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Petrified Lightning A Discussion of Sand Fulgurites

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Fulgurites are a unique occurrence in nature. This term, derived from the Latin word fulgur meaning lightning, applies to any rocky substance that has been fused or vitrified by lightning.

The term fulgurite is generally applied to the vitreous tubes and crusts formed by the fusion of sand by lightning. When lightning strikes solid rock, the superficial coatings of glass produced are called rock fulgurites. This article is concerned primarily with sand fulgurites, specimens of which have been found throughout the world, including various parts of the United States: California, Florida, Illinois, Maine, Massachusetts, Michigan, New Jersey, North Carolina, Oregon, South Carolina, and Wisconsin.

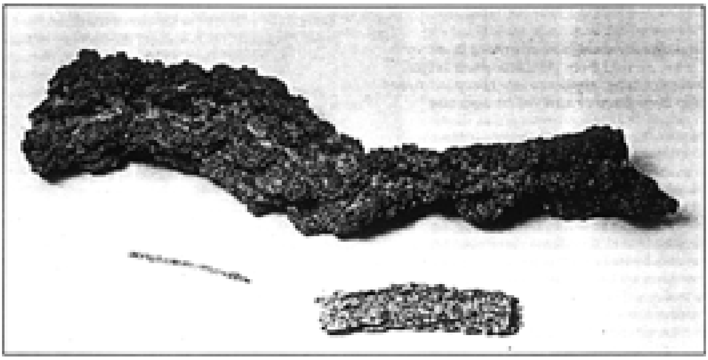
According to Petty (1936), the discovery of fulgurites was made in 1706 by a Pastor David Hermann in Germany, but many people credit a Dr. Hentzen as the first person to recognize the true character of glassy tubes found in the sand dunes of the Sennerheide near Padderborn, Germany. Fiedler (1817) wrote the first comprehensive paper on fulgurites while still a student at Gottingen. The first identification of a fulgurite in the United States came in 1861 when Hitchcock (1861) wrote of the discovery of fragments of a tube by Dr. A. Cobb of Montague, Massachusetts, at Northfield Farms. Barrows (1910) has published a complete history of the subject, including an extensive bibliography.

General Description

Fulgurites are generally found in quartz sands where tubes course downward from the surface, decreasing in diameter and branching along their descent. They can be twenty to thirty feet in length, with some as long as sixty feet. Diameters range up to a rare three inches. Bulbous or knobby enlargements found along the tube usually correspond to porous or impure layers in the sands. Pebbles in the path of the electrical discharge generally cause a deflection. Terminations vary from glassy, sack-like enlargements to a mealy, loose cementation of the partially fused sand particles.

Typically, fulgurites have a rough exterior with adhering sand particles; some also have threadlike appendages of fused silica that is projected outward. The tubes are often ridged parallel to their length with anywhere from two to four flat ridges present. Occasionally, the corrugations have a spiral arrangement, generally right handed, which is seen only along short sections of the fulgurite.

The interior cross section of a fulgurite is either elliptical or jagged, with three to five corners and indented sides. Interior surfaces are generally smooth and glassy with occasional glassy threads and blisterlike bubbles present on the inner walls. Wall thicknesses range from paper-thin to 2 millimeters. The jagged appearance of some tubes may be



A comparison of fulgurites from 1/16 inch to 2 inches in diameter. All were found in the sand dunes along lake Michigan, Oceana County, Michigan. Photo and specimens, Terry Huizing.

explained by ruptural deformation and collapse of an expanding tube of silica glass.

The color of fulgurites is somewhat drab. Externally they may be grayish white, yellowish brown, tan, brown, or dark gray to black. The surface may be mottled or spotted as well. The brown color may be localized due to an iron-rich layer in the sand. The glassy interior is generally colorless or slightly greenish or yellowish in tiny grains.

The interior glass contains many bubbles concentrated in the outer sections of the walls. The inclusion of quartz grains is also common in the outer edges of the walls. These quartz grains are white and opaque, and are minutely cracked, possibly due to thermal shock as beta quartz cools through the 573°C conversion temperature to alpha quartz. Cristobalite pseudomorphs or rims of cristobalite may be present around the quartz grains. Devitrification of the glass is almost never observed. The interior glass is isotropic with index of refraction values close to that of pure silica glass (1.462). The principal impurities are ferric iron, which causes the yellowish color, and aluminum, along with calcium and magnesium as seen in Table 1. Rogers (1946) mentioned that Lacroix named the silica glass of fulgurites lechatelierite. A refractive index of 1.457 ± .0003 was determined for lechatelierite from a section of fulgurite found in Riverside County, California. Although sand fulgurites are common, they are quite fragile because of the bubbles and cracks radiating outward from quartz inclusions.

Table 1: Analyses of Fulgurites (frondel, 1962)

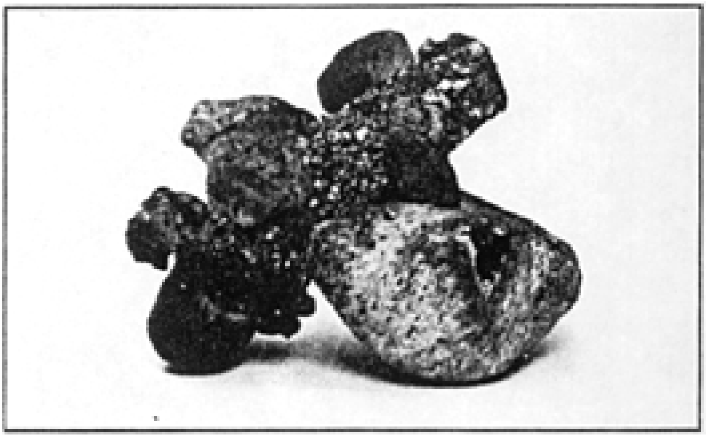
	1	2	3	4
SiO_2	93.8	99.0	91.66	90.2
Fe_2O_3		0.3		0.7
	3.8		6.69	
Al_2O_3		0.7		0.9
CaO	0.6		0.38	0.1
MgO			0.12	0.5
Na_2O			0.77	0.6
K_2O			0.73	0.5
Rem.			0.33	6.5
Total	98.2	100.2	100.68	100.5

1.Germany 2.New Jersey 3.Illinois 4.Holland

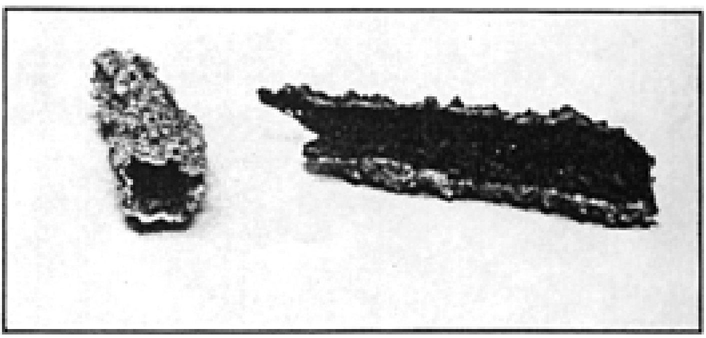
Origins

While lightning frequently strikes the earth, it is only where the surface materials are sandy that fulgurites are noted. According to Petty (1936), purity of the sand and good drainage result in favorable conditions for fulgurite formation if lightning strikes.

Tube length depends on two factors: the intensity of the lightning discharge, and the thickness of a relatively dry sand layer which acts as a nonconductor of a direct electric current (a dielectric). Low density discharges are often dissipated within the sand; high density discharges often pass through many feet of sand before the discharge is grounded. The bottom limit for fulgurite formation is determined by the existence of a ground water table or a wet stratum.



A hollow fulgurite showing rough exterior with adhering sand particles and an open fulgurite showing smooth, glassy interior. Photo, Terry Huizing.



Pebbles fused to a glassy, black fulgurite from Wolf Creek Pass, Colorado. Photo, Terry Huizing.

Each lightning discharge follows the path of least resistance, which may be a single path or branching and rebranching paths. The paths followed through the sand are similar to those followed from the cloud to the earth. The irregularities of the lightning path through the sand are probably due to differences in resistance to passage of the discharge. Such differences in resistance are due to changes in composition, moisture content, compaction of the strata, and inclined bedding. Darwin (1895) explained that fulgurites occur in groups because of the branching of lightning before it strikes the ground.

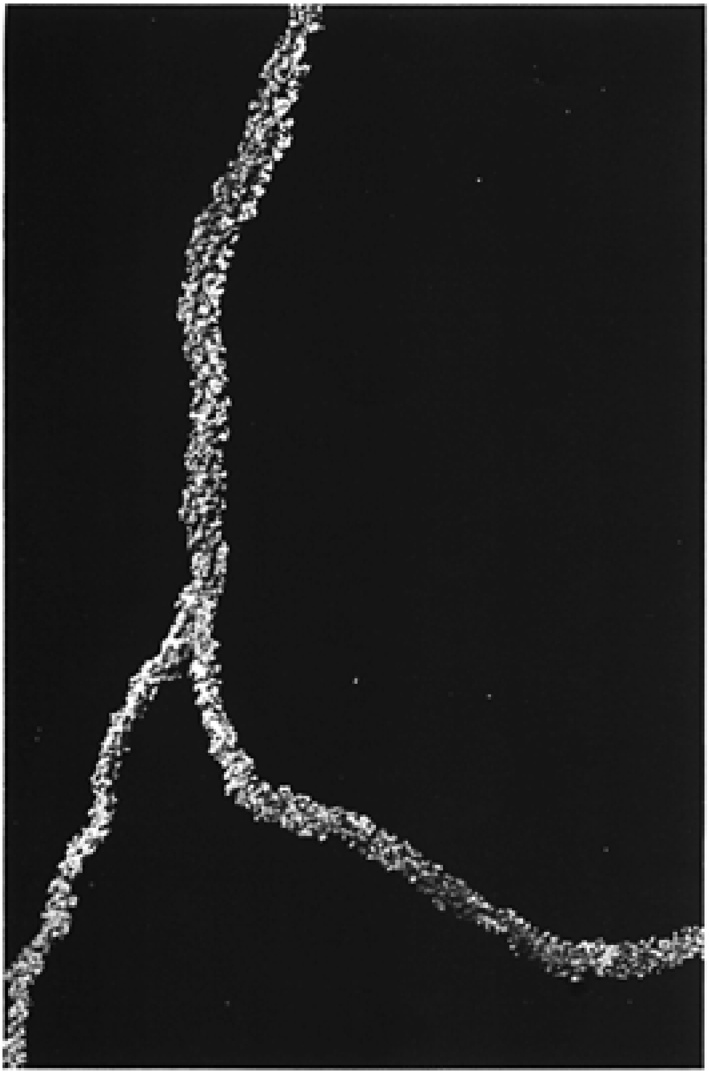
In addition, Petty (1936) offered three explanations for the tubular form of the fulgurite: it may be due to expansion of moisture present in the sand; it may be due to the expansion of air along the path of the discharge; or it may result from a mechanical thrusting aside of the sand which is then fused around the resulting hole. In theory, there is no mechanical force associated with an electric discharge, which implies that fulgurite formation is due to expansion of air and moisture. Since fulgurites form in relatively dry sands, the expansion of air is apparently the key factor for a tubular form. The amount of sand melted to form the tube depends on the intensity of the discharge which, in turn, regulates the energy expended in the form of heat. The melted sands acquire a cylindrical shape as a result of surface tensions. Tube diameter is dependent on the amount of expansion of air and moisture along the discharge path. When the air and moisture expansion is large in proportion to the amount of sand melted, a large-bored, thin-walled tube is produced.

Other explanations by Myers and Peck (1925) suggest that the tubelike structure of fulgurites is partially due to a rapid, sudden cooling, otherwise glass could not have formed. It could be that the volume of sand fused to glass was greater than the volume of the resultant glass. As a result, the glass, in a viscous state, is drawn by cohesion to the sides of a cylindrical mold. Included bubbles are most likely due to moisture trapped during the rapid fusion of the sand.

Significant American Occurrences

In 1861 the first fulgurite was identified in the United States when Hitchcock (1861) was given some more or less tubular specimens with glazed cavities inside and rough exteriors. The specimens actually resembled branched coral, and consisted of fine sand that was fused by heat on the inside of the mass. These specimens were found by Dr. A. Cobb (of Montague, Massachusetts) at Northfield Farms, Massachusetts.

Diller (1884) mentioned fulgurites found on Santa Rosa Island, south of Pensacola, Florida. A Mr. Stearns found tubular



A portion of a 5 1/2 foot recovered section of a fulgurite. Diameter is 1 inch. Branching is a permanent record of the course of the discharge. Found in Oceana County, Michigan. Photo and specimen, Terry Huizing.

fragments in a crooked trail leading from a tree struck by lightning, thus indicating the fulgurite's electric origin. The two specimens were about fifty centimeters long, with a diameter ranging from seven to fifteen millimeters. One fragment retained its cylindrical shape; the other fragment collapsed, while in a plastic condition, from the pressure of the surrounding sand. Even though walls of the tubes were only about 0.25 millimeters thick, they were not very fragile. They appeared rough and irregular with many small openings, and the exteriors were dull with vitreous interiors of a light gray translucent quality. The minute presence of iron oxide was indicated by a light brown clouding in the glass under the microscope. A few remnants of quartz grains were also observed.

Bayley (1892) described a fulgurite found in a garden in Waterville, Maine. The sand forming the fulgurite appeared to be of glacial origin, made up of a mixture of angular and rounded grains of quartz, feldspar, hornblende, and some fragments of a green earthy material, and slate. The specimen was three inches long, and had an elliptical cross section with axes of one inch and three-fourths of an inch. The exterior surface was rough and thickly covered with sand grains, and the interior was glazed with a transparent coating of light yellowish-green glass about one millimeter thick. The corrugations of the fulgurite possessed a spiral twist in opposite directions on opposite sides of the tube. These were referred to as "wings," and were covered with little knobs, which were hollow spaces enclosed within walls of glass and sand. These "wings" were a single layer of glass; sand grains adhered to both sides of the layer. This particular fulgurite was very fragile.

Hobbs (1899) described a spiral fulgurite found in Cutler, Wisconsin, which seemed quite similar to the spiral fulgurite found in Maine. The sand from which the fulgurite was formed was relatively pure, light brown in color, and composed primarily of translucent quartz grains with an average diameter of one sixty-fourth of an inch. The tube was about five inches long and "as thick as a man's thumb." The interior had a few dark specks surrounded by iron oxide stains. The fulgurite's surface was irregular and traversed by corrugations wrapping around the tube. The sand grains on the surface were of varying colors depending upon the degree of fusion. Since both the Waterville, Maine, fulgurite and this one show a spiral twist, it can be assumed that the structure is not accidental, but due to the conditions of the lightning discharge.

Barrows (1909) described a fulgurite found in the Raritan Sands of New Jersey. The sand from which the fulgurite formed was composed of angular grains of quartz in various sizes, with a small amount of dark silicates, and very little feldspar. At the locality the sand rests on clay, and in places there are at least fifteen feet of sand full of carbonaceous material, and sandy clay between the sand and the clay stratum. The fulgurite was about fifteen feet long and showed a bulge each time a new layer of sediment was crossed. The diameter was about 3.2 centimeters to 0.3 centimeters, with an irregular exterior surface. The wall thickness varied a little in many places along the fulgurite. Ridges were not prominent. The interior wall of the fulgurite was composed of a highly glazed amorphous glass full of many sizes of vesicles, with patches of black and brown due to iron.

Myers and Peck (1925) studied a fulgurite found in South Amboy, New Jersey. This specimen was found in a sand pit during excavation for industrial uses. Its recovered length was nine feet. The largest diameter was three inches, gradually tapering to three-sixteenths of an inch. The fulgurite appeared to have only one branch and was essentially conical. The rough outer surface was coated with partially fused grains of sand varying in color from yellow and light brown to a dull white. The glassy interior was opaque white due to bubble inclusions, with some parts transparent from a lack of inclusions. Some black stained areas due to iron oxides were observed. The most remarkable feature was the hollow core which ran almost the entire length of the tube. A radiating structure from the core was observed with even the included bubbles elongated and arranged with long axes pointing towards the center. A chemical analysis of a representative section is given in Table 1 (item 2). The silica content is very high, which is typical of fulgurites. The sand surrounding the fulgurite was composed of discolored quartz grains with small amounts of a clay-like mineral. The grains adhering to the exterior of the fulgurite were found to have a quartz center surrounded by a fine grained border of cristobalite.

Petty (1936) published a paper on the fulgurites found in the Atlantic Coastal Plain. The particular fulgurites resembled shriveled roots with sand sticking to them, and had smooth, glassy interiors. The irregular surface of the tubes is due to spiny projections, corrugations, ridges, or winglike extensions. The ridges seemed to have a slight spiral twist to them as already described for the Waterville, Maine, and Wisconsin fulgurites. The interior glass was colorless, grayish, or blackish. Wall thicknesses varied from several millimeters to paper-thin, with some walls being discontinuous or lacelike. The diameters ranged from one-eighth of an inch to one inch with considerable variation in each tube. Some of these fulgurites were twenty to thirty feet long, with a few up to sixty feet. The tubes branched out downward, and sometimes followed a course parallel to the sand bedding.

Rogers (1946) described some fulgurites found in Riverside County, California. These specimens were hollow, branching, cylindrical objects, of medium gray color. They varied in length between six and thirty centimeters, and had a diameter from one-half to two centimeters. The sand grains on the outside were angular and composed of quartz, orthoclase, microcline, plagioclase, biotite, magnetite, zircon, and some rock fragments. Lechatelierite, the silica glass, and cristobalite are both found in thin sections of this fulgurite, but no evidence of tridymite was found.

Conclusion

Fulgurites are relatively common, yet their discovery is rare because of their fragile nature. Many fulgurites are destroyed through compaction or tillage of soils, especially since sandy soils are not very stable. Fulgurites are always high in silica. Often they contain cristobalite and lechatelierite along with quartz and impurities. The difficulty of extraction, and the fact that their true identity is often not recognized, has resulted in the recovery of very few specimens. Many museums throughout the United States do not have good fulgurite specimens because of their special nature and because of the problems of recovery that are encountered once they are located. Fulgurites can easily be thought of as one of the most fascinating gifts that Nature has given us.

Mary Gailliot was graduated from the University of Virginia in the spring of 1979 with a degree in environmental sciences.

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THE EVENT

PETRIFIED LIGHTNING FROM CENTRAL FLORIDA

A PROJECT BY ALLAN MCCOLLUM

CONTEMPORARY ART MUSEUM
UNIVERSITY OF SOUTH FLORIDA

MUSEUM OF SCIENCE AND INDUSTRY
TAMPA, FLORIDA