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FULGURITE FROM MOUNT THIELSON, OREGON

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The occurrence of lightning-tubes (Blitzröhren) or fulgurites, as they are frequently named, in this country has received little attention and it is very rarely that specimens have found their way into our museums. This cannot be due to their scarcity for there is good reason to believe they are common in the western part of the United States. They deserve special attention because they are the product of an exceptional method of fusion.

The terms fulgurite and lightning-tube are frequently used synonymously; but it seems desirable that the former be applied to the substance resulting from the electric fusion and the latter to the tubular form in which fulgurite usually occurs.

Mr. L. C. Johnson has just called my attention to some lightning-tubes found by Mr. Silas Stearns on Santa Rosa Island south of Pensacola, Fla. Mr. Stearns reports that where the tubular fragments were found there was a crooked trail of them leading from a tree struck by lightning, so that in this case, as well as in the one noted many years ago (1790) by Priestly, their electric origin is clearly indicated. Each of the two fragments is about 50 centimeters long, and the diameter of the tube varies from 7 to 15 millimeters. The smaller one retains its cylindrical character, but the other, while in a plastic condition was collapsed by the pressure of the surrounding sand. Not withstanding the fact that the walls of the tubes are only about 0.25mm in thickness they are not fragile. They are pierced by numerous small openings, with fused edges, which help to make the surface very rough and irregular. Upon the outside the tubes are dull, but within they have a brilliant lustrous glazing. The fulgurite is translucent, of a light gray, almost white color, and contains many gas cavities. Under the microscope it appears for the most part perfectly clear and amorphous. There is rarely seen a light brown clouding, due to the presence of oxide of iron in the sand from which the fulgurite was produced by the electric fusion. Remnants of quartz grains may be discovered in the colorless glass, but they are not abundant.

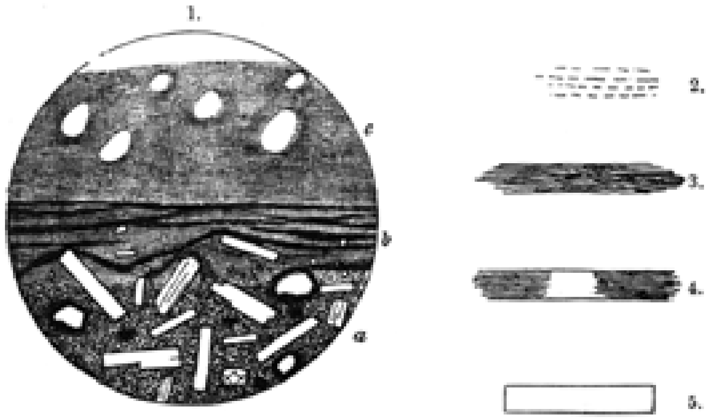
Last summer a party of the U.S. Geological Survey, in my charge under the direction of Capt. Dutton, while making a reconnaissance of the Cascade Range, ascended Mt. Thielson, which is the most acute and precipitous peak south of the Columbia. It is the majestic remnant of a large deep crater to the southeastward. Ensign E. E. Hayden, who alone ascended the upper portion of the peak, reports that the last two hundred feet are very dangerous, the summit being small and the footing insecure.[1] Among the specimens collected upon the summit are several of fulgurite, that had been formed by the fusion of an interesting basalt, in which instead of augite, there is a rhombic pyroxene associated with the olivine. Chemical analysis has shown that the rhombic pyroxene is hypersthene. This

[1]Since this article was written the author has ascended Mt. Shasta, Cal., and found upon its summit fulgurites in the form of incrustations and lightning-tubes.

basalt holds the same relation to hypersthene-andesite as ordinary basalt does to augite andesite, and it may be designated hypersthene basalt.

Although fulgurite is frequently formed by the fusion of loose sand it is seldom seen in connection with solid rocks. Saussure found the hornblende schist on the summit of Mont Blanc coated with drops and bubbles of blackish glass which were attributed to lightning. A yellowish enamel formed by the fusion of mica schist was observed by Ramond on one of the prominent summits of the Pyrenees. In the same region he found a similar effect produced upon fragments of siliceous fetid limestone. In all of these cases the fulgurite occurs as a purely superficial coating, and not in the form of lightning-tubes. It has also been observed in connection with phonolite (Klingstein porphyr) in the Auvergne; and Humboldt found it on one of the very acute volcanic mountains of Mexico, where it had resulted from the fusion of "reddish trachytic porphry" (andesite). The summit, like that of Mt. Thielson, is very small and precipitous, and the vesicular, spongy rock furnishes insecure footing. Here lightning-tubes were found penetrating the porous mass, and in several cases it seemed as if the fulgurite, welling up out of the tube, had overflowed the adjoining surface. The most interesting and extensive development of fulgurite, however, has been pointed out by Abich as occurring upon Little Ararat, in Armenia, where the whole summit of augite-andesite is perforated by numerous lightning-tubes to considerable depths. Wichmann examined the fulgurite microscopically and found it a pale green glass full of gas pores.

The fulgurite of Mt. Thielson occurs in the form of a superficial coating and lightning-tubes. Although spread over considerable surface, it is not evenly distributed, but arranged in patches of drops and bubbles of glass in very much the same way as paint which has been put upon a greasy surface. The drops and bubbles of glass are translucent and have a greenish brown color. Many of them have conical depressions which appear to have been produced by atmospheric pressure while the fulgurite was in a viscous state. The thickness of the coating between the bubbles is about 0.2 mm, and lighter colored. At several places where lightning-tubes descend from the surface into the rock the fulgurite has accumulated around the hole. The rock is porous and at places even spongy. The cavities are lined with minute clear colorless crystals and it appears evident that this structure has not been produced by the electricity. Lightning-tubes, ranging in diameter from 10.5 to 21 mm, penetrate the rock a few inches. They appear to have been formed by lining preexisting tubes and cavities with fulgurite; for there is no evidence of compression in the adjoining rock. The fulgurite walls of one of these tubes has a thickness of 2mm; it is filled with round bubbles so as to be almost pumiceous and its interior is brightly glazed. The hardness of the fulgurite is a little below that of ordinary glass. It is rather tough, strongly lustrous, and has a specific gravity of about 2.5. In the flame of an alcohol lamp thin splinters readily fuse without intumescence. The groundmass of the rock fuses much less readily than the fulgurite to a very dark glass. Small fragments of the fulgurite when heated become strongly magnetic. It appears to be entirely insoluble in strong acids, even in aqua-regia, and is not affected by boiling solutions of potassium hydrate or sodium carbonate. The accompanying figure (fig. 1) represents a section of one side of a lightning-tube and shows the relation of the fulgurite to the unaltered basaltic rock which appears beneath. Its line of contact with the fulgurite is irregular. The black-bordered olivine grains and crystals of feldspar project into it and show no prominent effects of the fusion, while the hypersthene is distinctly rounded on the edges and the groundmass has been melted much more readily than any other portion of the rock. The fulgurite is divided into two more or less distinct bands. The band (c) nearest the middle of the lightning-tube is a uniformly light coffee-brown glass, which contains a number of nearly spherical vesicles. Between the zone of pure fulgurite (c) and the unaltered rock (a) there is a narrower belt (b) in which the fusion has been less complete and the dark fluidal banding parallel to the length of the tube is prominent. This zone is frequently more or less granular. It is not only penetrated by crystals of feldspar, hypersthene and olivine projecting from the adjacent rock, but envelops numer-



Section of one side of a Lightning-tube from Mt. Thielson, Oregon. *a*, unaltered hypersthene basalt; *b*, mixed zone; *c*, fulgurite.

ous crystal remnants of these minerals scattered throughout. It contains some small round bubbles, but they do not appear nearly so abundant as in the fulgurite described by Wichmann from Little Ararat; nor have I been able to discover any radial arrangement in the longer axes of the larger vesicles. The superficial coating of fulgurite is composed wholly of coffee-brown glass without any marked fluidal structure.

A striking feature of the fulgurite is the absence of all products of crystallization from the electric fusion. It is true that fulgurite frequently envelops crystals and crystal fragments, but these are easily recognized as remnants of that portion of the rock melted to produce the fulgurite. They are not the products of crystallization from the electric fusion but from previous volcanic fusion. The entire absence of all crystallites and all microlites which are usually abundant in tachylyte, hyalomelane and obsidian may be used as a means of distinguishing fulgurite from other natural glasses. It is doubtless due to the fact that the source of the heat being very limited in both time and space, the cooling is so sudden that there is no opportunity given for the crystallizing forces to act before the mass is rigid. That the cooling takes place very suddenly is shown by the lightning tubes in loose sand where, by the electric current, the sand is thrust aside, a hole made, the sand fused, and the tube formed and cooled in many cases before the sand can rush together again to fill up the hole. In some cases, however, the pressure of the sand is so great that the tube while soft is collapsed without breaking. That the fulgurite was cooled very suddenly is shown also by the fact that when heated red hot for but two minutes in a Bunsen flame and then examined under the microscope the beginnings of crystallites can be readily detected. As already stated, the microscope revealed the fact that the fulgurite was formed chiefly by the fusion of the groundmass.

In order to determine more fully the character of the material melted, an attempt was made to crystallize the fulgurite. A completely amorphous fragment nearly as large as a pea was kept at a red heat in a Bunsen flame for six hours. It fused very slightly on the exterior and lost its vitreous character entirely. A thin section of it under the microscope showed that it had assumed a distinctly, radial-fibrous, microfelsitic structure. A larger portion of fulgurite was taken, finely pulverized and fused in a small platinum crucible before a blast lamp for nearly five hours without intermission. When cooled the fused mass in the lower part of the crucible was found to be clear and colorless, while the upper portion was tough, black and basaltic in appearance. Under the microscope the dark colored portion was found to be crowded with distinctly striated feldspar microlites and a multitude of others, very minute, which were indeterminable, besides many minute octahedrons of magnetite. Between these microlites, arranged in a basaltic fashion, could be detected a trace of pyroxene, apparently monoclinic, with considerable brownish glass and dark globulitic base. An interesting feature in this section is the accumulation of the smallest microlites into elongated groups (fig. 2) in which all the individuals are parallel, as if to indicate their ultimate combination to form a single crystal. The clear and colorless portion of the fused mass found upon the bottom of the crucible contained many perfect crystals of feldspar and shows very completely their development from bundles of microlitic fibers The fibrous bundles (fig. 3) frequently have irregular ends, but the sides are generally straight. Consolidation begins in the middle, as represented in figure 4, and gradually advances both ways, until a perfectly clear compact crystal of feldspar (fig. 5), without any trace of fibrous structure, is completed. The elongated groups of parallel microlites (fig. 2) appear to be one of the earliest stages in the development of the feldspar crystals in this case, and growth is analogous to that of the hornblende crystals described by Zirkel in the diorite from New Pass, Nevada. That the fulgurite is formed chiefly by the fusion of the groundmass of the rock is shown clearly also by the following chemical analysis made by Professor Clarke and Dr. Chatard in the laboratory of the U. S. Geological Survey. The amount of fulgurite obtainable from the hand specimens was very small and sufficient for only a partial analysis. The alumina and iron were estimated together, and the amounts of potash and soda were not determined.

	Fulgurite	Groundmass
Silica (SiO_2)	55.04	55.85
Alumina (Al_2O_3)	28.99	22.95
Ferric oxide (Fe_2O_3)		4.59
Lime (CaO)	7.86	8.41
Magnesia (MgO)	5.85	3.08
Potash (K_2O)		2.67
Soda (NaO)		2.16
Loss by ignition	1.11	0.52
	98.85	100.23

The groundmass was separated from the olivine, hypersthene, and all but a trace of the feldspar by means of Thoulet's solution, and the magnetite was removed from it by hydrochloric acid. The presence of a larger proportion of magnesia in the fulgurite indicates the fusion of some of the hypersthene.

Nearly all of the fulgurite is either superficial or confined to the lining of preexisting cavities. This is what we should expect from the well known fact that electricity always spreads itself upon the surface of a body. A small portion of the fulgurite, however, seems to have been produced within the adjoining compact rock by fusing the groundmass. It occurs in small irregular nodules or strings, frequently full of bubbles and occasionally possessing a distinct fluidal structure approximately parallel to the course of the electric current. It is difficult to conceive how a distinct fluidal structure may have been produced in these small masses, which were but momentarily viscous and completely hemmed in upon all sides, unless it is due to the repulsion of the particles among themselves. It is well known that particles electrified by a passing current repel each other most forcibly in the direction of the current, and this repulsion may perhaps explain the lines of motion in the developed fulgurite as well as those which are so prominent parallel to the length of the lightning tubes. To the same repulsion may be due, at least in part, the accumulation of fulgurite about the openings of small tubes upon the surface of the rock. In describing such accumulation one author has remarked that the tubes seem to have boiled over. The effusion of fulgurite from the tubes was doubtless facilitated by the expansion and forcible ejection of the air within the cavity. The heat developed in the rock by the lightning is only momentary and proportional to the electrical resistance. The high temperature of any individual crystal within the heterogeneous path of the current may depend chiefly upon the resistance which that mineral offers; for the elevated temperature is of so short duration that the increase due to conduction at any point would be small. The brevity of the whole operation indicates that the fulgurite is the product of fusion purely and not in any considerable degree due to the action of one part as a solvent upon another. On this account it is interesting to note that the order of fusion in the formation of fulgurite holds no definite relation whatever to the order of crystallization when the rock solidifies from a molten magma. The groundmass (last product of crystallization) with its numerous grains of magnetite (first product of crystallization) have yielded most readily to the heat developed by the passing current. Next to these the hypersthene shows the greatest amount of alteration, while the difficultly fusible feldspar exhibits but slight traces of modification and the infusible olivine remains wholly unchanged. So far as observations have yet been made upon the production of fulgurite by the fusion of a heterogeneous rock it appears that the amount of melting experienced by each ingredient depends chiefly upon its degree of fusibility.

Notwithstanding the valuable researches of numerous observers on the electrical characters of minerals too little is yet known to determine how important a factor the electrical resistance of each mineral may be in determining the composition of the fulgurite. On account of the diaphaneity of the conductor and the great strength of the current by which fulgurite is produced it affords an excellent opportunity for the study of electric fusion. The presence of a porous rock, rich in iron, upon a prominent, acutely pointed mountain-summit in a region of violent electric storms presents the most favorable condition for the extensive formation of fulgurite.

U. S. Geol. Survey, Washington, D. C., May 27, 1884.

THE EVENT

Petrified Lightning from Central Florida

a Project by Allan McCollum

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