.

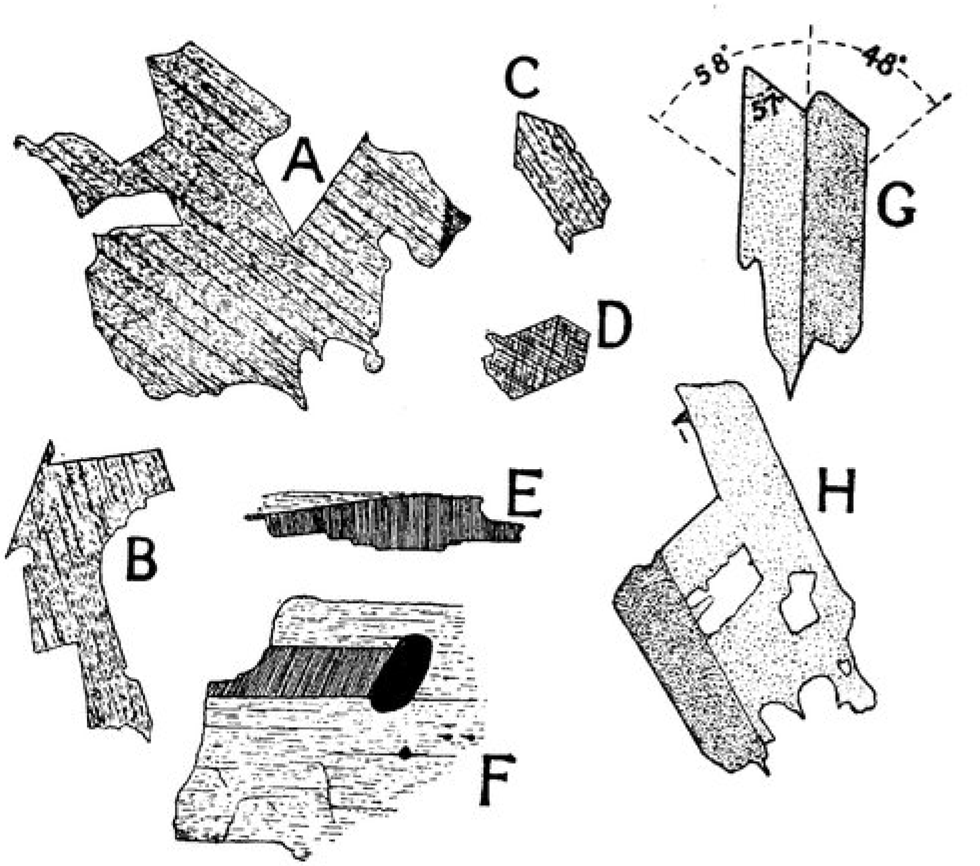
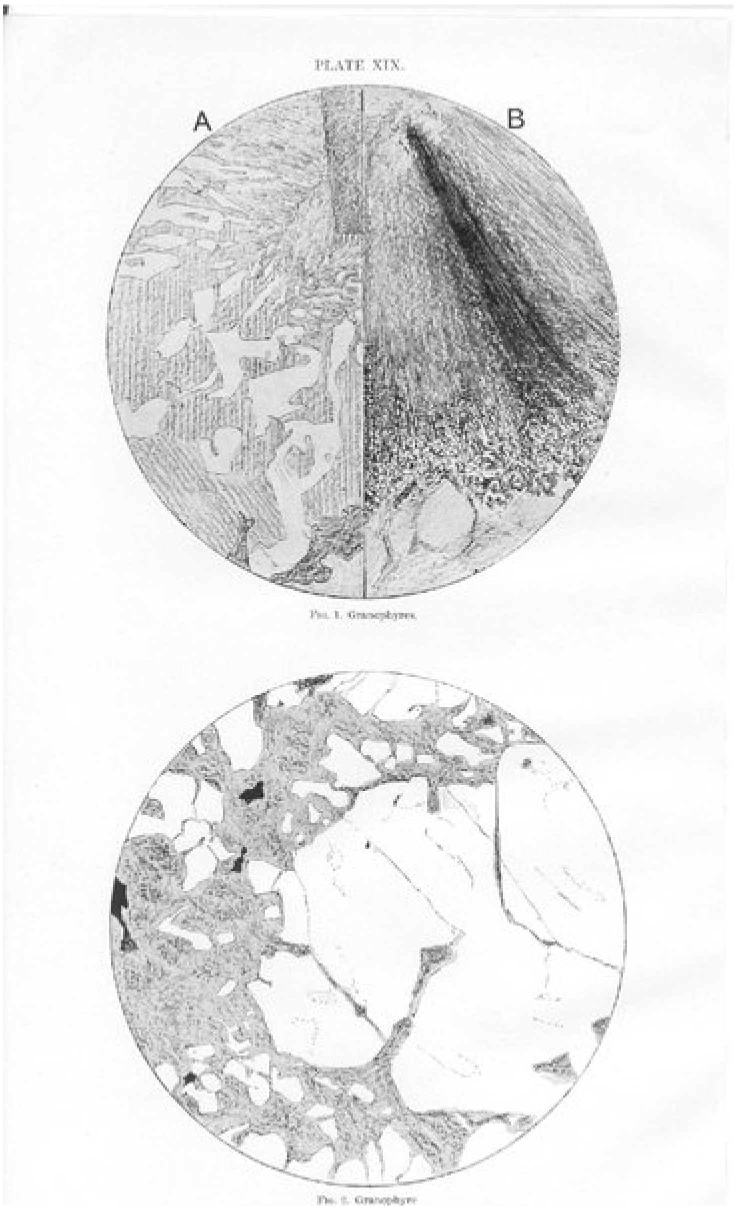


FIG. 34.—Some rarer minerals of the granophyres. A to D × 30, E to H × 100.
A to D are riebeckite crystals from the granophyre of Meall Dearg, illustrating the allotriomorphic habit of the larger and the idiomorphic shape of the smaller crystals [8856].
E and F show an unidentified brown mineral intergrown with green horneblende in a granophyre from Druim na Cleochd [3198].
G and H are twinned crystals of allanite(?) in the granophyre of Allt Fearna, near Broadford. In the former are shown the approximate positions of the axes of strongest absorption for the two individuals.

(Figure 34) Some rarer minerals of the granophyres. A to D × 30, E to H × 100. A to D are riebeckite crystals from the granophyre of Meall Dearg, illustrating the allotriomorphic habit of the larger and the idiomorphic shape of the smaller crystals (S8856) [NG 495 227]. E and F show an unidentified brown mineral intergrown with green horneblende in a granophyre from Druim na Cleochd (S3198). G and H are twinned crystals of allanite(?) in the granophyre of Allt Fearna, near Broadford. In the former are shown the approximate positions of the axes of strongest absorption for the two individuals.



(Plate 19) Fig. 1. Graphic structures in granophyres; × 40, crossed nicols. A. Roadside E. of Strollamus Bridge: showing micrographic intergrowth of striated oligoclase and quartz, and in the upper part of orthoclase and quartz, in connection with an orthoclase phenocryst. See p. 161. B. Glas-Bheinn Bheag, near margin of intrusion: showing part of a single spherulite with the gradation from a cryptographic structure near the centre of growth to a visibly micrographic towards the periphery. See p. 281. Fig. 2. (S2667) [NG 50 24] × 40. Granophyric granite, Marsco: showing a rude micrographic growth round a grain of quartz. See p. 162.

PLATE VII.

Fig. 1.

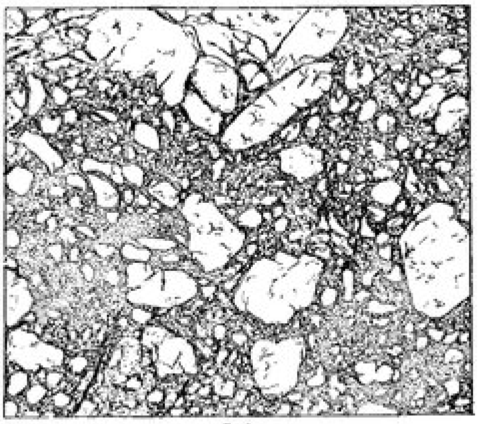


Fig. 2.

Crushed granite, from the shore between Allt Fearna and Strollamus Lodge, 2½ miles N.W. of Broadford. Natural size. The lower figure is from a typical specimen, while the upper one shows an earlier stage in the process of brecciation.

(Plate 7) Crushed granite, from the shore between Allt Fearna and Strollamus Lodge, 2½ miles N.W. of Broadford. Natural size. The lower figure is from a typical specimen, while the upper one shows an earlier stage in the process of brecciation,