3. *On FULGURITES from MONTE VISO.* By FRANK RUTLEY, Esq., F.G.S., Lecturer on Mineralogy in the Royal School of Mines. (Read December 5, 1888.)

[PLATE III.]

THE specimens described in this paper were collected within six or seven feet of the summit of Monte Viso (about 12,680 feet above the sea-level) by Mr. James Eccles, F.G.S., who kindly forwarded them to me for examination.

The larger one, fig. 1, Pl. III., is a piece of compact bluish-grey rock, about $6\frac{1}{2}$ inches long by $1\frac{3}{4}$ inch in its greatest breadth. In one part it shows a delicate banding, the direction of which is indicated by an arrow, *b*, placed on the left of the figure. This banding, however, is not distinctly visible on the surface represented, although it is well defined on the back of the specimen, which is bounded on one side by a smooth joint-plane, *c c*, upon portions of which a thin crust of fulgurite-glass has been formed. The outer surfaces are far less even; but if not actually joint-planes, they have, at all events, been directions of easy fission, suggestive of a system of intersecting joints, and these, in several parts, are incrustated with minute pellets and thin films of fulgurite-glass.

The surface shown in fig. 1, Pl. III. (natural size), has been ploughed out by lightning, the track being marked by curved and branching, hemicylindrical furrows, *a a*, varying from about $\frac{1}{2}$ inch to $\frac{3}{4}$ inch in diameter.

These tubes are lined with a thin crust of dark brown, vesicular fulgurite-glass, and one of the smallest branches of the longest tube is completely filled with this substance. The approximate thickness of the glassy lining of part of a tube is shown in fig. 2, Pl. III., while the slaggy and vesicular character of the vitrified surface is represented in fig. 3, Pl. III., as seen under a very low magnifying-power, where *a a* represents a portion of one of the lightning-tubes with its glassy lining; *b*, a delicate band in the rock due to foliation, and *f* some minute grains of fulgurite-glass adhering to the surface of the rock and situated at a slight distance from the left wall of the tube. This drawing was made from a specimen considerably smaller than the one first described, and it shows only part of a single tube having an average diameter of $\frac{1}{3}$ inch.

Before describing the microscopic characters of the fulgurite-glass it may be well to give some account of the mineral constitution of the rock from which, through fusion, the glass has been formed.

When a thin section of this rock is examined under the microscope, a general schistose and, in places, an almost fibrous-looking structure is visible, due to an intimate admixture of glaucophane and epidote, the former of a pale blue, the latter of a pale yellowish colour.

The glaucophane appears, as a rule, in imperfectly developed

prisms, seldom, if ever, showing any distinct terminal faces; while much of it seems to consist of minute grains and extremely small prisms, mixed with a considerable amount of epidote. The angle of the prism in one or two sections of glaucophane, taken transversely to the vertical axis, was similar to that of hornblende, 124° to 125° . In orthopinacoidal sections, apparently those chiefly seen in the slides which have been prepared, the pleochroism is well marked, vibrations parallel to ϵ = pale yellowish-green to greenish-blue, while those parallel to $\mathfrak{h}$ = lavender-blue, the absorption being $\epsilon > \mathfrak{h}$, as in the glaucophane of Ōtakisan in Japan described by Prof. B. Kotô*.

The extinction-angle in a clinopinacoidal section, measured with a Bertrand's stauroscope-ocular, is about 5° only. The prisms are very commonly traversed by transverse fissures, as in actinolite. In one or two of the slides a little diallage occurs, sometimes enclosing numerous crystals of glaucophane, so that the extinction-angle cannot be clearly ascertained; some small patches of diallage, however, appear to extinguish at an angle of about 39° to the direction of the characteristic separation-planes or cleavages (*i. e.* to $\infty P \infty$ or 100). The mineral is of a pale-greenish tint, exhibits scarcely a trace of pleochroism, and shows no definite crystallographic boundaries.

In most, if not in all, of the sections prepared from this rock numerous little crystals are present, which are either partially or wholly opaque, and which, where they transmit light, appear of a more or less deep brown colour. Their partial or entire opacity is due to the presence of a decomposition-product, which, by surface-illumination, is seen to be white. Owing to the prevalence of this opaque matter the character of the pleochroism cannot be made out.

These crystals appear, in section, mostly as very acute rhombs, of which the obtuse angle ranges between 130° and 140° . The mean of five careful measurements gave $135^{\circ} 36'$. It seems therefore very probable that these crystals are sphene in an advanced stage of alteration. One measurement gave $136^{\circ} 15'$, which is almost the angle between the faces $\frac{2}{3} P 2$, or $\bar{1}23 : \bar{1}\bar{2}3$ in sphene, while several others gave approximately 133° , which is nearly the angle of the prism. It would be unsafe, however, to attach much importance to these measurements, since, owing to the opacity of the crystals, it is impossible to determine, by means of optical characters, in what directions they are cut†. The epidote present in the rock occurs mostly in small, irregularly shaped or rounded grains, seldom in distinct crystals.

A very striking feature in sections of this rock is the presence of crystals of garnet, which, viewed by transmitted light, appear nearly colourless or of pale yellow or yellowish-green tints. They are, for the most part, of very irregular form, are strongly fissured, and seldom show any definite crystallographic boundaries, although occasionally

* "A Note on Glaucophane," Journ. Coll. Sci. Imp. Univ. Tōkyō, vol. i. pt. 1, p. 4.

† Dr. F. H. Hatch, to whom I have since submitted the sections, is also inclined to regard these crystals as altered sphene.

sections are seen which may be referred to rhombic dodecahedra. They are isotropic.

From the foregoing observations it appears, therefore, that the rock is a glaucophane-epidote schist in which garnet, sphene, and occasionally diallage are present.

Fig. 1 shows the general appearance of a section of this glaucophane-schist, as viewed in ordinary transmitted light and magnified 120 linear. The large irregularly shaped crystals are garnet, the brown and partly opaque crystals, of which two are shown at the bottom of the figure, are sphene, while the remainder consists of blue glaucophane and yellowish or yellowish-green epidote.

Professor Judd considers that the rock somewhat closely resembles the glaucophane-schists and eclogites of the Ile de Groix, off the coast of Brittany, described by Dr. Barrois. In the association of glaucophane

Fig. 1.

Glaucophane-Schist, $\times 120$.

phane with epidote it also resembles the glaucophane-schist described by Professor Kotô, to whose kindness I am indebted for specimens of the Ôtakisan rock. It is also possibly allied, to some extent, in mineral constitution to the glaucophane-eclogite of the Val d'Aoste, described by Professor Bonney*.

The summit of Monte Viso is stated by Studer to consist of serpentine; but, prior to any microscopic examination of the rock, Mr. Eccles expressed his belief that it was probably what Prof. Studer had described as "*grüne Schiefer*," and certainly not serpentine, although Mr. Eccles remarks that serpentine is not unfrequently associated with the "*grüne Schiefer*."

I have to thank Professor Judd for kindly allowing sections from

* Mineralogical Magazine, Dec. 1885.

these specimens to be made in the Science Schools at South Kensington, and Mr. Chapman has been most successful in the exceedingly delicate and difficult operation of preparing slices of the rock with portions of the fulgurite-glass adhering to the surface.

Having described to some extent the nature of the rock itself, these vitreous incrustations will now claim our attention. Before the sections were prepared, a few small pellets of fulgurite-glass were scraped from the surface of one of the specimens, crushed, and examined under a quarter-inch objective. Two rod-like microliths (longulites) were first observed in a small fragment of glass which was picked with the point of a knife from one of the surfaces, either of fracture or rough cleavage, on the larger specimen, fig. 1, Pl. III. These microliths were, when first seen, situated at a slight distance from one another; but, owing to the viscosity of the balsam in which they were mounted, it was found that after an hour or more the smaller one had shifted its position, so as to come in contact with the larger microlith. Evidently, then, one of these rod-like bodies was free to move, and was not imbedded in the glass-fragment, a circumstance which necessarily raised the question whether the other was also unattached.

Another small sample was consequently taken, also from a fractured surface of the rock, and crushed, so that the fragments might be thin enough for microscopic examination. Here, again, microliths appeared, not only on or in the fulgurite-glass, but also in considerable numbers in the fine powder which resulted from the crushing of the fragments.

Thinking it might be possible that they belonged rather to the rock itself than to the actually fused rock-matter, another minute pellet of fulgurite-glass was removed, and, on examining it with a lens, a small quantity of the rock was found adhering as a film to the surface of the pellet where it had been detached.

To avoid any such source of error, a very small blister of fulgurite-glass was removed from the interior of one of the lightning-tubes (*a*, fig. 1, Pl. III.), where the lining of vesicular glass was sufficiently thick to insure perfect isolation of the glass from the rock. This, when crushed and examined under a power of about 250 diameters, showed that the glass is, as a rule, remarkably pure, but that not only gas-bubbles but globulites occur in it, in places, and these occasionally form margarites and longulites, some of the rod-like bodies which come under the last denomination distinctly exhibiting double refraction. A few of the better-formed examples can be proved to lie *within* the fulgurite-glass, since adjacent globulites can be brought into focus both above and below them.

I have taken especial pains to verify this point, since, so far as I know, this is the first instance of the occurrence of crystallites in fulgurite-glass which has hitherto been recorded. In these specimens the globulitic and longulitic conditions are frequently visible, but the margaritic stage is not so common. Adopting Vogelsang's terminology, all of these bodies would be included under the name of crystallites. A longulite and some globulites are shown in fig. 4,

Pl. III., as seen under a magnifying-power of 250 linear. Fig. 5, Pl. III., shows a few margarites, selected from different fragments, while fig. 6 gives a fair idea of the vesicular character of the fulgurite-glass, as seen in a fragment taken from the interior of one of the lightning-tubes and magnified 120 linear. Fig. 7 represents a microlith imbedded in a fragment of fulgurite-glass. This microlith shows distinct double refraction, and the direction of maximum extinction makes an angle of about 16° to 17° with the longest axis.

In a thin section of excessively vesicular fulgurite-glass taken from the specimen represented in fig. 1, Pl. III., there are some good examples of microliths which exhibit very distinct double refraction; some of them appear to show parallel, and others oblique extinctions, the latter giving an extinction-angle of 15° to 20° with the longest axis. That both those showing parallel and those giving oblique extinctions are identical seems highly probable, their apparent differences in this respect being most likely due to the positions in which they lie in the section. That some of them are clinometric is certain. That they are all clinometric is probable. In this section globulites are also plentiful. They occur either singly or in lines (margarites) composed of several globulites, occasionally five in number. Besides these linear groupings other arrangements are also seen—groups of three globulites massed trefoilwise, as in fig. 8 *b*, Pl. III., are not uncommon, while less frequently cruciform groupings, similar to that represented under *a* in the same figure, may be seen. The fulgurite-glass, when viewed by transmitted light, ranges from a tolerably deep coffee-colour to pale yellowish-brown or almost colourless, according to the thickness. The vesicles in the glass are, as a rule, perfectly spherical, and in some instances so numerous and closely packed that the glass is quite spongy in character.

Where the fulgurite-glass comes in contact with the rock the latter appears to have undergone no appreciable alteration beyond the development of a very narrow band of opaque, white matter, resembling the substance of the altered crystals of sphene which the rock contains. The band is exceedingly variable in thickness, and occasionally thins almost entirely away, as shown in the dark irregular belt which crosses fig. 2, where the upper portion of the drawing represents the crust of vesicular fulgurite-glass lining one of the lightning-tubes, while the lower portion shows the rock ($\times 120$ linear). In one section a minute, rounded grain of schist, containing a fragment of a strongly depolarizing crystal, probably epidote, appears to have been taken up in the fulgurite-glass.

As regards the opaque white band, already mentioned as occurring at the junction of the glass with the rock, I am much more disposed to think that it is due to the presence of altered sphene than to any alteration of the rock-surface induced by the action of lightning; for a line drawn through other parts of the section might easily pass through crystals and segregations of similar white matter of like extent and continuity. If it were an alteration-product engendered suddenly by an intense heat we should rather expect

to find the rock altered to a uniform depth around the lightning-tube*.

Throughout this paper I have spoken of these ramifying, vitrified grooves as *tubes*, because it is my impression that the lightning did not produce these channels upon the exposed surfaces, but actually penetrated the rock; and Mr. Eccles informed me that he saw one of these tubes penetrating the rock *in place*; unfortunately, however, the difficulty of detaching the piece of stone, without crushing the tube, prevented him from securing this most interesting specimen. Lightning-tubes more than an inch in diameter, penetrating an andesitic rock on the summit of Little Ararat, have also been described by Abich as far back as 1870†. I think it may therefore be taken for granted that these ramifying channels are portions of tubes laid open to us in section by the rock having been split along planes of easy fission.

Fig. 2.

Contact of Fulgurite-Glass with Glaucophane-Schist.

Another interesting problem presents itself in the occurrence of minute glassy pellets and thin vitrified crusts on these joint-planes and fractures. Their existence is, I think, to be accounted for, if we assume that the lightning as it penetrated the rock also split and shattered it, preferably in the direction of pre-existing structural planes, and, just as a flash may be seen to emanate from the breech-joint of a rifle when fired in the dark, so we may conceive that the flash of the lightning penetrated, and actually prized open, the joint-planes in the neighbourhood of the tubes which it formed, in this instance fusing the surfaces along which it passed.

The occurrence of globulites, margarites, longulites, and micro-liths in the fulgurite-glass would seem to indicate a less sudden cooling of the fused matter than is assumed to be usual in such

* There are, however, peculiar contact-phenomena to be observed sometimes where tachylitic glass comes against a rock-surface, and it is just possible that this may be a similar case. *Vide* "Some Additional Occurrences of Tachylite," by Grenville A. J. Cole, *Quart. Journ. Geol. Soc.* vol. xlv. p. 301.

† *Sitzungsber. d. Akad. Wiss. Wien*, vol. lx. p. 155.

cases; but, be this as it may, these bodies appear, unquestionably, to have been formed during the refrigeration of the fulgurite, the glass presenting none of the signs which would characterize a subsequent devitrification or secondary change. It must be confessed, however, that we know as yet nothing of the manner in which fulgurite-glasses would undergo devitrification; but, judging from the mineral constitution of this rock, it is possible that we might look for somewhat similar changes in a tachylyte.

EXPLANATION OF PLATE III.

- Fig. 1. Specimen of glaucophane-epidote schist, containing garnet, altered sphene, and occasionally a little diallage, from Monte Viso, Cottian Alps. *aa.* Lightning-tubes split open along a joint-plane or uneven plane of easy fission. The tubes are lined with a dark-brown glass. *b.* Arrow indicating the general direction of banding or foliation in the specimen. *cc.* Trace of a smooth joint-surface. Natural size.
2. Section of part of a lightning-tube, showing approximate thickness of the glassy lining. Natural size.
 3. *aa.* Portion of a lightning-tube, showing the slaggy, vesicular character of the vitreous lining. *b.* Narrow band, due to foliation and lying in a direction approximately at right angles to that of the lightning-tube. *f.* Minute pellets of vitreous matter adhering to the rock, and situated not far from the wall of the tube. $\times$ between 2 and 3 diameters.
 4. Fragment of fulgurite-glass, containing globulites and longulites. $\times$ 250 linear.
 5. Margarites selected from different fragments of fulgurite-glass in which they occur. $\times$ 570 linear.
 6. Fragment of vesicular fulgurite-glass, broken from the lining of one of the lightning-tubes. $\times$ 120 linear.
 7. Doubly refracting microlith in fulgurite-glass. (Oblique extinction between 15° and 17° from the longest axis.) $\times$ 570 linear.
 8. *a* and *b.* Groups of globulites occurring in a section of fulgurite-glass. $\times$ 570 linear.

DISCUSSION.

Mr. ECCLES agreed with the Author's observations concerning the mode of production of the tubes, which were produced at the same time that the two surfaces were sundered. As regards the absence of glass in parts of the tubes, he considered it might be due to weathering.

F Rutley del. FH Michael lith.

FULAURITES FROM MONTE VISO
12580 FEET

Montana, Texas, 1890.