References to Dr. Kerr's papers on electro-optics :—

"Philosophical Magazine," Ser. 4, vol. 50, 1875; pp. 337 and 446.
" " Ser. 5, vol. 8, 1879; pp. 85 and 229.
" " " 13, 1882; pp. 153 and 248.

Faraday gives a list of bodies with the sign of the electrification they acquired by friction, which is here reproduced for comparison with my results.

Name of dielectric.	Sign of the electro-optical effect.	Sign of electrification by friction.
Distilled water	+	+
Carbon disulphide	+	+
Naphthaline	+	+
Naphtha	+	+
Caoutchoucine	+	+
Spermaceti	+	−
Oil of turpentine	+	−
Resin (dissolved in alcohol)	+	−
Alcohol (ethyl)	−	−
Lard	−	−
Beeswax	−	−
Castor oil	−	−
Olive oil	−	−

III. "Notes on Alteration induced by Heat in certain Vitreous Rocks; based on the Experiments of Douglas Herman, F.I.C., F.C.S., and G. F. Rodwell, late Science Master in Marlborough College." By Frank Rutley, F.G.S., Lecturer on Mineralogy in the Royal School of Mines. Communicated by Professor T. G. Bonney, D.Sc., F.R.S., &c. Received May 18, 1886.

[Plates 3—5.]

In this paper an endeavour is made to show the nature of the changes which have resulted from the action of heat upon certain vitreous rocks. The changes which take place in such rocks through natural processes may sometimes be effected by heat alone, at others by heat in presence of moisture. Of these actions the latter is probably the more frequent, but, at the outset, it seems important to ascertain the action simply of dry heat before studying the more complicated conditions engendered by the presence of water and the pressure of superincumbent rock masses.

The following examples which have been operated upon are few, but typical, and the alterations which they have undergone will be found to have a certain petrological significance.

The first subject taken for experiment was a small fragment of the well-known pitchstone of Corriegills in the Isle of Arran. This was kept at a temperature ranging from 500° up to about 1100° C., during a period of 216 hours. The change visible at the end of the nine days' heating is not so strongly marked as might have been expected, the fragment still exhibiting a resinous lustre, but the colour, originally a deep green, has been altered to a deep reddish-brown or chocolate colour. The rock in its normal condition has already been described by Mr. S. Allport* and others, and a section cut from the specimen before heating presents exactly the same characters shown in Allport's drawings, published in the "Geological Magazine," in Vogelsang's "Krystalliten," Plate 13, fig. 2, and in Zirkel's "Mikroskopische Beschaffenheit der Mineralien und Gesteine," fig. 43.

A section made from the specimen now described, but prepared prior to heating, has furnished the figs. 1, 3, and 5, on Plate 3. The three right-hand figures on the same plate have been drawn from a section made after nine days' heating at a temperature ranging from 500° up to about 1100° C. For the sake of comparison the figures on opposite sides of the plate have been drawn under the same amplification.

When the artificially altered rock is examined under a power of 25 linear it presents the general appearance shown in fig. 2, Plate 3. On comparing this with fig. 1 on the same plate we see that a marked change has taken place. The clear spaces surrounding the crystallites or belonites of hornblende have increased, while the dusty-looking matter no longer shades off into the clear glass but lies within more or less sharply defined boundaries. It also presents a coarser appearance than in the section taken from the unaltered specimen. With increased amplification the character of the change becomes more clearly perceptible.

In fig. 4, Plate 3, we find, on comparing it with fig. 2 on the same plate, that the hornblende belonites themselves have undergone very considerable alteration. They have to a great extent lost their frond-like appearance. Their delicate lateral growths seem to have shrivelled up, and their green or greenish-brown colour has changed to a deep rusty brown. Their stems or central rods have become opaque, and the lateral fringes frequently share this opacity. They seem, in fact, mere withered representatives of the greenish fern-like crystallites which occur in the natural state of the rock, and the change appears

* "On the Microscopical Structure of the Pitchstone of Arran," "Geol. Mag.," 1872.

to consist in the peroxidation of the protoxide of iron in the hornblende. The general aspect of these crystallites is much darker than that of their unaltered representatives, and they stand out in bold contrast to the clear glass around them.

On looking at the left-hand portion of fig. 4, Plate 3, we see a number of coarse spiculæ which under a lower power, as in fig. 2, Plate 3, appear merely as stippling. This stippling in fig. 2 is the altered condition of those parts of fig. 1 which are softly shaded, or seem to be so under an amplification of 25 linear. When magnified 250 diameters this portion of the normal rock still appears finely stippled, but contains numbers of very minute spiculæ, as shown in fig. 3, Plate 3. When we compare this stippling in fig. 3 with the coarse spiculæ on the left of fig. 4, Plate 3, the extent of the alteration produced by the nine days' heating becomes striking. It is probable that these spiculæ are hornblende, and that they are evidently a further development of the much smaller ones so plentiful in the glassy ground-mass of the unaltered rock. In the dusty looking parts of the unaltered glass we find, under an amplification of 1150 diameters, some indication of the source from which this wealth of crystalline spiculæ has been derived, fainter and smaller spiculæ being visible, together with sparsely distributed dark specks, a few blunt-ended colourless microliths, and a profusion colourless globulites, as in fig. 5, Plate 3.

The spiculæ shown on the left of fig. 4 are again represented in fig. 6, Plate 3, under a power of 1150 diameters. They are grouped in a stellate manner and constitute a large proportion of the rock, while the fine dusty matter previously visible has almost entirely disappeared. Although, through the agency of dry heat, we have here an instance of further crystalline development, yet no approach to a felsitic structure is discernible in the glassy matter of this rock; the new crystallites which have been formed being certainly neither felspar nor quartz, but possibly actinolite.

The next specimen to be considered is a piece of black obsidian from Ascension, about as typical an obsidian as it would be possible to find, and showing a faintly banded structure. The general microscopic character of this rock is shown in figs. 1 and 3, Plate 4, fig. 1 being magnified 25, and fig. 3 570 diameters. In fig. 1 the banded structure is well marked, and streams of colourless microliths lie with their longest axes in the general direction of the banding. A fragment of this rock was kept for the same period at the same range of temperature adopted in the case of the Arran pitchstone.

The rock in its normal condition is a deep black glass with a well-marked conchoidal fracture. In section, when not very thin, it appears by transmitted light of a brown or coffee colour, and contains,

as already stated, numerous microliths, mostly bacillar or spicular, sometimes in rectangular forms, and often shaped like a butcher's meat-tray. In the artificially heated specimen a remarkably vesicular structure has been developed, the rock, in fact, has become filled with vesicles, mostly spherical, or approximately so. The sand in which the specimen was heated has adhered firmly to its surface. Vitreous lustre is visible on fractures. Under the microscope between crossed Nicols the rock shows no sign of devitrification from its protracted heating, but the section is full of the large vesicles which have been developed (fig. 2, Plate 4). The glass still contains great numbers of microliths, a few small stellate or cruciform groups being here and there visible, but it seems probable that they are fresh developments, and that the old ones have been dissolved, for there is no longer any banded structure, or only very faint indications of it, the microliths lying in all directions and not in streams. This view is favoured by the almost necessary assumption that the rock must have been reduced to a condition bordering on fusion to have permitted the development of such an extremely vesicular structure, while further evidence of this is seen in the firm adhesion to the surface of the specimen of the sand-grains in which it was embedded during the process of heating. In spite, however, of the great molecular change of position implied by this development of vesicles, there is no sign of devitrification, unless indeed the microliths be fresh ones formed during the heating of the specimen, or during two days in which it cooled from 800° to about 100° C. They do not probably equal those present in the normal condition of the rock.

Fig. 4, Plate 4, represents part of a section of a piece of the same obsidian, which was kept for 701 hours at a temperature ranging from about 850° to 1100° C. The specimen has been nearly fused, and is pitted on the surface by the impressions of the sand-grains in which it was embedded, a few of the grains still adhering. There is a resinous or subvitreous lustre on some parts of the specimen, but one face is dull. Internally it is full of vesicles, but a thin compact crust exists in which there are none, and this crust is continuous with the spongy vesicular portion. One or two of the cavities are nearly half an inch in diameter, *i.e.*, they occupy nearly the whole thickness of the specimen, while others are of very small dimensions. They are irregular in form, and appear as a rule to communicate with one another.

Under the microscope, with an amplification of twenty-five diameters, the section shows large irregular vesicles; their walls (*i.e.*, what remains of the rock) appearing to consist of greenish-brown matter traversed by opaque and approximately parallel bands. The translucent portions of the section seem, under this low power, to consist of micro-crystalline matter, the general aspect being that of fine dust

mixed with a felted microlithic substance, while between crossed Nicols numerous doubly refracting granules and needles are visible.

Where the actual margin or outer crust of the specimen is included in the section the substance is quite transparent and colourless by ordinary transmitted light, and is seen to contain numerous green microliths.

By reflected light the whole section appears of a greyish-white, except the parallel bands, which are of a rather darker grey, and the more vitreous portion of the outer crust, which appears dark. The extreme outer crust is seen by substage illumination to be almost or quite opaque.

Under a power of 250 diameters the outer crust may be distinguished as consisting of three layers, the outermost of extreme thinness, transparent, and coffee-coloured; the next quite opaque or feebly transmitting a brown or brownish-green light. It is of much greater thickness than the outermost glassy layer, and consists of greenish-brown microliths matted parallel to one another, and directed with their longest axes at an angle to the outer surface of the specimen, the angle being sometimes nearly a right angle, and seldom less than about 20° or 30°. This shades off or fringes off into a clear colourless glass layer, also containing numerous greenish-brown spicular microliths, evidently identical in character with those which, by their massing together, form the nearly opaque band last described. It is not easy to say what these microliths are, but they appear to be some form of amphibole or pyroxene; they have, as a rule, a somewhat frayed and ragged or fibrous aspect, and it seems occasionally that they either belong to the rhombic system, or extinguish at a very small angle with their longest axes. With the exception of the glassy band in the thin outer crust, the remainder of the rock has been completely devitrified, fig. 4, Plate 4. Owing to the porous nature of the specimen it was scarcely possible to prepare a very thin section, but, judging from what can be seen, it consists of doubly refracting microliths with an admixture of minute crystalline granules.

The devitrification does not in this case appear to be precisely of the same character as that met with in naturally devitrified obsidians, but at all events we have here a proof that the action of dry heat during 701 hours has been capable of devitrifying this glassy rock.

The next specimen, a black obsidian from the Yellowstone District, Montana, U.S., was in the first instance kept at a temperature ranging from 500° to about 1100° C. for 216 hours. Some of the sand in which the specimen was heated adheres firmly to its surface. On fractures the rock is still vitreous in lustre, but it appears of a much paler colour than in its natural condition. This is probably due to the development of great numbers of small vesicles, the colour being now grey, whereas in the unaltered specimen it was black.

Microscopic examination of a section of this obsidian in its normal condition shows the presence of numerous trichites, resembling small eyelashes, and often occurring in radial or stellate groups; globulites are also plentiful, but, with the exception of these and some minute gas-pores, the obsidian is remarkably free from enclosures, although here and there a few porphyritic felspar crystals and a spherule or two occur. This was, therefore, regarded as a very favourable specimen to experiment upon.

The appearance of a section of this rock in its normal condition is represented in fig. 5, Plate 4, as seen under a magnifying power of 570 diameters. In this drawing rather faint indications of banding are shown. Part of the same section is also represented in fig. 7, magnified 570 linear, in which some of the trichites are visible. The specimen which was heated for 216 hours has developed an exceedingly vesicular structure, but apart from this it appears to have undergone but little change. The vesicles are large, fig. 6, Plate 4. Their sections are nearly all circular or approximately so. The trichites seem to have disappeared entirely, but some small opaque granules are now visible, and in some instances they have distinctly triangular sections. These by reflected light appear black and are no doubt magnetite.

In order to ascertain what change would take place by further heating, another fragment, taken from the same specimen as the preceding, was heated for a period of 701 hours at a temperature of from 850° to about 1100° C.

The rock is still vitreous, but a marked change has occurred. The specimen had no sand adhering to its surface, and it perfectly preserved its original external form, the conchoidal fractures and sharp cutting edges remaining quite distinct, but the outer surface has merely a dull sub-resinous or flint-like lustre, although on freshly fractured surfaces the lustre is quite vitreous. Here and there upon the surface *very slight* elevations occur, and these are mostly perforated by a diminutive hole, as if made with a common sewing-needle. When a point was inserted in one of these apertures and the crust was prized off, a remarkably cavernous interior was exposed, the cavities appearing to have been formed by the coalescence of more or less spherical vesicles, averaging from a quarter to half an inch in diameter.

In these cavities white crystalline pellets were found, for the most part about a third the size of the cavities in which they respectively occurred.

Three of these pellets are represented in the middle line of figures on Plate 4. Some of them are approximately spherical, and they are usually crystalline crusts, either empty or enveloping a smaller pellet of the same kind. The walls of the cavities in which they occur are also at

times lined with crystals apparently of the same mineral. The pellets themselves are too friable to admit of any sections of them being cut, while no satisfactory conclusion has yet been arrived at by crushing them and examining the fragments under the microscope. Small glistening faces sometimes showing a certain parallelism of growth may be detected with the help of a lens, and, so far as general appearances go, the mineral bears a somewhat close resemblance to rhyacolite. They are, at all events, probably anhydrous silicates allied to the felspar or nepheline groups. In some cases the pellets adhere slightly to the walls of the vesicles, yet in one or two instances they appeared to be loose, but may possibly have been detached by the shock in breaking open the specimen. On examining one of these pellets by reflected light under a half-inch objective, the white crystalline surface was seen to be studded with minute black or deep blackish-red crystals, having a brilliant metallic lustre. One of them exhibited a six-sided face as shown in the bottom figure of the middle line in Plate 4. This was turned sufficiently well into position to enable all parts of the face to be brought at once into focus, when it was found that measurement of the angle formed by adjacent edges was 60°. There is, therefore, little doubt that these small crystals are specular iron, which has separated out during the process of artificial heating, no such crystals being visible in a microscopic section of the rock in its normal condition.

Under a power of 250 linear the section of this artificially heated rock still appears as a clear glass, but trichites similar to those present in the unaltered obsidian are again seen; they are, however, much more numerous. A vesicular structure still exists, and the sections of the vesicles are sometimes circular, at others oval. Two or three porphyritic felspar crystals occur in this section, one of them, apparently twinned on the Carlsbad type, has a very irregular outline, somewhat like that of a comb with broken teeth. Felspar crystals with equally irregular contours occur, however, in the unaltered rock.

In this specimen the devitrification has been confined to the formation of the white crystalline pellets, the rest is glass, containing trichites and globulites, which of course may be regarded as evidences of incipient devitrification. Still they are also present in the unaltered rock, and between the two sections the differences are barely appreciable, even under the microscope. Figs. 7 and 8 (Plate 4) show how close the resemblance is.

Being anxious to ascertain the result of dry heat upon basic as well as highly silicated glassy rocks, a small fragment of the very vesicular basalt-glass from Mokua Weo Weo, Sandwich Islands, was treated in the same manner as the previously described specimens. This became completely disintegrated in the process of section-cutting.

The specimen had, however, quite lost its vitreous lustre, and had changed from black to a pale brown colour. Another fragment of basalt-glass from Kilauea, very vesicular, but less so than the previous sample, was kept at a high temperature, about 750° to 1200° C., for a period of 960 hours.

The effect of this heating has been to completely destroy all glassy lustre. The specimen is still vesicular, but the colour has, like that of the Mokua specimen, changed from black to purplish-grey or light brown.

Fig. 1, Plate 5, shows the general character of a section of the unaltered basalt-glass of Kilauea, cut from the same specimen as that submitted to the furnace. The drawing, made under an amplification of 25 linear, shows portions of three vesicles, several crystals of olivine, some small spherulites, and numerous crystallites, in a clear brown glass. The minute crystallites in this lava are extremely beautiful, and especially worthy of careful study. They frequently assume delicate pectinate forms, which one would think quite as likely to be preserved or to be re-formed after the fiery ordeal as the little trichites in the obsidian previously described. A glance, however, at the section prepared from the altered specimen at once dispels all hope of seeing them again, or indeed of seeing anything which is not translucent, and does not occupy the entire thickness of the thin section which, in spite of its thinness, appears of a deep brownish-black and perfectly opaque. When examined by reflected light under a power giving about 30 diameters it is then seen to be of a deep reddish-brown colour with paler streaks, often cracks, which circle round the porphyritic crystals of olivine, which are still present and seem to have undergone little or no change (fig. 2, Plate 5). These cracks represent perlitic structure, evidently due to unequal tension in the glass surrounding the olivine crystals. The opacity of the altered rock must probably be attributed to the passage of some of the protoxide of iron in the normal rock into the state of peroxide, thus giving rise to the formation of magnetite. The normal rock is scarcely, if at all, magnetic, but the altered specimen causes a strong deflection of the needle.

This passage of a clear basic glass into a perfectly opaque substance is a point of considerable interest, since it seems highly probable that some of the opaque and extremely scoriaceous lapilli in certain volcanic tuffs of palæozoic age are simply fragments of basic glassy lavas, like those of the Sandwich Islands, which have undergone a change similar to that here described. That in course of time the magnetite in some of these ancient lapilli should pass into limonite is also a point worth bearing in mind.

It seems probable that some of the opaque lapilli and dust in the volcanic ejectamenta of Snowdon and Brent Tor, especially those of

the latter locality, where the lavas are chiefly of a basic character, may be simply altered fragments of vesicular basalt-glass.

The following specimens were prepared some years since by Mr. G. F. Rodwell, late Science Master in Marlborough College. Fig. 3, Plate 5, represents part of a section made from a black vesicular glass which resulted from the fusion of some of the basalt from the Giants' Causeway, in an ordinary Stourbridge-clay crucible, over a gas furnace. The mass was then rapidly cooled. The glass appears perfectly clear, and shows merely vesicles and irregular cracks. Another sample of the same rock was also fused in the same manner, but was allowed to cool slowly. A section cut from this (fig. 4, Plate 5) is translucent only on certain edges, where a prismatic structure is visible, the marginal portions of the prisms showing a radiating crystalline or fibrous character as indicated in the drawing. The rest of the section is opaque, as in the altered Kilauea lava. It may be added that a somewhat similar prismatic structure is occasionally to be seen in opaque specimens from the Sandwich Island lavas. Among Mr. Rodwell's numerous experiments he placed a fragment of cold basalt from the Giants' Causeway upon the surface of a molten mass of the same rock and allowed it to sink to the bottom of the crucible. Figs. 5 and 6, Plate 5, represent parts of a section taken through the enveloped fragment and the enveloping glass. The latter is quite clear, as shown on the right of fig. 6. On the left of this figure will be seen a belt of opaque matter, which intervenes between the fragment of basalt, seen on the left of fig. 5, and the clear glass on the right of fig. 6; while on the right of fig. 5 we see more of this opaque belt where it comes in contact with the enveloped fragment of basalt. The boundaries of this opaque belt are sharply defined, especially where it adjoins the clear glass. Within this dark belt are numerous radiating groups of colourless, transparent, acicular crystals, the terminations of some of them being shown in the dark half of fig. 5, Plate 5.

Whether the formation of this opaque zone is due to the chilling influence of the cold fragment on the hot magma into which it sank, is a question which may have its bearings upon the formation of tachylyte at the sides of intrusive veins and dykes of basalt where the molten mass has come in contact with the walls of a fissure. It may also be that the fragment of basalt parted with its heat less rapidly than the surrounding magma, and that the latter consequently cooled more slowly where it came in contact with the fragment. This seems at least a plausible explanation, and harmonises with the results of Mr. Rodwell's earlier experiments, shown in figs. 3 and 4, Plate 5.

Additional investigations will be made upon the rocks treated of in this paper, since the results hitherto obtained have been effected under conditions which may not be regarded as the most favourable for producing changes similar to those which take place in nature,

and it is hoped that another series of experiments may throw a better light upon the threshold of this subject.

The pitchstone from Arran (figs. 2, 4, and 6, Plate 3), the obsidian from Ascension (fig. 2, Plate 4), the obsidian from the Yellowstone (fig. 6, Plate 4), and the basalt-glass from Kilauea (fig. 2, Plate 5), were all heated at the same time and under the same conditions as the slab of "British plate" glass represented in figs. 1 and 2, Plate 6, in a paper on devitrified glass laid before this Society last year.*

This slab was $\frac{3}{4}$ inch thick, and the heat employed was sufficient to completely devitrify it, and also to partially fuse the glass.

Another piece of "rough plate" glass, one inch thick, containing less lime, and consequently less easily devitrified than the slab just mentioned, was also heated in the same kiln as the obsidians described in this paper, and was completely devitrified, with the exception of a spot about $\frac{1}{8}$ inch in diameter near the centre.

The obsidian from Ascension (fig. 4, Plate 4), and that from the Yellowstone (fig. 8 and small central figures on Plate 4) were in the kiln 701 hours. In the same kiln were the following specimens of artificial glass figured in the paper just cited.

Specimen	132,	fig. 4,	Plate 6.
,,	136,	,, 5,	,,
,,	137,	,, 3,	,,
,,	143,	,, 9,	Plate 4.

The cause of the vesicular character, and the changes in volume produced by dry heat in the rocks described in this paper, the enormous swelling which is frequently manifested, and, on continuance of heat, the return to about the original bulk, without appreciable loss of weight, and also the question of the presence of water, will supply materials for a future paper, in which it is hoped that some experiments on changes induced in vitreous rocks by heat in presence of water vapour may also be described.

Alteration of Pitchstone.

Plate 3.

1. Pitchstone, Corriegills, Arran. ×25.
2. The same kept at a dry heat ranging up to about 1100° C., 216 hours. ×25.

3†. Pitchstone, Corriegills. ×250.

4. The same after heating from 500° to *cir.* 1100° C., for 216 hours. ×250. Showing the alteration of the hornblende belonites to shrivelled (rusty coloured) bodies, and the coarse spiculæ developed in certain parts of the ground-mass.

* "Proc. Roy. Soc.," vol. 39 (1885), pp. 88–107.

† Figs. 1, 3, and 5, Plate 3, represent the rock in its normal condition.

5*. Pitchstone, Corriegills. ×1150. Showing portion of the ground-mass containing globulites and microliths.

6. The same after heating from 500° to *cir.* 1100° C. for 216 hours. ×1150. Showing the alteration which the ground-mass, corresponding to that in fig. 5, has undergone.

Alteration of Obsidian.

Plate 4.

1†. Black obsidian, Ascension. ×25.

2. The same after heating for 216 hours from 500° to 1100° C. ×25.

3†. Black obsidian, Ascension. ×570.

4. The same after heating for 701 hours from 850° to 1100 C. ×570.

5†. Black obsidian, Yellowstone, Montana, U.S. ×25.

6. The same after heating for 216 hours from 500° to 1100 C. ×25.

7†. Black obsidian, Yellowstone. ×570.

8. The same after heating for 701 hours from 850° to 1100 C. ×570.

Of the small figures occupying the middle line in the plate the three upper ones represent greyish-white crystalline pellets, frequently hollow, and often bearing minute crystals of specular iron. These pellets were taken from the large vesicles developed in the Yellowstone obsidian by heating from 850° to 1100° C. during 701 hours. ×4.

The lowest figure in the middle line represents one of the minute crystals of specular iron which was attached to the outer surface of one of the above pellets. ×120.

Alteration of Basalt-glass.

Plate 5.

1‡. Vesicular basalt-glass, Kilauea, Sandwich Islands. ×25.

2. The same after exposure to a dry heat for 260 hours at a temperature ranging from about 700° to 1200° C. ×25.

3. Vesicular glass formed by the fusion of basalt from the Giant's Causeway, Antrim, in a Stourbridge-clay crucible; the fused mass having been rapidly cooled. ×55.

4. The same rock similarly fused and slowly cooled. ×55.

5. Fragment of basalt (Giant's Causeway) placed on the surface of a molten mass, similar to No. 3, and allowed to sink into it. On the left is the fragment of basalt, and on the right the

* Figs. 1, 3, and 5, Plate 3, represent the rock in its normal condition.

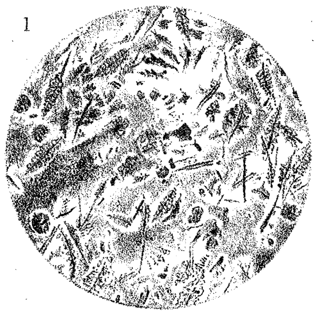
† Figs. 1, 3, 5, and 7, Plate 4, represent the rocks in their normal condition.

‡ Fig. 1 and the left half of fig. 5, Plate 5, represent the rocks in their normal conditions. In the latter case, however, there may be slight alteration.

PITCHSTONE

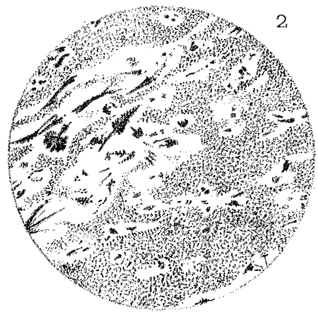
NORMAL | ALTERED

1



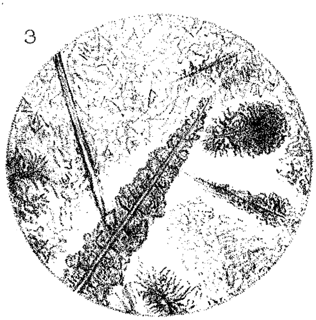
× 25

2



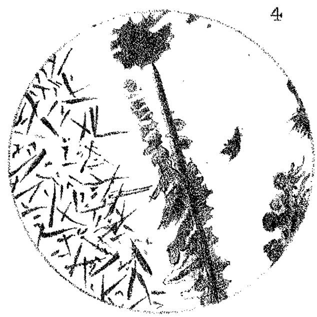
× 25

3



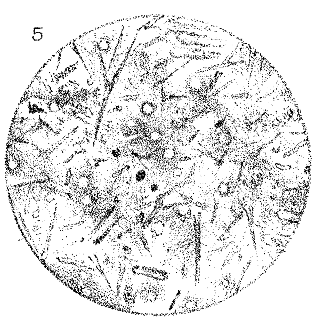
× 250

4



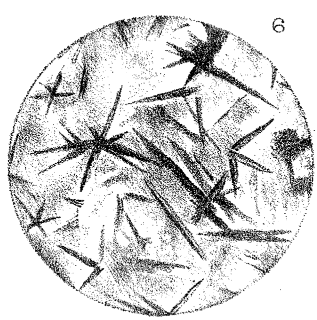
× 250

5



× 1150

6

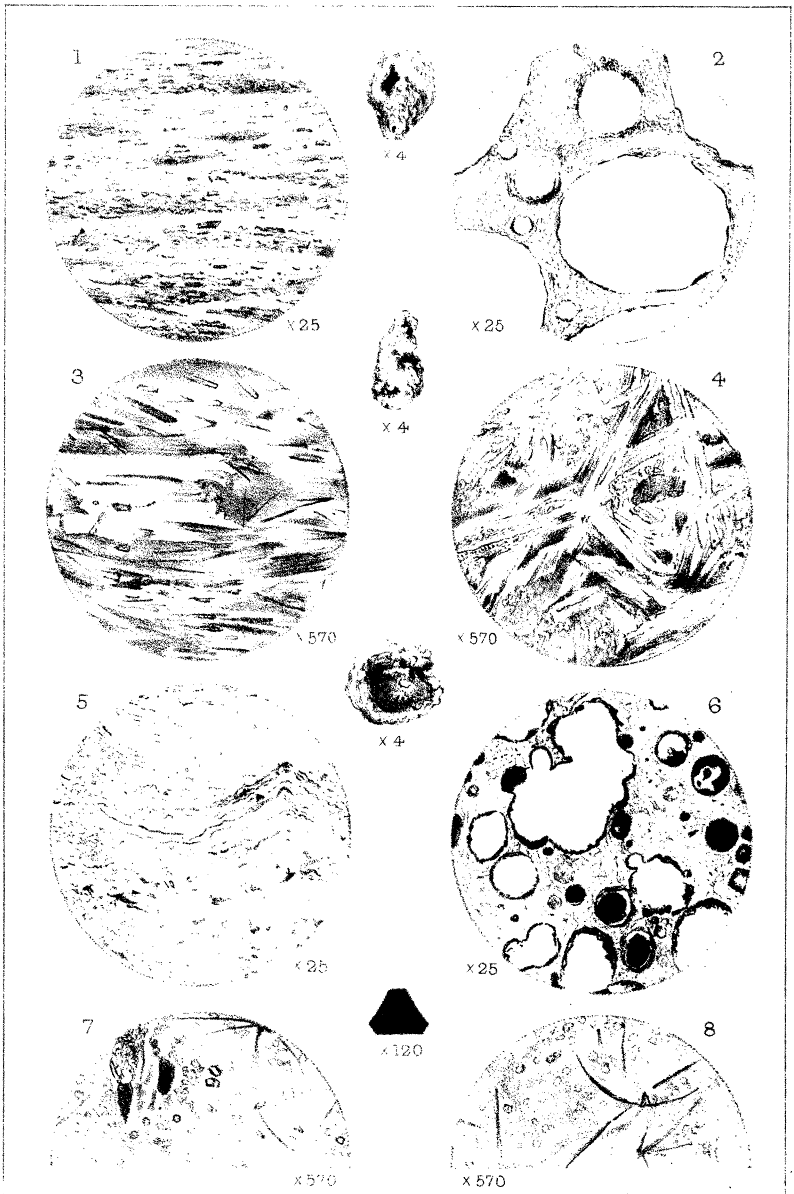


× 1150

Frank Rutley del. West, Newman & Co. lith.

OBSIDIAN

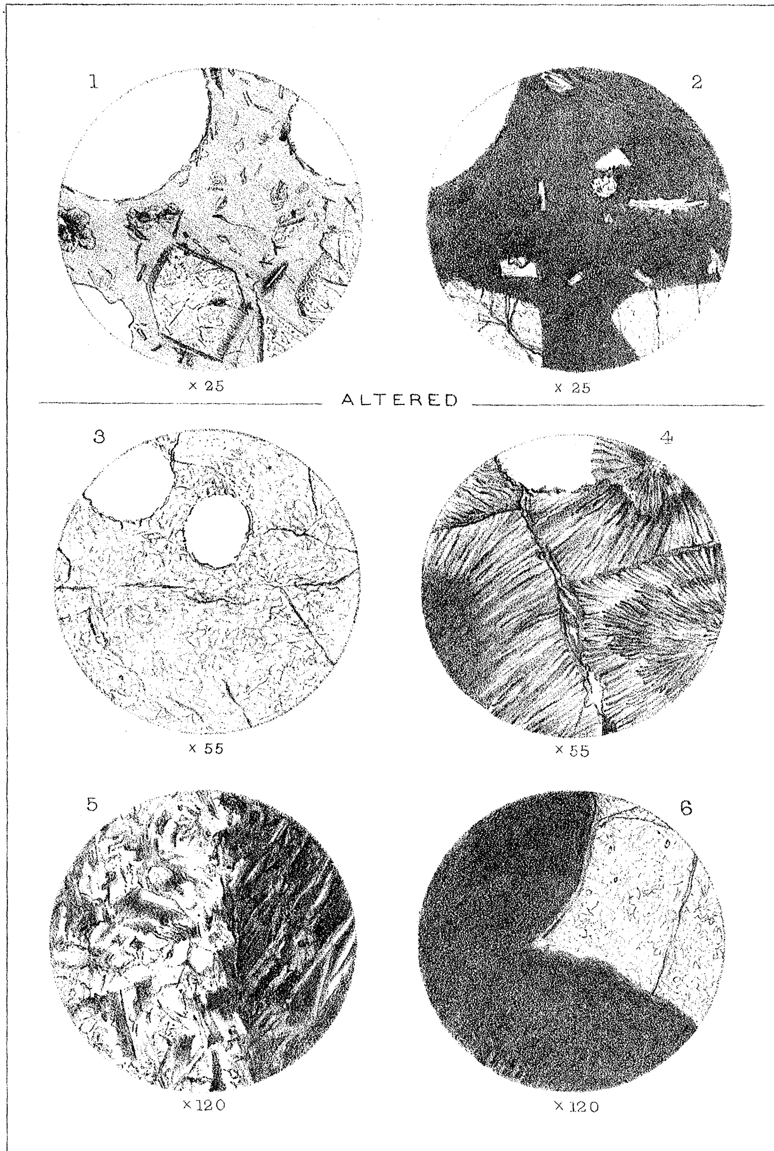
NORMAL ALTERED



Frank Rutley del. West, Newman & Co. lith.

BASALT-GLASS.

NORMAL ALTERED.



Frank Rutley del. West, Newman & Co. lith.

dark tachylytic belt formed between it and the clear basalt-glass. ×120.

6. Portion of the same preparation, showing the sharp division of the tachylytic belt from the clear basalt-glass. ×120.

IV. "On the Relation between the Thickness and the Surface-tension of Liquid Films." By A. W. REINOLD, M.A., F.R.S., Professor of Physics in the Royal Naval College, Greenwich, and A. W. RÜCKER, M.A., F.R.S. Received May 15, 1886.

(Abstract.)

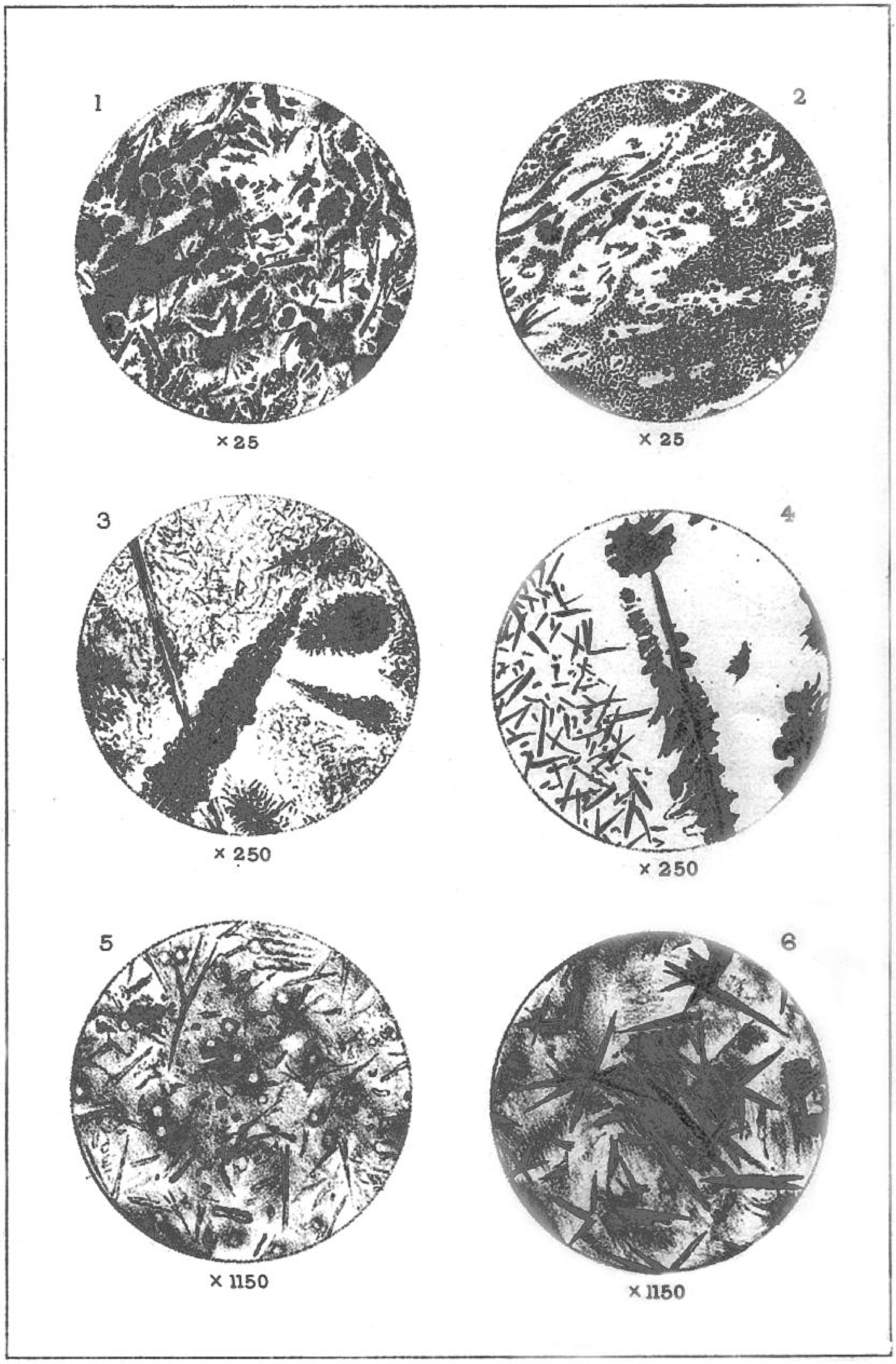
Plateau, Lüdtge, and van der Mensbrugghe have investigated experimentally the relation between the thickness and surface-tension of thin films. None of these observers, however, have used films thin enough to show the black of the first order of Newton's colours. The authors have therefore made a careful comparison of the surface-tension of black films with that of coloured films, the thickness of which was from 10 to 100 times greater. The principle of their method is the same as that utilised in Lüdtge's experiments. The interiors of the films to be compared are connected, and the relation between their surface-tensions is deduced from measurements by which their curvature is determined. In the authors' experiments a cylindrical film was thus balanced against another, which, though sometimes cylindrical and sometimes spherical, was initially of the same curvature as itself. The necessity for this arrangement arises from the fact that the authors' previous observations have shown that a film thins to the black of the first order more readily if it is cylindrical than if it is of any other form. The fact that small changes in the forms of cylindrical and spherical films, attached to two circular rings, convert them into unduloids or nodoids, renders the mathematical theory somewhat complicated, but other considerations have been made to give way to the necessity of obtaining films which readily yield the black.

The *sensitiveness* of the methods employed by the authors and by previous experimenters is investigated. All these methods depend upon the measurement of a length, such as the change in the diameter of a cylinder, or in the sagitta of a spherical segment (Lüdtge and van der Mensbrugghe), or the displacement of the liquid in a manometer tube (Plateau).

Let an increment $d\mathrm{T}$ in the surface-tension T produce an alteration $d\mathrm{L}$ in this length. The fraction $\mathrm{T}\,d\mathrm{L}/d\mathrm{T}$ is taken as a measure of the *sensitiveness* of the experiment. If $d\mathrm{L}$ and $d\mathrm{T}$ are infinitely small, this

PITCHSTONE

NORMAL ALTERED



Alteration of Pitchstone.

Plate 3.

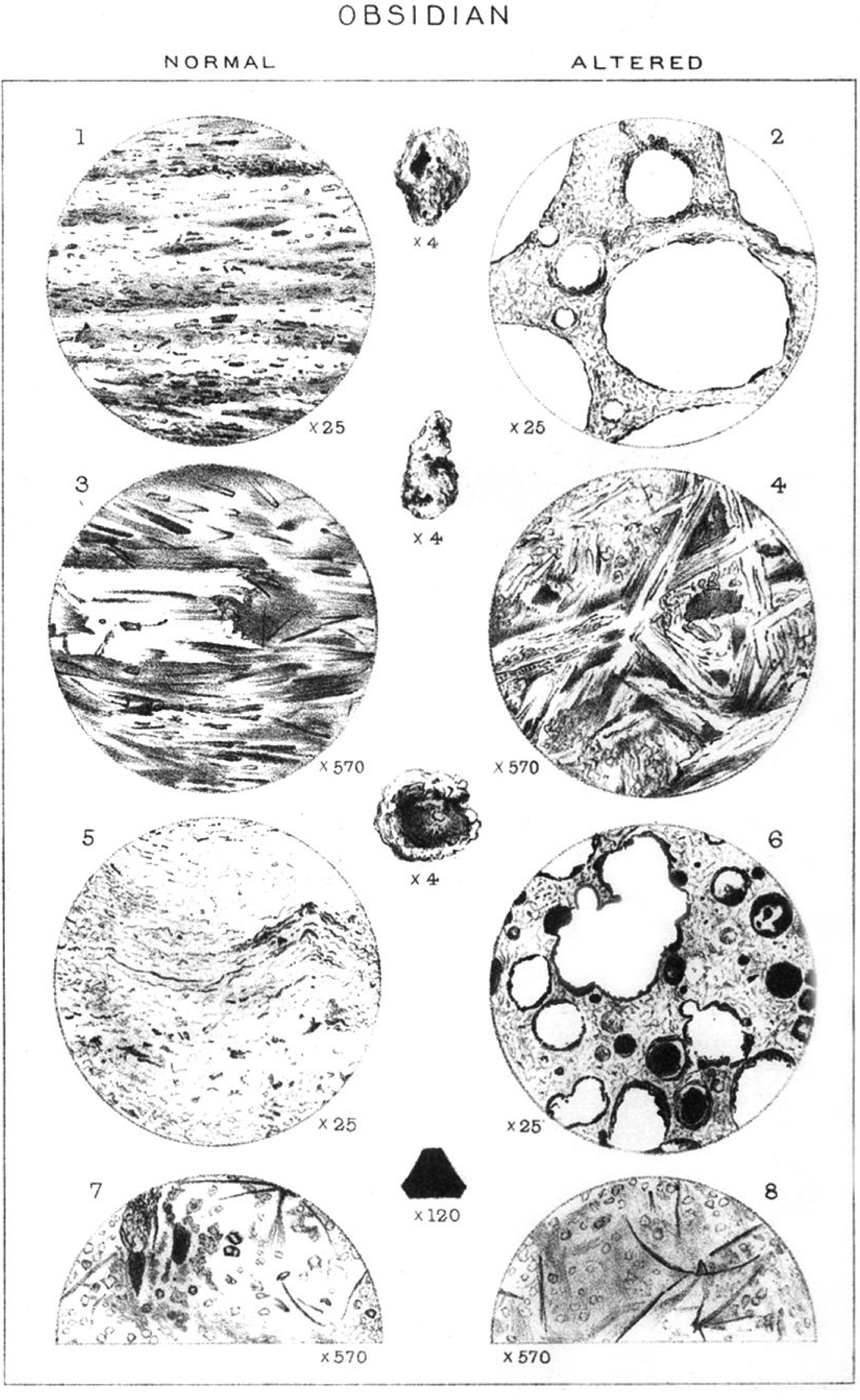
1. Pitchstone, Corriegills, Arran. ×25.
2. The same kept at a dry heat ranging up to about 1100° C., 216 hours. ×25.

3†. Pitchstone, Corriegills. ×250.

4. The same after heating from 500° to *cir.* 1100° C., for 216 hours. ×250. Showing the alteration of the hornblende belonites to shrivelled (rusty coloured) bodies, and the coarse spiculæ developed in certain parts of the ground-mass.

5*. Pitchstone, Corriegills. ×1150. Showing portion of the ground-mass containing globulites and microliths.

6. The same after heating from 500° to *cir.* 1100° C. for 216 hours. ×1150. Showing the alteration which the ground-mass, corresponding to that in fig. 5, has undergone.



Alteration of Obsidian.

Plate 4.

1†. Black obsidian, Ascension. ×25.

2. The same after heating for 216 hours from 500° to 1100° C. ×25.

3†. Black obsidian, Ascension. ×570.

4. The same after heating for 701 hours from 850° to 1100 C. ×570.

5†. Black obsidian, Yellowstone, Montana, U.S. ×25.

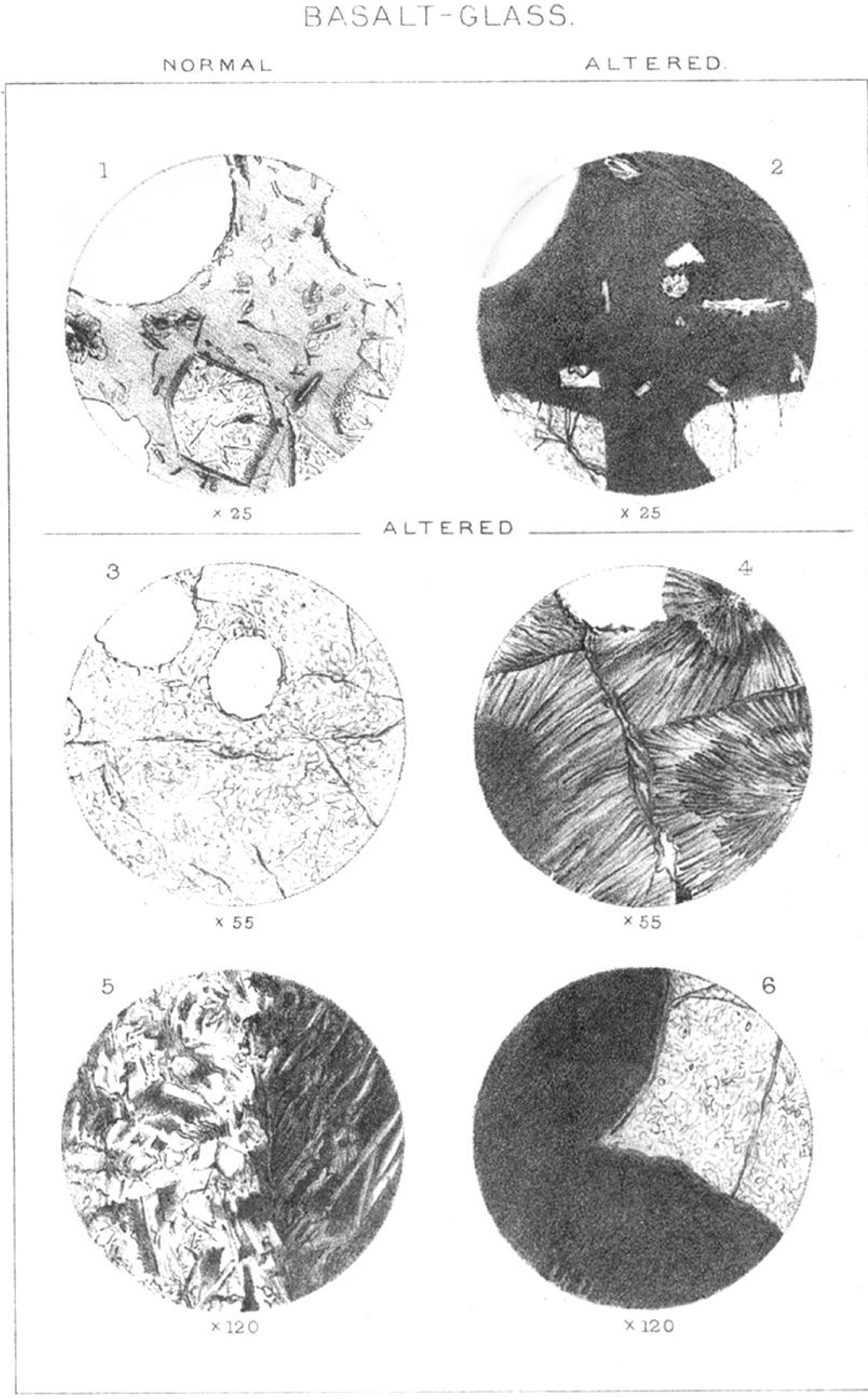
6. The same after heating for 216 hours from 500° to 1100 C. ×25.

7†. Black obsidian, Yellowstone. ×570.

8. The same after heating for 701 hours from 850° to 1100 C. ×570.

Of the small figures occupying the middle line in the plate the three upper ones represent greyish-white crystalline pellets, frequently hollow, and often bearing minute crystals of specular iron. These pellets were taken from the large vesicles developed in the Yellowstone obsidian by heating from 850° to 1100° C. during 701 hours. ×4.

The lowest figure in the middle line represents one of the minute crystals of specular iron which was attached to the outer surface of one of the above pellets. ×120.



Alteration of Basalt-glass.

Plate 5.

1‡. Vesicular basalt-glass, Kilauea, Sandwich Islands. ×25.

2. The same after exposure to a dry heat for 260 hours at a temperature ranging from about 700° to 1200° C. ×25.

3. Vesicular glass formed by the fusion of basalt from the Giant's Causeway, Antrim, in a Stourbridge-clay crucible; the fused mass having been rapidly cooled. ×55.

4. The same rock similarly fused and slowly cooled. ×55.

5. Fragment of basalt (Giant's Causeway) placed on the surface of a molten mass, similar to No. 3, and allowed to sink into it. On the left is the fragment of basalt, and on the right the dark tachylytic belt formed between it and the clear basalt-glass. ×120.

6. Portion of the same preparation, showing the sharp division of the tachylytic belt from the clear basalt-glass. ×120.