23. *On* Composite Spherulites *in* Obsidian, *from* Hot-Springs, *near* Little Lake, California. By Frank Rutley, Esq., F.G.S., Lecturer on Mineralogy in the Royal School of Mines. (Read March 26, 1890.)

[Plate XVII.]

In a paper read before the Royal Society in 1885 *, allusion was made to certain greyish or yellowish-white spherulites occurring in a specimen of black obsidian which was given me by the late Mr. John Arthur Phillips, F.R.S.

These spherulites (portions of two occur in the specimen) are about an inch in diameter and are seen to consist of numerous spherulites of very much smaller dimensions. In the paper referred to it was suggested "that the smaller spherulitic structure was set up in the large spherule after its formation, the vestiges of a radiating crystalline structure tending to confirm this view." This opinion was based merely upon what could be seen on a fractured surface by the help of a pocket-lens. The microscopic examination of a section made through one of these bodies seems, however, to show that the smaller spherulites were formed first, and that after they had assembled together in spheroidal aggregates, a radiating crystallization was set up within the mass, travelling stage by stage from the centre to the periphery.

As I have not yet met with any account of precisely similar spherulites, even in Mr. Iddings's monograph †, it seems to me that the following notes may prove of some interest to petrographers.

In reflected light, but better when dark-ground illumination is employed, the entire section of the spherulite is seen to be composed of much smaller spherical or spheroidal bodies, so closely packed that they are usually in contact, the matter occupying the interstices appearing darker than the spherical or spheroidal bodies themselves, which latter, by dark-ground illumination, appear brightly lighted, fig. 4, Pl. XVII. In ordinary transmitted light these bodies are scarcely to be recognized, except in a few parts of the section, where they are somewhat darker than the remaining portions, although they are more or less translucent (fig. 1, Pl. XVII.). These are the small pellets which, by the help of a lens or even by unassisted vision, may be seen to compose the large spherulites in the hand-specimen. In the following description these smaller bodies will be termed primitive spherulites.

The general aspect of the section, when viewed in ordinary trans-

* "On the Microscopic Characters of some Specimens of Devitrified Glass, with Notes on certain Analogous Structures in Rocks," by Douglas Herman and Frank Rutley. Communicated by Prof. T. G. Bonney, D.Sc., F.R.S. Proc. Roy. Soc. vol. xxxix. p. 106.

† "Obsidian Cliff, Yellowstone National Park," Seventh Annual Report, U.S. Geol. Surv. Washington, 1888.

mitted light, is that of a portion of a large spherulite composed of anastomosing flexuous rods or fibres diverging from an approximately common centre. The rods or fibres are traversed transversely to their length by delicate cracks, which are very numerous but interrupted (fig. 2, Pl. XVII.). Between the rods or fibres there is more or less isotropic matter with minute globulites. The latter appear to be ranged in irregular linear aggregates following the direction of the crystalline rods. Trichites and granules and minute crystals of magnetite are somewhat plentiful in this fibrous mass.

When viewed between crossed nicols the fibres or rods composing the spherulite polarize, but not vividly, and the extinction, so far as it can be made out in the matted mass of fibres, appears frequently to be parallel and at right angles to their length, at other times it seems to make an angle approximating to 21° with the long axis of the rod, which would correspond to the extinction seen on (010) in orthoclase. It would therefore appear that the divergent rods which constitute the main bulk of the spherulite are orthoclase, as in the cases described by Iddings in his work on "Obsidian Cliff." There is, however, little dependence to be placed upon the measurement of the extinction-angles, since the confused and branching character of the rods (fig. 5, Pl. XVII.) is, I believe, due to the fact that the entire mass is made up of a succession of divergent bundles of rods, similar to those met with in artificially devitrified glass. Where this structure is strongly marked the section shows a well-defined concentric banding (fig. 3, Pl. XVII.), each band occurring at the terminal boundary of one zone of bundles of divergent rods, which boundary forms the floor from which the divergent crystalline fasciculi of the next zone grew.

The most interesting point is that *these concentric bandings pass completely through the primitive spherulites* already alluded to, as shown in fig. 4, Pl. XVII., which represents the same part of the section given in fig. 3, the different appearances being due to the methods of illumination respectively employed. It may therefore, I think, be safely assumed that the divergent crystalline structure of the large spherulite was developed subsequently to the massing together of the small (primitive) ones, which are also traversed by the divergent structure proper to the large or secondary spherulite.

The small or primitive spherulites show no fibrous or crystalline structure of their own. What appears to be tridymite is present in a small cavity situated at a little distance from the margin of the spherulite, and it is probable that some of the isotropic matter occurring between the divergent fibres of the spherulite may also be referred to this mineral, as in some of the cases described by Iddings *.

Colourless microliths may be detected in the section, but they do not appear to be numerous.

Some of the dark specks which, in reflected light, are seen to be of a reddish or brownish colour, may be regarded as iron-oxides.

* *Op. cit.*

To sum up the history of these spherulites, I think we may assume that in the first instance small spherulitic bodies (the primitive spherulites) were developed in the obsidian before it assumed a condition of rigidity. Secondly, that these small spherulites floated towards certain points in the still viscid lava and segregated in more or less spherical groups, although what determined their movements, whether mutual attraction or some other cause, there is no evidence to show. Thirdly, that from a point or points, situated at or near the centre of each group, crystallization was set up, giving rise to a radiating fibrous or rod-like structure, which gradually developed zone after zone of divergent tufts or fibres, until the entire mass of primitive spherulites was permeated by this secondary structure, a structure engendering a molecular rearrangement of the mass such as would obliterate any trace of structure which the primitive spherulites might have originally possessed.

There are two or three small spherulites visible in the section, which apparently arrived too late to be incorporated in the general mass and which occupy conspicuous positions on the margin of the crowd, and an independent divergent crystalline structure has been developed about them as shown in fig. 6, Pl. XVII.

It was not until the foregoing notes were made that I had the good fortune to see Mr. Iddings, whose work has already been alluded to, and to converse with him upon the question now under consideration.

Mr. Iddings has examined the specimen and section now laid before the Society, and kindly given me his opinion upon them.

He considers that the bodies which I have here ventured to term primitive spherulites are of secondary origin, and that they probably consist to a large extent of tridymite, although from his cursory examination of the section he could not speak positively as to the presence of this mineral.

In this case he stated that he reasoned from analogy, and that he had seen very similar phenomena in the spherulites and lithophysæ occurring in the obsidians of the Yellowstone National Park. From an examination of a vast amount of material collected in that district, he had been able to trace out structures of this class ranging from some very obscure or minute to others occurring on a sufficiently large scale to admit of more accurate determination.

In the present case he considered, 1st. that the spherulites or lithophysæ (he regarded them as the latter) originated in the development of a radial crystallization, in which felspar microlites were developed in a succession of twins which gave rise to delicate ramifying growths; 2nd, that diminution of volume resulted from this action of crystallization, and that vacuities were thus produced between the twigs, if one may so term them, of this divergent crystalline structure, so that the mass of the spherulite or lithophysa was thoroughly cavernous or spongy in texture; 3rd, that within these spaces tridymite was subsequently developed in small spherical bodies consisting of aggregates of minute scales or plates of tridymite, and that between these small spherical pellets of tridymite vacuities still remained. In such empty spaces he finds that in most cases emery or other grinding-material has collected during the preparation of sections. In the central portion of one of the fractured spherulites in the specimen now described, he detected one or two small crystals of altered fayalite.

Although it is not very easy to give the results of a conversation accurately, without having taken notes at the time, yet I think that I have here expressed the opinion with which Mr. Iddings favoured me, clearly and correctly, and he kindly gave me permission to make this statement.

That it is difficult, if not dangerous, to question the opinion of a careful observer who has had such unparalleled opportunities for the study of spherulitic structures as Mr. Iddings has enjoyed, is a fact of which I am fully cognizant; yet there appear in this particular instance to be certain matters of detail which seem to support the conclusions expressed by me in the foregoing paper.

They may be summarized in the following manner:—

1st. That although diminution in volume is attendant upon crystallization in cases such as that with which we are now dealing, would it occur to an extent so appreciable that a cavernous or spongy structure would be thus developed throughout the entire mass of a spherical body an inch in diameter, or would it not rather result in the production of one or two appreciably large fissures or cavities such as are met with in lithophysæ, assuming that those fissures or cavities would not be developed through other causes than contraction?

2nd. That if such a spongy condition of the spherulitic body were induced, so that the entire spherulite consisted merely of divergent and anastomosing filaments composed of felspar microliths, forming a kind of delicate network, the interspaces of which were filled neither with vitreous matter nor with any other solid, would tridymite deposited within such interspaces be developed in the form of closely-packed, well-defined, spherical pellets, or would it tend to crystallize out along the twigs of the divergent microlithic structure of the spherulite, thus filling all the interspaces completely?

3rd. That tridymite is in the habit of forming more or less spherical groups is well known, but would such spherical groups be formed in a closely matted aggregate of crystalline rods, since each small pellet (primitive spherulite) would consist as much of felspar as of tridymite? Furthermore, would not these minute felspathic rods afford surfaces along which crystallization would be set up, and thus seriously impede the crystallization of the tridymite in spherical aggregates, if, indeed, it would not render such spherical development impossible?

4th. The small spherical pellets have well-defined boundaries such as ordinary spherulites might have. Examination in polarized light reveals the presence of comparatively little, if any, isotropic matter, the pellets appearing to consist to a very large extent of doubly refracting fibres or matted microliths. From this fact alone it is evident that it would be useless to attempt to determine the presence of tridymite, either by solubility of the pellets in a solution of an alkaline carbonate or by specific gravity.

5th. Where spaces occur between the small pellets or primitive spherulites, they are filled with crypto-crystalline matter associated with isotropic matter, which may be glass or which may be tridymite.

6th. On comparing what I here regard as the secondary structure developed in this spherulite with the structures produced by the devitrification of artificially formed glass, there appears to be a very strong resemblance in most cases, making allowance, of course, for differences in texture. The ramifications of the crystalline rods here indicate the existence of divergent crystalline bundles, which are probably bounded by radial planes of arrest, planes which in this instance evade detection by reason of the delicate nature of the rods composing each bundle, and the consequently confused appearance caused by the overlap of several fasciculi within the thickness of the section; whereas, in a more coarse phase of devitrification, a single bundle would occupy the entire thickness of the section, so that, in such a case, the arrest-planes would be well defined.

Now it is evident that if the initial points of divergent groups originate very close to one another along one of the circumferential bands of a spherulite (which band may be taken to represent a pause in the crystalline development) those rods which diverge most strongly from any radius of the spherulite will be quickly arrested by the development of similar rods in the adjacent bundles, and such rods will be excessively short, while those which approximate more closely to radii of the spherulite will be comparatively long. Under such circumstances, the crystalline rods belonging to successive zones will exhibit an apparent continuity. This seems to support the view that the divergent crystalline structure in these spherulites differs in no essential respect from the structure commonly observed in manufactured glass which has been artificially devitrified.

Taking all these points into consideration, I am inclined to think that the conclusions arrived at in this paper are substantially correct; but, on the other hand, the wide experience of Mr. Iddings in connexion with obsidians and the structures developed in them, renders his opinion worthy of the most careful attention.

I trust that I have in no way misinterpreted his views, and I would gladly substitute them for my own if, in this instance, I felt that they offered a more satisfactory explanation of the phenomena here described.

EXPLANATION OF PLATE XVII.

Fig. 1. Border of composite spherulite in black obsidian, from Hot-Springs, near Little Lake, California, × 45. Ordinary transmitted light.

The light upper portion of the drawing represents the obsidian. The boundary of the spherulite is here seen to be irregular, owing to the partial reception of two smaller spherulites. The latter were traversed by the radial fibrous structure of the large spherulite with which they are incorporated.

Fig. 2. Ditto, × 195. Ordinary transmitted light.
The radial structure is here seen to be crossed by short and delicate circumferential shrinkage-cracks. The crystals and specks are magnetite.

3. Part of the same spherulite, × 45. Ordinary transmitted light, showing concentric banding.

4. The same part of the section shown in fig. 3, × 45, dark-ground illumination. By this method of illumination the composite nature of the spherulite becomes clearly demonstrable, and it may be shown that it is composed of a number of small, closely packed, primitive spherulites, through which the concentric banding is seen to pass.

5. Radial fibrous structure of the same spherulite, as seen between crossed nicols, the principal sections of the latter being situated at 45° to the general direction of the fibration. The fibres are felspars, apparently orthoclase, × 195.

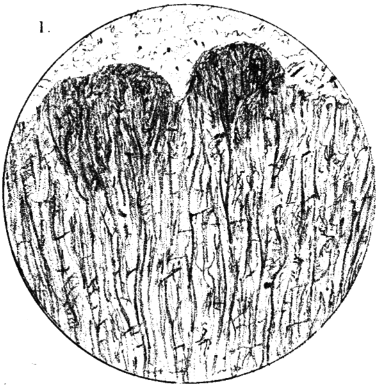
6. Marginal portion of the same spherulite, showing smaller outlying spherulites, around which an independent radial crystallization has been set up, × 18. Oblique ordinary transmitted light.

Discussion.

The Chairman said that the sequence of the different portions brought forward with so much care by the Author is one which admits of much discussion.

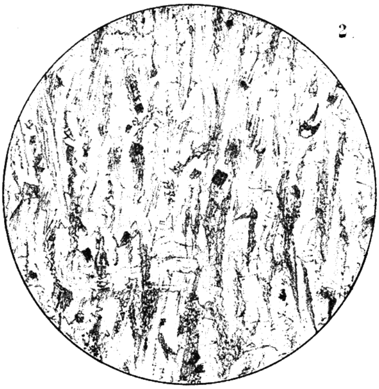
Rev. E. Hill said that the explanation of the divergence of these crystallizations was extremely interesting. As to which structure came first, it is difficult to determine. In the section exhibited under the microscope he agreed with Mr. Rutley as to the sequence. The question of molecular motion after consolidation in igneous rocks is a subject of great importance.

1.



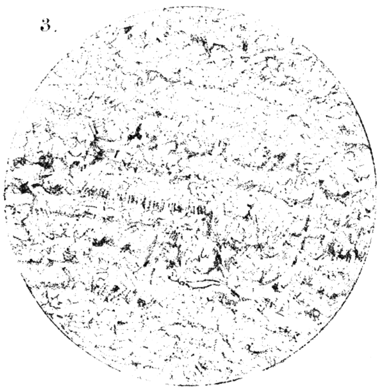
× 45

2.



× 195.

3.



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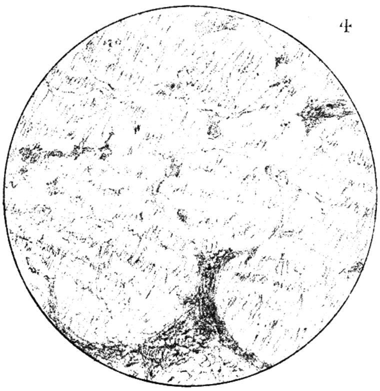

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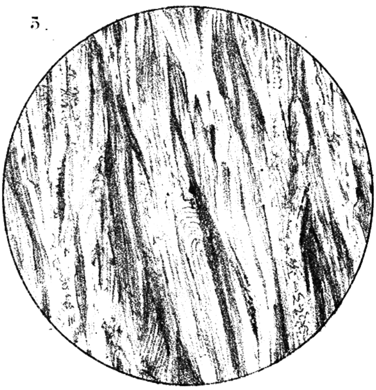

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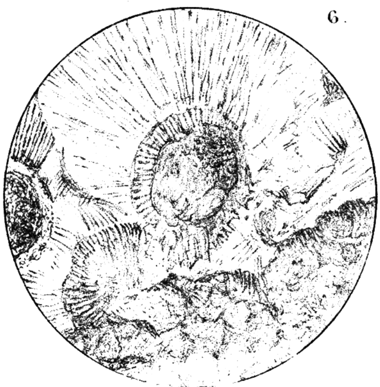

× 18.

Frank Rutley del. F. H. Michael lith. Mintern Bros. imp.

COMPOSITE SPHERULITES IN OBSIDIAN.

Hot Springs near Little Lake, California.