Chapter 19 Basic dykes: tachylytic selvages

In this chapter we shall give some account of the selvages of black glass which occasionally border the basic dykes of our area. With the dykes we shall include such intrusive sheets or sills as have come under our notice, in which like phenomena are observed. Some exceptional cases will be noticed, in which the vitreous character affects more or less the whole width or thickness of the intrusion, instead of being confined to narrow marginal zones. Further, while treating of the truly glassy form locally assumed by the basic magmas, we shall describe also those modifications in which there has been a considerable development of crystallitic growth, usually with spherulitic arrangement, some of the rocks embraced here being such as are sometimes styled "variolites".

From one or two incidental references in Macculloch's work it seems probable that he had observed instances of tachylytic selvages in Skye. The true nature of this vitreous substance was, however, first recognised by Necker,<ref>*Edin. New Phil. Journ.,* vol. xxix., p. 75; 1840.</ref> who found it as a crust two or three inches thick on a basic dyke in the "Beal valley" to the north of Portree. It had previously been observed here by Murchison, who regarded it as a pitchstone: Necker discovered that it is denser and more fusible than the rocks properly ranged under this title, and considered it as bearing the same relation to the basic rocks that true pitchstone does to the acid. In 1882 Dr Heddle<ref>*Min. Mag.,* vol. *v.,* p. 8; 1882.</ref> noticed a tachylyte forming a half-inch crust at the lower surface of a basic sheet (presumably an intrusive sill) on the Quiraing, and he proved by chemical analyses its practical identity in composition with the rock which it borders. In the following year Professors Judd and Cole<ref>Quart. *Journ. Geol. Soc.,* vol. xxxix., pp. 444–464, pl. XIII., XIV.; 1883.</ref> gave a full description of the "Beal" rock with some others in the Western Isles; and subsequently the latter author,<ref>*Ibid.,* vol. xliv., pp. 300–307, pl. XI.; 1888.</ref> in a supplementary paper, did the same for the Quiraing occurrence.

So far as our observation has extended, tachylytic selvages to the ordinary basic dykes are of rare occurrence in the basaltic portion of the island. A thin film of glassy material resembling coal in appearance coats the surface of some of the smaller basalt dykes on Meall Odhar Beag and Ben Lee, to the north-west of Loch Sligachan, and a few other occurrences have been noted. Any approach to a vitreous selvage is very exceptional also in the mountains. Macculloch<ref>*Description of the Western Islands of Scotland,* vol. i., p. 402; 1819.</ref> found on Gars-bheinn a loose fragment showing the transition of basalt into "a fine black pitchstone", presumably from a dyke cutting the gabbro or the metamorphosed lavas. A small basalt dyke with selvages of tachylyte, 1/10 inch thick, intersects the strip of gabbro enveloped in the granite of Marsco, as seen in the gully on the north-west face. A few other small dykes with glassy edges have been observed cutting the gabbros and peridotites of the Cuillins in An Garbh-choire and elsewhere.

When tachylytic selvages occur, they are usually very thin: excepting the examples at the "Beal" and the Quiraing, we know none in the north-western and central parts of the island exceeding 1/10 inch, It may be remarked generally that evidences of decided chilling are less frequently met with in the parts of Skye where the country rocks are igneous than in the parts farther south-east, where sedimentary strata prevail. Possibly the temperature of the "country rocks at the time when the dykes were injected is in part answerable for this difference; but there are doubtless other factors which would influence the rate of cooling of a dyke, more especially the specific thermal conductivity of the rock forming the walls. Professor Kendall<ref>*Geol. Mag.* 1898, p. 555.</ref> has pointed out the influence of this on the formation of tachylytic margins to basalt dykes in Mull: a selvage which has a thickness of ¼ inch in contact with a sheet of compact basalt is reduced to a mere film when the dyke passes through a highly vesicular sheet. A similar change is seen in some of our Skye dykes which have glassy selvages.

In the Sleat district Mr Clough has found that selvages of black tachylyte are not uncommon, but most of them are extremely thin, perhaps not more than 1/20 inch.<ref>Examples are noted at the following places: three or four dykes to the N.E. of Ob Allt an Daraich, between Broadford and Kyleakin; Rudha Guail, to the N.E. of Isle Ornsay; two dykes at ½ mile and ¼ mile S.W. of Rudha Guail; 300 yards N. of Camas Daraich, near Tarskavaig; two dykes at ■ mile and ¼ mile S.W. of Ob Gauscavaig, in the same neighbourhood; 150 yards E.S.E. of Armadale pier; ■ mile E.S.E. of Sgùrr na Leth-bheinn, near the Point of Sleat. All these are either in Torridon Sandstone or in Moine Schists.</ref> In certain instances, which are worth particularising, he has observed a more considerable development of the basalt-glass, or even a small dyke wholly composed of it. At the head of a small burn ■ mile south of Loch Ashik, near Broadford, tachylyte forms the whole of two narrow dykes, six or eight inches across, running E.–W., within a broader dyke of ophitic dolerite with N.N.W. bearing. It is crowded with quasi-spherulitic growths, which are much larger in the interior of a dyke than at the margins. On the N.W. side of Allt Evan, ■ mile N.E. of Kinloch, is a dyke of spherulitic tachylyte a foot thick, with specific gravity of 2.80. Some of the spherulites in it are as large as boys' marbles. Where the bridle-road crosses Allt Thuill, to the N.E. of Loch na Dal, near Isle Ornsay, the later of two north-westerly dykes in the burn shows a glassy modification. On the north side of the road the dyke is three or four feet wide, and has tachylytic selvages from 1 to 3 inches thick, besides a few thin streaks and patches more in the interior. On the south side of the road the dyke is reduced to 12–18 inches in width, and here the whole, or nearly the whole, has a resinous lustre, with a specific gravity of 2.81. It is perhaps significant that several of these thicker bands of tachylyte are found in connection with dykes intersecting earlier intrusions of basalt or dolerite, doubtless better conductors of heat than such rocks as the Torridon Sandstone. A like remark applies to the sheet at Rudh' an Iasgaich, described below. We shall, however, show reason for believing that the tendency to assume the vitreous form in these rocks is primarily dependent upon some peculiarity in their composition as compared with the ordinary basic intrusions of the region.

We have stated that tachylyte selvages are sometimes found on the basic sills and sheets of intrusive habit, as well as on the dykes. In some cases, as in a sheet of spherulitic basalt at Camas Daraich near the Point of Sleat, the glass is little more than *a* skin on the surface; in other cases, as in Heddle's instance at the Quiraing, it forms a rather more considerable crust. Mr Clough has observed two cases presenting features of interest to be further described. One is to the west and north-west of Knock, where the tachylyte and the compact rock immediately next to it are seen in unusually extensive exposures, some perhaps 100 yards long and nearly as broad. The other is on the west coast of Sleat, about half-way between Rudh' an Iasgaich and Rudha Charn nan Cearc, where glassy selvages up to 3 inches in thickness occur on the margins of a thin basalt sheet, which runs rather irregularly along the interior of *a* thicker sill of dolerite intruded at the base of the Mesozoic strata. The relations have been described and figured by Sir A. Geikie.<ref>*Quart. Journ. Geol. Soc.,* vol. lii., pp. 179, 180, fig. 23; 1896.</ref>Other sheets with selvages of tachylyte were observed at the S.W. side of Loch Doir' an Eich, farther to the N.W., and at Ard Thurinish near the southern extremity of Sleat.

In their mode of occurrence and customary thickness the tachylytic selvages in Skye resemble those in others of the Western Isles. In Mull, for example, in nearly fifty examples catalogued by Prof. Kendall, the thickness is not often more than ■ to ¼ inch, and the greatest thickness recorded is 2¼ inches, at Glen Aros. At Loch Scridain, however, in the same island, Prof. Heddle<ref>*Trans. Geol. Soc. Glasg.,* vol. x., pp. 80–95; 1895.</ref> has described a dyke bordered by tachylyte which in certain local expansions reaches a thickness of 6 or 7 inches, and even 22 inches.

If we examine in the field a dyke which has tachylyte selvages, we find as a rule that the rock becomes very compact as the margin is approached, and takes on a resinous lustre like that of some pitchstones. This change is a gradual one; but the final change to the thin crust of true tachylyte, black and lustrous as polished jet, comes on rather suddenly. It is in the basalt-pitchstone rather than the true tachylyte or basalt-obsidian that some of the special structures often occur, such as relatively large spherulites conspicuous to the eye. The glassy edge is often finely fissured, the delicate cracks running perpendicularly to the boundary surface, and the compact pitchy-looking rock may also be divided sometimes in a remarkable manner. Of the Allt Thuill dyke, Mr Clough notes that in the selvages there are "closely fitting perlitic forms, some of which are more than an inch in length in one direction parallel to the side of the dyke, and not much less in breadth in the same plane. The tachylyte also contains spherulites, bodies of a spherical or oval shape, and spherulitic rods like those in the trachyte dykes. to be described later". Some of his more interesting observations relate to the sills or sheets with tachylytic selvages already mentioned. The first of the two cases described in the following note shows features analogous with the curious reticulated structure in the Eskdale dyke, Dumfriesshire, as detailed by Sir A. Geikie.<ref>*Proc. Roy. Phys. Soc. Edin.,* vol. *v.,* pp. 242, 243, plate V.; 1880: *Trans. Roy. Soc. Edin.,* vol. my., p. 41; 1888: *Ancient Volcanoes of Great Britain,* vol. ii., pp. 133, 134; 1897.</ref>

"In some of the extensive exposures of the sheets near Knock we see a rectangular pattern formed by more or less straight-running bands which project on the weathered face and have median sutures (Figure 69) and (Figure 70). These bands have not now a glassy aspect, and their sides often weather with a rusty colour. Neighbouring bands make different angles with one another and enclose spaces which are filled in with a black glassy tachylyte with small perlitic forms. These bands are perhaps of the same character as the 'sheaths' of the Eskdale pitchstone dyke, and the tachylyte interspaces may be compared with the 'cores' of the same dyke. Some of the sheaths end bluntly, or diverge into two branches, each of which ends bluntly, within a 'core'. In some parts the 'sheaths' which run in one direction are much closer together than those which cross them, but the directions of the closer set are liable to vary rather rapidly. A little below the tachylyte there are often close joints or divisional lines which remind us of the joints to be mentioned near Rudh' an Iasgaich. Some of them are connected by other shorter joints which make considerable angles with them.

In the thin sheet mentioned near Rudh' an Tasgaich the tachylyte at the surface is in some places as much as three inches thick and crowded with perlitic forms. The parts next below the tachylyte are intersected by many close joints, often hardly half an inch apart, some of which are nearly at right angles to the adjoining tachylyte surface, while others make a slight angle with it. These joints are very varied in direction and often curved. Their general effect gives the appearance of a number of rather ill-defined oval forms, from eight to eighteen inches in length, and separated from one another by spaces which are often about the same breadth as themselves: these oval forms are crossed, near their long axes, by joints which are nearly parallel to them, and also near the sides by other joints which become more curved and more nearly parallel to the sides as the sides are approached. The spaces between the forms are also crossed by a multitude of joints which keep as a rule nearly parallel to the side of the oval form which is nearest them. These joints become gradually less prominent and numerous as they proceed toward the interior of the sheet, and about a foot off the surface they are hardly noticeable. Similar joints also occur near the under surface of the sheet". (C. T. Clough.)

One dyke which is worthy of notice on account of its historic interest is that which has already been mentioned as the "Beal" dyke. The name does not appear in this form on the maps of the Ordnance Survey, but Am Bile is marked on the six-inch map, and not far from this place is the dyke which we identify as that noticed by earlier writers. It is immediately west of the little inlet named Port a' Bhata, about 1¼ mile E.N.E. of Portree, and is reached by a steep road leading down from the farm of Torvaig, which is marked on the one-inch map. At this place a recess in the basalt cliffs is occupied by Jurassic rocks, and the dyke traverses these in a generally N.W.–S.E. direction. It has a maximum width of about 6 feet. The south-westerly face is well exposed, and shows a crust of tachylyte varying in thickness up to about an inch. The actual surface shows everywhere a delicate linear marking which we interpret as a flow-structure, and the direction of this varies considerably and rapidly. Thus towards the landward (N.W.) end of the exposure it dips S.E. at about 50°; farther seaward it becomes vertical, and then dips in the opposite direction; while still farther it becomes sensibly horizontal. These changes are observed in a distance of about 30 yards. It is one among other cases which seem to show that the flow of a rock-magma in a dyke-fissure is by no means always in the vertical direction. Illustrations of this are much more frequent among the intermediate than among the basic dykes of our area, and we shall return to the subject in a later chapter (Chapter 23).

Passing from the characters of the tachylytes as seen in the field to a closer examination of the rocks themselves, we consider first their *chemical composition.* We reproduce in the accompanying table the analyses of two examples from Skye, and, for comparison, of four other British representatives. Of these four, the first three, and possibly the last also, belong to the Tertiary suite of intrusions.

	I	II	A	B	C	D
SiO_2	45.613	52.59	53.03	55.40	56.05	53.63
Al_2O_3	14.423	17.33	20.09	13.24	17.13	15.93
Fe_2O_3	4.927	11.14	9.43	5.48	10.30	20.00
FeO	9.411	not det.	not det.	5.64	not det.	not det.
MnO	0.153	0.66	not det.	0.80	trace	trace
MgO	4.000	2.62	2.63	1.57	1.52	0.78
CaO	8.098	6.47	6.05	7.07	6.66	7.88
Na_2O	4.186	4.21	4–52	2.01	3.29	4.48
K_2O	2.397	2 40	1.27	1.64	0.98	0.50
H_2O	6.830	3.27 (ign.)	2.64 (ign.)	7.20	3.50 (ign.)	0.56 (ign.)
	100.090	100.72	99.66	100.05	99.53	103.76
Spec. gray.	2.68	2.72	2.83		2.714	2.99

I. Quiraing; anal. M. F. Heddle, *Min. Mag.,* vol. v., p. 8; 1882.

II "Beal"; anal. Hodgkinson, *Quart. Journ. Geol. Soc.,* vol. xxxix., p. 455: 1883. Traces of barium and copper.

A. Ardtun, Mull; anal. G. A. J. Cole, *Quart. Journ. Geol. Soc.,* vol. xliv., p. 303; 1888.

B. Slievenalargy, Co. Down; anal. S. Haughton, *Journ. Roy. Geol. Soc. Irel.,* vol. iv., p. 231: 1877.

C. Lamlash, Arran; anal. Delesse, *Ann. des mines* (5), vol. xiii., p. 369: 1858.

D. Carrock Fell, Cumberland; anal. R. H. Adie, *Quart. Journ. Geol. Soc.,* vol. xlv., p. 298; 1889. Traces of titanic acid. The high total of this analysis is unsatisfactory, even with allowance for part of the iron being in the ferrous state.

Although the six rocks show a considerable range of silica-percentage, they are evidently, as a group, somewhat more acid than the ordinary basalt and dolerite dykes and sills of the region. Another and equally noticeable point is the low proportion of magnesia, while in most cases the alkalies are decidedly high for basic rocks. The dyke of "the Beal" or Am Bile we have already referred to in the preceding chapter, and have attached to the peculiar type named mugearite. We have also noticed (pp. 263–269) the Quiraing rock, and have pointed out in its analysis peculiarities of the same kind though less marked in degree. It is probable that in other occurrences in Skye, in which there is an unusually amount of basic glass, there is something of the same peculiarity of composition. In default of chemical data, this is sometimes indicated by the nature of the enclosed crystallitic elements, *e.g.* by the development of oligoclase microlites rather than labradorite. In certain cases it cannot be doubted that, if the conditions of consolidation had been such as to produce a crystalline aggregate instead of a glass, the dominant constituents would be felspars of comparatively acid kinds, while the more basic elements would be represented principally by magnetite and sometimes olivine. It appears that magmas having this kind of composition assume the vitreous form more freely than ordinary basalt-magmas.

In the literature of the subject we find that the basic glasses (excluding those altered by subsequent hydration) have often been divided into tachylytes and hyalomelanes, and that the most typical examples of the latter are generally characterised by rather high silica and alkalies and constantly low magnesia. This distinction seems to correspond in a general way with that suggested by a study of our rocks, and a chemical investigation might perhaps enable us to carry it out. One distinctive character claimed for the hyalomelanes is their greater resistance to solution by acids; and it is noteworthy that such rocks as those of "the Beal", Gribun, and Lamlash are only slightly soluble.<ref> Judd and Cole, *Quart. Journ. Geol. Soc.,* vol. xxxix., p. 452; 1883,</ref> This test has, however, been discredited by Rosenbusch and others; and we are content here to indicate what seems to be a real distinction without desiring to revive a rather ill-defined terminology.

Some interest attaches to the *specific gravity* of the tachylytes. Professors Judd and Cole have remarked that "the basalt-glass of the Western Isles of Scotland appears to be generally distinguished by its very high specific gravity". As regards the vitreous modification of the ordinary basalt dykes, our observations are quite in accord with this statement. Seven fresh examples from Skye gave the figures 2.76 to 2.92, with average 2.84. The somewhat less basic tachylytes, however, with less magnesia and more alkalies in proportion to lime, are often less dense, and for the most part have specific gravities between 2.65 and 2.75, though sometimes up to 2.80. These, as we have remarked, include the most considerable developments of basic glass known in Skye. It should be remembered that the specific gravity is considerably affected by secondary changes. We have selected the freshest material obtainable for our determinations, but in some cases of tachylytes of low density from other areas there is no definite information concerning the state of preservation of the rocks.

Taking the specific gravities of the tachylytes of the Western Isles as a whole, and comparing with their cheinical analyses, we obtain results which at first sight appear rather discordant. In the following list we collect from various sources the particulars for all those cases for which we have chemical data, arranging them in order of specific gravity, and adding for comparison the tachylyte from Carrock Fell, Cumberland. Judging merely by these figures, it appears that the specific gravity bears no close relation to the silica-percentage, within the limits 45 to 55. The three specimens richest in iron are also the three densest, and the order of the three follows the same rule, but the rest of the list shows no such correspondence. The examples richer in water are without exception the lighter. the comparison of the first and last on the list being especially striking;<ref> Of the Slievenalargy and Ballymacilreiny tachylytes, the one very rich and the other very poor in water, the specific gravities are unfortunately not recorded.</ref> and this is probably a point of importance. There is another essential circumstance, which does not appear in the chemical analyses. These rocks, although conveniently spoken of as basalt-glasses, often contain a considerable proportion of individualised minerals and aggregations in the form of spherulitic, crystallitic, and globulitic growths; and the relative amount of these in the glassy matrix may affect the specific gravity of the rock to an important degree, apart from differences in total chemical composition.

	Specific gravity	Silica	Total Iron (as metal)	Water
Quiraing, Skye	2.68	45.61	10.77	6.83
Lamlash, Arran	2.714	55.20	7.70	3.50 (ign.)
Beal, Skye	2.72	52.59	7.80	3.27 (ign.)
Gribun, Mull	2.82	50.51	10.05	
Brodick, Arran	2.83	53.96		
Ardtun, Mull	2.83	53.03	6.60	2.64 (ign.)
Screpidale, Raasay	2.84	46.68	10.80	
Sorne, Mull	2.89	47.46	12.47	
Carrock Fell, Cumberland	2.99	53.63	14.00	0.56 (ign.)

A curious anomaly appears, however, in at least one case, on comparing the specific gravity of a tachylyte selvage with that of the interior of the same dyke. In a dyke on Lamlash, Arran, Delesse<ref>*Ann. des mines* (5), vol. xiii., p. 369; 1858.</ref> found for the interior 2.649 and for the selvage 2.714. In the same dyke the late Mr Thomas Davies<ref>*Quart. Journ. Geol. Soc.,* vol. xxxix., p. 449; 1883.</ref> found 2.67 for the interior and 2.72, 2.74, 2.78 for successive zones of the selvage, the last being the extreme edge. On the assumption that the chemical composition is the same throughout, this seems to be inconsistent with the general principle that substances are denser in the crystalline than in the vitreous form. This principle is abundantly verified by experiments, including those of Delesse himself. In a carefully conducted experiment by Barus<ref>*Amer. Journ. Sci.* (3), vol. xlii., pp. 498, 499; 1891.</ref>a diabase of specific gravity 3.0178 gave after fusion a glass of specific gravity 2.717; showing therefore a decrease of 9 per cent. in density or an increase of 11 per cent. in volume.

The French observer noticed the discrepancy, but considered it easily explicable by the fact that the tachylyte contains more silica and a little less water than the basalt. Professors Judd and Cole,<ref>*Quart. Journ. Geol. Soc.,* vol. xxxix., pp. 449, 453: 1883,</ref> with apparent justice, regard this explanation as inadequate, the observed differences falling within the limits of error. The more important figures in Delesse's analyses are:

	Dyke	Selvage
SiO_2	55.20	56.05
Fe_2O_3 (including FeO)	11.00	10.30
Ignition	3.85	3.50

in which it will be seen that the differences in silica and iron, if significant at all, ought to tell in the direction of a *lower* density for the glassy selvage. The difference in water shown is very small: if real, it probably indicates that the basalt of the central part of the dyke has suffered somewhat from secondary alteration. There may possibly be a difference in the relative proportions of ferric and ferrous iron, not separated in the analyses.

To ascertain whether basic rocks do really make an exception to the general rule would require careful analyses of the dykes and their selvages to prove identity of composition. It is unfortunate that in the only pair of analyses of this kind which we possess from Skye, those of the Quiraing occurrence, the specific gravity of the interior is not recorded. We are able to show, however, that the Lamlash dyke is by no means unique in having a vitreous selvage of higher density than itself. The "Beal dyke" gave the following results with the hydrostatic balance:

(S9373) [NG 5040 4457]	Centre of dyke	2.645
(S9374) [NG 5040 4457]	Part next selvage	2.678
(S9375) [NG 5040 4457]	Glassy selvage	2.686

In this case, however, the difference may not be very significant, for the interior of the dyke at least is not in a fresh condition. It may be remarked that, while secondary alteration probably reduces in most cases the density of crystalline rocks, this is not always the case. In the first of the three rocks mentioned next below there is a certain amount of pyrites formed, which tells in the opposite direction to vitiate the comparison. Professor Sollas has kindly determined for us by his diffusion-column the specific gravities of the glassy skins of some of our basalt dykes, and we here compare these with the results found by the hydrostatic balancefor the interior or for the whole specimen:

(S8845) [NG 501 255]	Dyke on N.W. face of Marsco	
	Part next to selvage (altered)	2.90
	Glassy selvage	2.80
(S8846) [NG 492 337]	Dyke on Meall Odhar Beag	
	Whole specimen	2.86
	Glassy selvage	2.91
(S8847) [NG 502 342]	Dyke N.W. of Ben Lee	
	Whole specimen	2.84
	Glassy selvage	2.94

In the last two, which are fresh rocks, the glassy selvage is very decidedly denser than a specimen representing the full width of the narrow dyke: a comparison of selvage with interior would of course show a slightly greater difference of the same kind. It is possible that there may be some real difference in chemical composition between the central and the marginal parts; and if such difference exists, and has been set up as a result of differentiation in place, it probably takes the form of a certain concentration of iron-oxides in the margin, which would account for the higher density of that part.

In describing the *micro-structure* of the rocks we shall endeavour to distinguish the *true basalt-tachylytes* from those of more peculiar composition, approximating in varying degree to the mugearite type. We shall begin with the former, which, as a rule, are found only as thin skins on the surfaces of a dyke or sheet.

In the first place a few words are called for relative to the occurrence of a vitreous "base" in the general mass of some of our basalt dykes and sheets. We have already remarked that any notable amount of glass in the body of an intrusion is of rare occurrence. In some instances, however, the marginal part developer an abundant glassy base, without assuming the character of a tachylyte, and interesting micro-structures are found. We select to illustrate this an intrusive sheet or sill in the Torridonian grits of the Isle of Soay, ¼ mile W. by N. of An Dubh-sgeire. The marginal part of this is a dark rock of generally doleritic aspect, and of specific gravity 2.80, enclosing very numerous dull black spots of round or ovoid shape up to ¼ inch or more in diameter. These spots, very conspicuous on a cut face, are scarcely to be detected on an ordinary fracture, but stand out prominently on the weathered surface. A thin slice (S9987) [NG 464 141] shows that they represent vesicles, into which the residual magma has forced its way at a late stage in the consolidation. We shall have to notice this circumstance as specially characteristic of the augite-andesite dykes, but this rock is of thoroughly basic composition. A brown residual "base" is abundantly present. In the interstices of theolabradorite crystals and (decomposed) augite grains it is a true glass; but in the larger and more defined patches which represent the vesicles it is mostly found to depolarise. Here a large part is made up of little spherulitic growths of the kind that we shall have to notice so frequently in the tachylytes and variolites. Owing to the oblique extinction of the felspar elements, which constitute most of their substance, these spherulites do not show the "black cross" effect; but the radiate structure is evident, and is rendered more so by the arrangement of numerous slender dark rods, representing probably destroyed augite.

Coming now to those basalt dykes which have glassy selvages, we notice as an invariable characteristic that the marginal part of such a dyke has a strongly banded structure parallel to the bounding wall. A transverse section will often show as many as six or eight narrow bands, averaging perhaps 1/20 inch in width; the outermost of which is the actual tachylyte, while the others show a great variety of micro-structure, into which true glass enters in some proportion. The outermost band is that which in a hand-specimen is conspicuous for its jet-like colour and lustre, while the others have a more subdued aspect — pitchy, resinous, or quite dull.

The actual tachylyte is extremely dark, becoming transparent only in very thin slices or finely crushed splinters. It shows then a deep brown colour, usually a reddish or yellowish brown, but sometimes with an olive tone. It is not always homogeneous, but often shows minute opaque spots or scarcely resolvable aggregates of dust of the kind termed "cumulites". There are as a rule no distinct crystallites, but an occasional small phenocryst, usually of felspar, may be enclosed here as well as in the other bands. Scattered microscopic amygdules, either spherical or ovoid, occur in some cases.

The succeeding bands have not usually the opacity of the true tachylyte, but show various depths of brown coloration, and also differ in the nature of their structures. Crystalline or crystallitic matter enters in various ways, and its proportion relative to the glassy base does not always decrease progressively outwards. The several bands are fairly well defined, but the sharpest division is usually that which separates the penultimate one from the border of true tachylyte. The principal varieties of micro-structure depend upon the presence of different spherulitic growths and of crystallites, and upon the extent to which these encroach upon the glassy base.

The spherulites are usually from 1/100 to 1/40 inch in diameter, though both smaller and larger examples have been found. They may be isolated in a glassy matrix or closely packed to make up the whole of a particular band. In the former case they are sharply bounded, with a spherical or ovoid outline, a ragged or irregularly stellate form being rarely found; in the latter case they show polygonal boundaries, due to mutual interference. Sometimes again spherulites in a glassy matrix coalesce in rows parallel to the wall of the dyke. The spherulites are always paler than the glass, and when best developed show a strong yellowish brown colour in thin slices. The centre of each spherulite is of a deeper brown colour, which fades gradually into a paler tint towards the periphery. There can be little doubt that the colour of the spherulites results mainly from an admixture of glass in the interstices of the felspar fibres which constitute the essential element of the structure. The proportion of glass varies in different cases, and is higher in the centre than at the periphery. The appearance between crossed nicols agrees with this. In some cases spherulites of dark colour are sensibly isotropic, but the more ordinary examples depolarise very decidedly. This is most pronounced in the paler spherulites, and especially so in the pale peripheral zone, where the birefringence approximates to that of a felspar. Some indication of radiate structure may or may not be perceptible in natural light, but it is seen with the aid of crossed nicols, whenever the depolarisation is sufficiently strong. The dark brushes, having more or less roughly the "black cross" arrangement, are most distinct in the outer portion of each spherulite. As a rule there is a certain irregularly tufted appearance, as if the fine fibres were grouped in sub-parallel bundles, the bundles rather than the individual fibres having the radiate disposition.

In exceptional cases there are features which are not easily explained by our simple conception of these spherulites as aggregates of felspar fibres with interstitial brown glass. A specimen from Ben Lee, near Sligachan, consists in one band of closely packed spherulites about 1/50 inch in diameter, which, though strongly depolarising, are of a deep colour (Figure 71), E. Each spherulite is built up of several distinct tufts or irregular sectors, of which some are deep brown, while others have a grey or fawn colour. They are quite strongly pleochroic, the brown portions showing a stronger absorption for vibrations in the direction of the radius and the grey portions for vibrations in the transverse direction. Almost identical phenomena have been described by Prof. Grenville Cole<ref>*Quart. Journ,. Geol. Soc.,* vol. xliv., p. 302, p1. XI., fig. 2; 1888.</ref> in a tachylyte from Ardtun in Mull. In our rock the pleochroism is stronger in the brown parts than in the grey, and certain of the latter which have a rather browner tone than the rest behave like the brown parts as regards the direction of stronger absorption. Prof. Cole suggests that the phenomena may be due to the presence of fibres of some pleochroic mineral, perhaps an alkali-bearing pyroxene, as an element in the spherulitic aggregate. This is possible, though it is not easy to specify any known mineral which is likely to occur and possesses the required quality of pleochroism. An alternative explanation might perhaps be based on the fact that colourless anisotropic crystals may acquire pleochroism when stained.<ref>Weinschenk, *Zeits. anorg. Chem.,* vol. xii., p. 377; 1896.</ref> It is to be remarked, however, that the brown and grey parts of the spherulites differ also in respect of optical orientation. In the former the fibres have the "positive" character, *i.e.* the axis of optical elasticity most nearly parallel to the length of the fibre is the least axis. The grey sectors are "negative", but those of a browner grey tint which resemble the brown parts in the quality of their pleochroism resemble them also in being positive. In all cases, then, the least axis of optical elasticity corresponds with the stronger absorption. These facts perhaps point to the presence of actual pleochroic fibres mingled with the felspar, and apparently to the presence of two different pleochroic minerals, one in the brown sectors and the other in the grey.

As probably distinct from spherulites, we may mention the occurrence in some cases of dark spherical spots, often coalescing into botryoidal aggregates, which show no apparent structure and have no reaction upon polarised light. These are perhaps of a "concretionary" rather than a spherulitic nature.

Apart from the felspar fibres of the spherulites and the globulitic separation of iron-oxide in the glass, distinct crystallites are not very characteristic of the rocks under discussion. When present, they are of the usual minerals — felspar, olivine, and probably augite, this last generally decomposed. Fibrous terminations, sheaf-like groupings, skeletal forms, and other characteristic habits are found; but we can rarely see any indication of crystallites, other than the fibres of felspar, entering into the radiate arrangement of the spherulites.

After the foregoing general description a few examples will suffice to exhibit the kind of variety met with among these rocks. A simple case is illustrated by a small dyke on the north-west face of Marsco. The hand-specimen is a very compact-looking basalt showing rare crystals of augite and labradorite and rather numerous patches of iron pyrites. At about 1½ inch from the edge the rock begins to assume a dull pitchy lustre, and this becomes gradually brighter, but the final change to the true tachylyte selvage is, as usual, rather an abrupt one. A thin slice (S8845) [NG 501 255] shows the compact basalt of the interior to consist of minute prisms of felspar, granules of augite, and skeleton growths of magnetite, with only a small amount of glassy base. In the pitchstone-like portion this last is in much greater quantity: the little felspars are still very abundant, but the augite granules become scarcer. Then the felspars also disappear, and the rock becomes a deep yellowish-brown glass, crowded with minute shadowy objects difficult to resolve. There are, however, dark globulites of iron-oxide, collected into nebulous patches ("cumulites "), within which are darker spots caused by a condensation of the same.

A 2½-inch dyke from Meall Odhar Beag, near Sligachan, appears very compact throughout, though with only dull lustre in the interior. The actual selvages are of black glass with fine fissures, which show as curved perlitic cracks on the contact-surface. A slice (S8846) [NG 492 337] shows rare crystals of felspar and green augite, about 1/100 inch long, distributed through the dyke. The general mass shows marked banding throughout. The central part consists of narrow bands alternately lighter and darker, an appearance dependent on the smaller or larger proportion of glassy base. Crystallites are in this case very abundant and of more than one kind, the most conspicuous being skeletons of felspar, often with forked extremities (Plate 23)., Fig. 1, B. The darker bands are almost opaque except for these crystallites. At about 3/10 inch from the edge of the dyke this almost opaque portion gives place to a light brown band irregularly fissured and composed of closely packed spherulites about 1/100 inch in diameter. This is succeeded by a narrow band containing small oval spherulites isolated in a glassy ground. The latter is opaque in a thin slice, and the same is true of the selvage, 1/10 inch wide, of actual tachylyte which follows.

From N.W. of the summit of Ben Lee, in the same neighbourhood, comes another 2½-inch dyke or vein, which in a hand-specimen closely resembles the preceding. In thin slices it shows a banded structure throughout, the successive bands exhibiting considerable variety of character, as shown in the accompanying figure (Figure 71).

About half a mile E.S.E. of Loch Mhic Charmichael, in the Sleat peninsula, a thin basalt sill (specific gravity of the interior 2.82) passes at the edge into a black glass. In a thin slice (S6854) [NG 653 096] this shows a deep brown colour, with only vague indications of crystallites. A little farther from the edge the rock, still in the main glassy, is crowded with fine felspar fibres and with minute rods of magnetite disposed in two sets to build a rectangular grating.

A rock collected by Mr Clough at Camas Daraich, near the Point of Sleet, is of interest as possibly throwing light on the minute structures of some of these semi-vitreous basalts, here presented on a larger scale. The rock is seen near the middle of the little bay as an irregular sheet one or two feet thick running nearly horizontally through a series of contorted granulitic grits.<ref> For a fuller description of the rock see Clough and Harker, *Trans. Edin. Geol. Soc.,* vol. vii., pp. 381–389, pl. XXIII; 1899.</ref> It is a thoroughly basic rock, of specific gravity 2.92, and consists almost wholly of spherules, often as much as 2½ or 3 inches in diameter. They are usually so closely packed as to leave little or no interstitial space, and consequently assume polyhedral outlines. In hand-specimens the rock is dark grey or almost black, with the peculiar sheen due to innumerable slender fibres, which are seen to have a radial arrangement about the centres of the individual spherules. Thin slices (S7845), etc.] show that these fibres are of felspar, probably labradorite, and that they form the bulk of the rock. The other minerals are olivine, in crystals 1/500 to 1/200. inch in diameter; augite, in granules and patches of about the same size; and magnetite in octahedra and granules still smaller (Plate 23)., Fig. 2, A. The olivine often builds good crystals, bounded by the forms *m* (110), *k* (021), and *b* (010); but the augite has a subophitic arrangement. This, the prevalent, type of the rock has very little residual base. A blacker and more lustrous specimen, however, taken nearer to the surface of the sill, is seen in the slice (S7846) [NM 566 996] to contain an abundance of brown glass. Here the divergent fibres of felspar are more slender, and the augite and magnetite specks smaller, while the olivine takes the form of little skeleton crystallites. These are elongated parallel to the a-axis of crystallography, and are hemimorphic with reference to the b-axis. They have forked terminations, and are often little more than shells occupied in the interior by glass (Plate 23)., Fig. 2, B. At the actual surface of the sill there is a thin tachylytic selvage, perhaps 1/20 inch in thickness. The special interest of this sill is that it presents on a relatively large scale, and in an unusually fresh state, that type of spherulitic structure, often called variolitic, which is associated with basaltic rocks. In most "variolites" which have been described the structure is on a much more minute scale, and is obscured in varying degree by subsequent chemical changes.

There remain to be noticed the *less basic tachylytes,* not corresponding in composition with normal basalts, and in some cases resembling in this respect the type which we have named mugearite. Here we no longer find the strong tendency of the glass to concentrate as a thin purely vitreous band at the actual margin, nor again the rapid variation in successive narrow bands differing in micro-structure. Typically we find a considerable proportion of glass throughout what may be a rather broad border, measuring several inches, with only gradual change in microstructure in this distance. The glass itself is commonly paler than in the true basaltic tachylytes, and is sometimes quite colourless in thin slices. Judged by the specimens that we have examined, there seems to be much less tendency to micro-spherulitic structures. On the other hand, there may be a much greater development of crystallitic growths, sometimes assuming complex groupings which have the general effect of spherulites of relatively large dimensions. These characteristics are not set forth as absolute, and examples are found in this group of tachylytes which reproduce in some measure special features already described in the former group.

The dyke of Am Bile or "the Beal" is an illustration of the last remark. The passage from the crystalline interior to the vitreous edge of the dyke, though not abrupt, is rapid, and is completed within a distance of 2 or 3 inches. The glass itself, though not nearly opaque, is of a yellowish to reddish brown colour. The mainly glassy part, though without marked parallel banding, exhibits some variety of structure. It is partly spherulitic, but the spherulites, excepting their darker centres, scarcely differ from the surrounding glass in colour, so that their outlines are usually invisible in natural light. These outlines are often irregularly toothed. The spherulites are about 1/20 inch in diameter, have an evident radiate structure, and depolarise. In both spherulites and matrix there are numerous little round spots of dark brown with a narrow paler border, which have no action on polarised light. Professors Judd and Cole have remarked in this tachylyte felspar crystals deeply honeycombed with glass-inclusions.<ref>*Quart. Journ. Geol. Soc.,* vol. xxxix„ pp. 459, p1. XIII., figs. 3, 5; 1883.</ref>These are of clear orthoclase or sanidine. They occur also in the interior of the dyke, and are perhaps xenocrysts. The glass also encloses crystals of oligoclase, which are not corroded, and both felspars have served as nuclei for spherulitic growths.

This rock, belonging in virtue of its chemical composition to the present group rather than to the former, is in petrographical characters intermediate between the two.

The next dyke to be noticed occurs at Allt Thuill, in the Sleat district, and has already been referred to as showing an unusual thickness of vitreous or semi-vitreous rock. The central portion, without noticeable lustre, contains only a small proportion of interstitial glass. There are little narrow rods of augite, from1/50 inch downward, often hollow or with brush-like extremities; narrow twinned crystals of oligoclase, about the same size or less; minute crystals of magnetite and needles of apatite, and perhaps a little orthoclase (S5429) [NG 748 171]. The vitreous margin of the dyke appears very dark in thin slices (S5428) [NG 748 171], (S8851) [NG 748 172]. This, however, is not due to any colour in the glass itself, but to a dense charge of finely divided magnetite in a perfectly colourless glassy base. There are abundant crystallites in addition to this, including augites with brush-like terminations, just like those noticed above, and felspar rods of more minute size. This highly vitreous marginal portion of the dyke passes gradually into the more crystalline interior without any noticeable banding.

A dyke to the south of Loch Ashik, near Broadford, is in great part vitreous throughout its width of six inches or more. The interior and principal portion has a pitchy lustre, while the selvages are of black glass, extending inward for an inch, or even in places two inches, though interrupted by narrow bands of duller aspect. Throughout there are bodies which look like large spherulites, rather shadowy in appearance except where accentuated by weathering. In the interior they range up to ½ inch in diameter, and are rather closely packed; towards the edge of the dyke they diminish to less than 1/20 inch, and are isolated in the matrix. Slices of the interior portion show a peculiar structure, the most prominent feature being innumerable dark rods set in a clear colourless matrix. Parallel rods are closely ranged in groups, which interlace at various angles; and it is a roughly radiate arrangement of the groups, not of the individual rods, that imparts the quasi-spherulitic structure. The interspaces between the spherical bodies have a constitution not very dissimilar, but here the rods are shorter and have a less regular arrangement. The colourless base is isotropic and clearly glassy. Towards the centre of each "spherulite", where it is in rather greater force relatively to the dark rods, it develops numerous little felspar microlites, occasionally with radiate grouping, and there may be a group of small felspar crystals with octahedra of magnetite at the actual centre. The felspar always gives sensibly straight extinction, and is presumably oligoclase. The dark rods which are so prominent a feature of the rock are not easily identified in all cases. In some places they seem to be opaque, and have irregularly serrate edges suggesting a string of octahedra of magnetite (Plate 23)., Fig. 1, A. In other places they are transparent, with the strong birefringence and high extinction-angles of augite. These latter are less abundant.

The dark glassy selvage shows a curious patchy structure in thin slices (S8848) [NG 691 233], etc. Portions are transparent, with a light brown colour, and encloses only scattered opaque globulites. The other and principal portions are dark, and present convex botryoidal boundaries to the paler patches, as if the pigment had been concentrated by a concretionary process. Here, but not in the pale portion, the abundant dark rods may sometimes be detected, and we may infer that these were formed after the concentration of the pigment.

The heterogeneous patchy nature of this selvage is illustrated by some specific gravity determinations kindly made for us by Professor Sollas with his diffusion-column. The greater part of the finely crushed powder gave from 2.74 to 2.85; but there was a heavier portion which gave 2.91, and a much lighter portion which gave 2.54. The less completely vitreous interior of the dyke gave, on a hand-specimen, the specific gravity 2.72. Under the microscope the greater part of the powder is translucent only in places; the denser part (sp. gr. 2.91) is almost all opaque; and the lighter part (sp. gr. 2.54) is translucent to transparent, with a greyish or greenish brown colour. Those minute chips which are not opaque show nevertheless occasional perfectly opaque spots, due presumably to a separation of magnetite.

The last example to be noticed is a dyke one foot wide from about ¾ mile N.E. of Kinloch. It has a black velvety appearance throughout, and is manifestly rich in glass. There are numerous well-defined bodies resembling spherulites, ¼ to ½ inch in diameter, scarcely visible on a fresh fracture, but very evident on a weathered surface. In thin slices (S8850) [NG 708 183], etc. these resemble in general character the "spherulites" in the preceding rock, having only a rude approach to the radiate structure. Here, however, the rods are of augite, often barred across at short intervals by magnetite (Plate 24)., Fig. 1, A. They are embedded in a colourless glass, which, however, assumes a pale brownish tint in the peripheral zone of each "spherulite". The interspaces do not differ essentially from the "spherulites" themselves. The latter have the character described throughout the greater part of their mass, but towards the centre of each little crystallites of felspar begin to develop in the colourless glass. At the centre the interstitial glass is reduced to a minimum, and the essential constituents are interlacing crystallites of felspar, augite, and magnetite. The felspar is mainly oligoclase, but there are some broader and more shapeless elements which are probably orthoclase (Plate 24)., Fig. 1, B.

We may suppose with some probability that the colourless interstitial glass in these rocks has approximately the composition of an oligoclase, perhaps with some admixture of potash-felspar; the iron as well as the magnesia being entirely contained in the crystallitic elements, a feature never found in the normal basalt tachylytes. The apparent absence of olivine and, in the last rock, the presence of abundant augite, suggest, however, that the composition differs from the mugearite type by a higher content of silica and lime.

There are some dykes in the south-eastern part of Skye which closely resemble the one last described in many respects, but are wholly crystalline One occurs at Lòn Buidhe, near Heast. A thin slice (S5771) [NG 657 177] shows grouped rods of augite set in a clear colourless matrix, and has much the same appearance as the preceding; but polarised light shows that the clear interstitial substance is here oligoclase. This felspar has a radiate arrangement about centres, building distinct spherulites about ■ inch in diameter, and we may even observe a brownish tint in the peripheral zone of each spherulite, as in the former case. Such rocks have decided affinities with those to be described as trachy-andesites (Chapter 23), and such evidence as we have concerning the age of the less basic tachylytes would permit of their being assigned to the same late epoch.

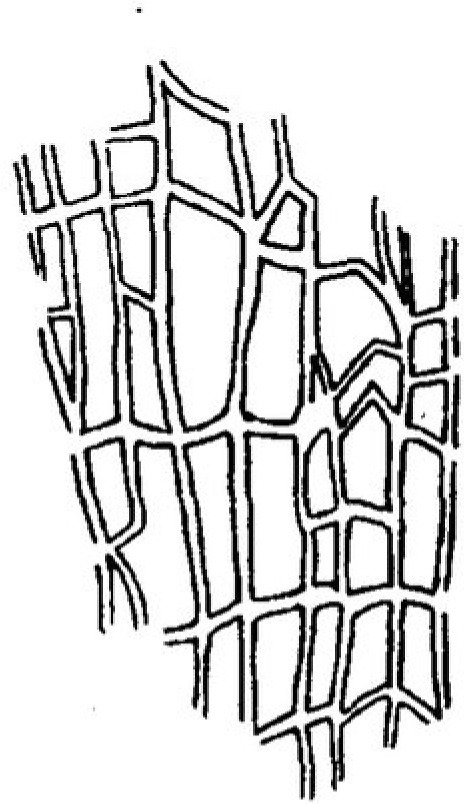


FIG. 69.—Sheaths and cores on surface of a basaltic sheet, rather more than $\frac{1}{3}$ mile S.W. of Cnoc a' Chàise Mòr, near Knock. Scale, $\frac{1}{4}$ of natural size. (C. T. C.)

(Figure 69) Sheaths and cores on surface of a basaltic sheet, rather more than ■ mile S.W. of Cnoc a' Chàise Mòr, near Knock. Scale, ¼ of natural size. (C. T. C.)

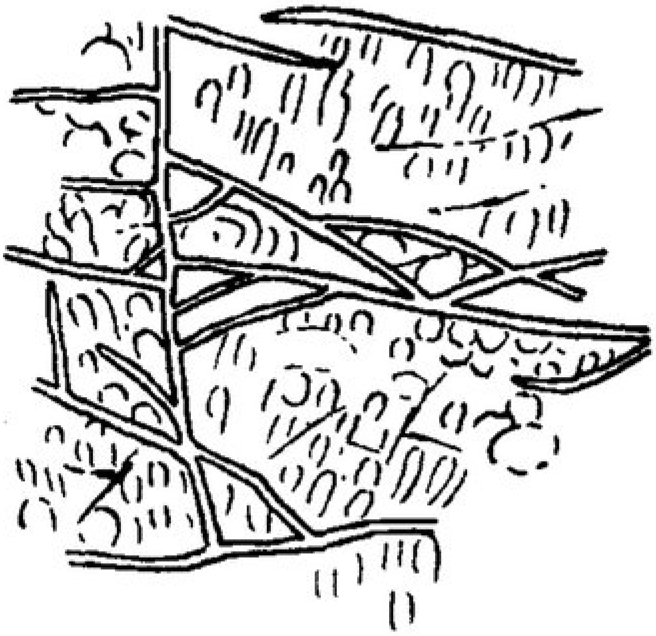


Fig. 70. — Sheaths and cores, the latter with perlitic forms, on surface of a basaltic sheet, same locality as the preceding. Scale, $\frac{1}{10}$ of natural size. (C. T. C.)

(Figure 70) Sheaths and cores, the latter with perlitic forms, on surface of a basaltic sheet, same locality as the preceding. Scale, 1/10 of natural size. (C. T. C.)

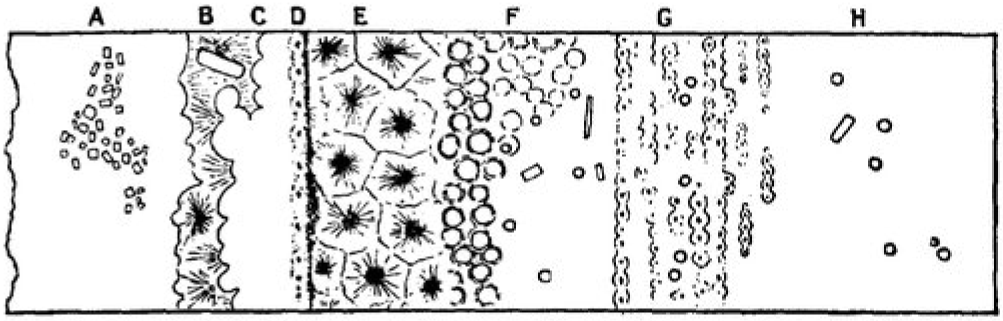


Fig. 71.—Margin of small basalt dyke, N.W. of Ben Lee, near Sligachan; × 10. This figure is merely diagrammatic.

A. Interior of dyke, very dark in the slice, but crowded with minute felspar microlites and enclosing locally groups of little felspar crystals.

B. Narrow spherulitic band, birefringent but without any good "black cross."

C. Dark spherical bodies of concretionary nature, without action on polarised light.

D. Single band of small spherulites like G, and narrow seam of black glass.

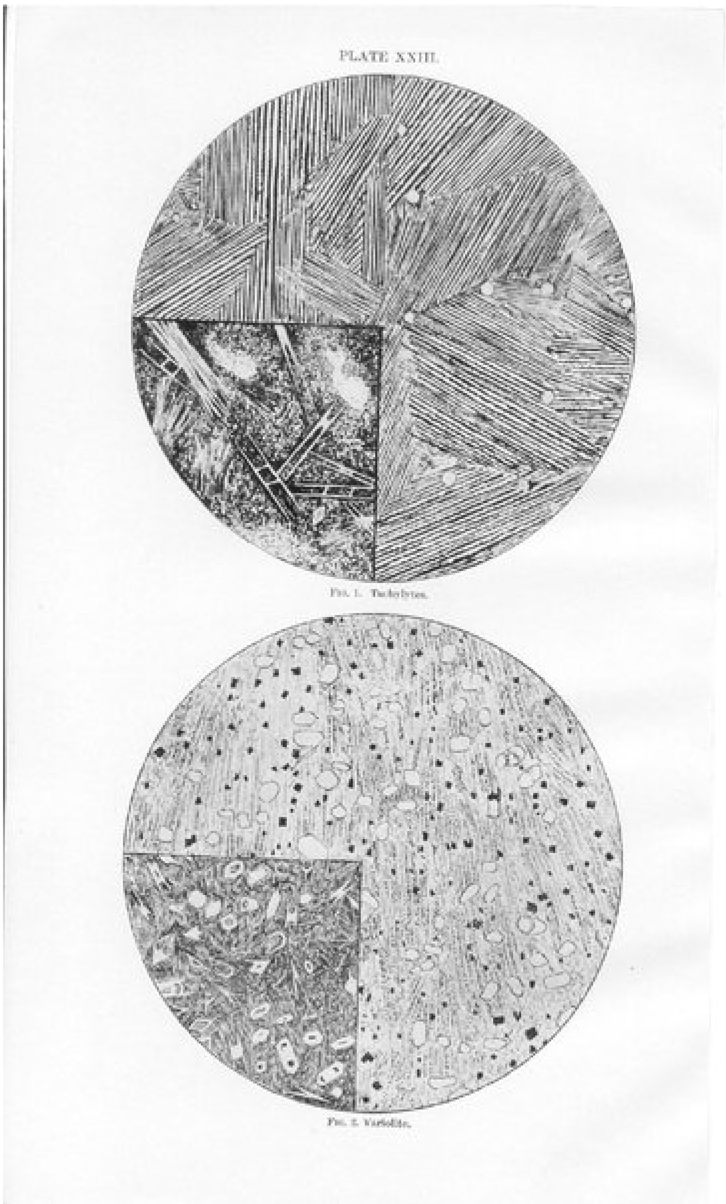
E. Pleochroic spherulites, described in text, p. 344.

F. Band full of obscure spherical bodies giving no reaction between crossed nicols.

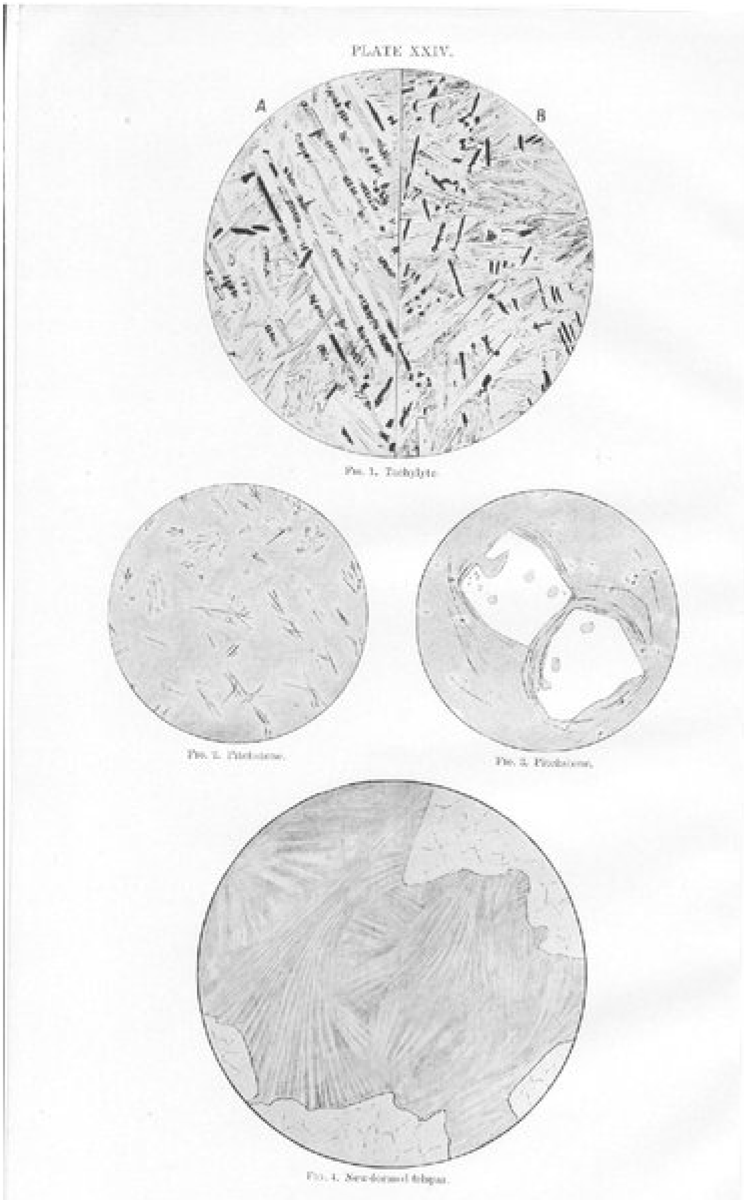
G. Minute spherulites, coalescing into bands.

H. Black glass forming actual edge of dyke.

(Figure 71) Margin of small basalt dyke, N.W. of Ben Lee, near Sligachan; × 10. This figure is merely diagrammatic. A. Interior of dyke, very dark in the slice, but crowded with minute felspar microlites aud enclosing locally groups of little felspar crystals. B. Narrow spherulitic band, birefringent but without any good "black cross". C. Dark spherical bodies of concretionary nature, without action on polarised light. D. Single band of small spherulites like G, and narrow seam of black glass. E. Pleochroic spherulites, described in text, p. 344. F. Band full of obscure spherical bodies giving no reaction between crossed nicols . G. Minute spherulites, coalescing into bands. H. Black glass forming actual edge of dyke.



(Plate 23) Fig. 1. A. (occupying three quadrants) (S8849) [NG 691 233] × 40. Tachylyte, dyke ■ mile S. of Loch Ashik, near Broadford: showing the central part of the dyke, which consists of a clear colourless glass crowded with rods of magnetite in parallel groups. The small clear spaces are amygdules. See p. 349. B. (lower left-hand quadrant) (S8846) [NG 492 337] × 200. Basalt, largely glassy, with skeleton crystallites of felspar, central part of a thin dyke with tachylytic selvages, N. slope of Meall Odhar Beag, near Sligachan. See p. 345. Fig. 2. × 40. Spherulitic or variolitic basalt, forming a sheet at Camas Daraich, Point of Sleat. See p. 347. A. (occupying three quadrants) (S7845) [NM 566 996]. Prevalent type, showing only part of one of the large spherulites. B. (lower left-hand quadrant) (S7846) [NM 566 996]. Marginal modification, largely vitreous, with olivine in the form of skeleton crystallites.



(Plate 24) Fig. 1. (S8850) [NG 708 183] × 150. Tachylyte, dyke ¾ m. N.E. of Kinloch, Sleat district: a quasi-spherulitic rock. See pp. 349, 350. A. Outer portion of one of the large spherulitic bodies, showing parallel rods of augite, with some magnetite, embedded in a colourless glass. B. Central part of a spherulite, showing abundant felspar, as well as augite and magnetite, with a smaller proportion of glassy base. Fig. 2. (S6794) [NG 617 233] × 20. Pitchstone, dyke in Allt a' Choire, above Coirechatachan, near Broadford: showing groups of crystallites, each surrounded by a clear ring. The turbid appearance of the rest of the glassy mass is due to a crowd of more minute crystallitic growths. See p. 407. Fig. 3. × 20. Pitchstone, E. slope of Glas Bheinn Mhòr; showing perlitic cracks surrounding phenocrysts of quartz: also groups of crystallites, each surrounded by a clear ring. See p. 405. Fig. 4. (S7479) [NG 523 201] × 30. Xenolith of quartzite from a basic dyke, S. end of Blath-bheinn. The figure shows the quartzite corroded by the basic magma and an inlet occupied by radiating fibres of new-formed felspar, probably oligoclase. See p. 352.