

THE ORIGIN AND OCCURRENCE OF FULGURITES IN THE ATLANTIC COASTAL PLAIN.*

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ABSTRACT

The character and field occurrence of fulgurites from the Cretaceous sands of North and South Carolina are described. Over one hundred tubes averaging about three-eighths of an inch in diameter have been collected. The tubes have been traced downward sixty feet and are surprisingly abundant in areas that could be examined in detail. The paper also includes a statement on artificial fulgurite formation and a bibliography on lightning as a geological factor.

INTRODUCTION.

The earliest recorded discovery of fulgurites was apparently made by Pastor David Hermann in Germany in 1706, but Voigt (81)¹ in 1805 credits a Dr. Hentzen as the first to recognize the true character of the tubes. Fiedler (31) made the first comprehensive study of them in 1817. In the United States, West (83) reported in 1843 a discovery of a fulgurite made a few years earlier in New York, and in 1861 Hitchcock (51) reports an occurrence in Massachusetts, followed in 1874 by Leeds (59) with a brief description of a fulgurite from North Carolina. Since then a number of papers on fulgurites have appeared, mostly concerned with descriptions of single occurrences or with the microscopic character of the materials. The present paper is a report, with special reference to form and field relations, of over 100 occurrences of fulgurites from the sands of the Coastal Plain of the Carolinas. A review of artificial fulgurites and a bibliography on lightning as a geological factor is added. A paper by Barrows (12) has been the source of many of the titles in the bibliography and of much help otherwise.

OCCURRENCES OF FULGURITES IN THE COASTAL PLAIN.

The fulgurites collected by the writer have been obtained from nine sand pits located in Lexington, Richland, and Chesterfield Counties, South Carolina, and Moore County, North Carolina. Dr. F. H. H. Calhoun has kindly furnished

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¹ Numbers in parentheses refer to the bibliography at the end of this paper.

a specimen collected near Wilmington, North Carolina. Other occurrences of fulgurites from the Coastal Plain have been reported by Leeds (59) at Fayetteville, North Carolina; by Merrill (60) at Sumter, South Carolina, and Santa Rosa Island, Florida; by Barrows (12), and by Myers and Peck (63) from New Jersey.

MACROSCOPIC APPEARANCE OF THE TUBES.

Externally the tubes roughly resemble shriveled roots to which sand has adhered, the outer surface appearing much like

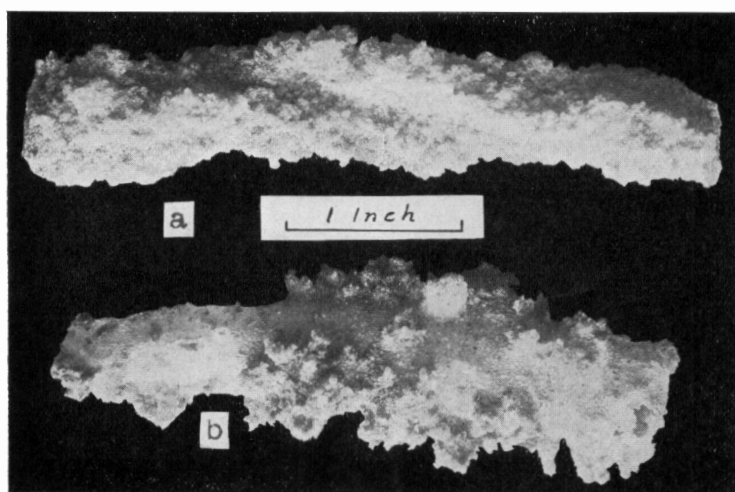


Fig. 1. Fulgurites with ridged (a) and with spiny (b) surfaces.

the sand from which the fulgurite is formed. The internal surface, on the other hand, is smooth and of glassy appearance, with a choncoïdal or botryoidal irregularity. Re-entrants associated with the outside projections occur, and the inner surface as a whole may be pitted by exploded gas vesicles.

When the outside loosely adherent sand grains are removed, the fused and partly-fused portions of the tube usually present an irregular surface whose irregularity is due to either spiny projections, corrugations, keel-like lumpy ridges, or thin wing-like extensions from the tube. The spiny projections may be either solid or tubular and may extend outward as much as an inch (Figs. 1b, 2a, 2c, 3a, 3b). The corrugations and

wings which are often interrupted, may gradually end, and occasionally branch (Figs. 1a, 3a). The ridges, usually three

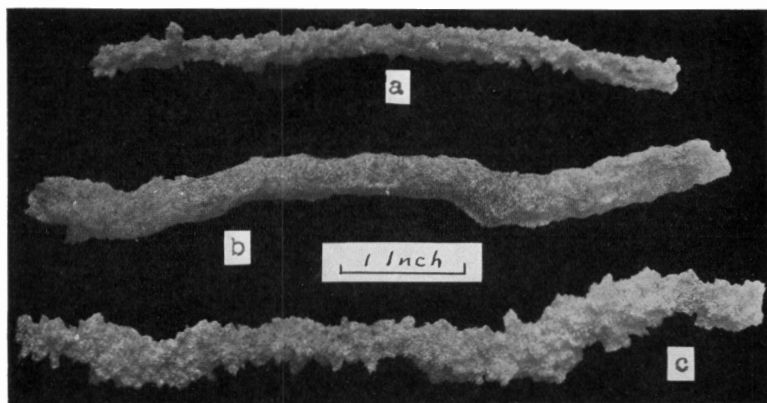


Fig. 2. Fulgurites with warty (a, c) and with slightly ridged (b) surfaces.

or four in number, extend roughly parallel to the long axis of the tube, but as shown in Fig. 1a and reported by others

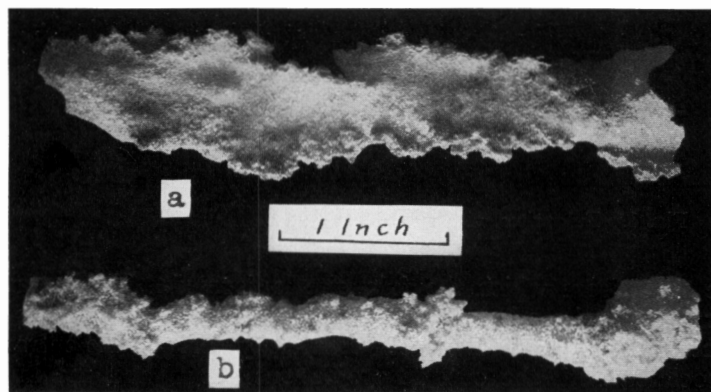


Fig. 3. Fulgurites with winged projections (a) and with ring enlargements (b).

(3, 14, 52) the ridges may have a right-hand spiral twist. The wings may extend outward as much as an inch.

While the irregularity of the outer surface is commonly due to projections from the tube which often result in thickening

the wall, in many instances the wall of the tube has collapsed while the glass was still plastic, giving an outer surface which roughly conforms to the cross-section of the collapsed tube.

Fulgurites usually have much the same surface character for the entire length but variations within short distances also occur. There does not seem to be any marked uniformity of surface character among different tubes near each other.

Many fulgurites are made of nearly colorless glass, spotted

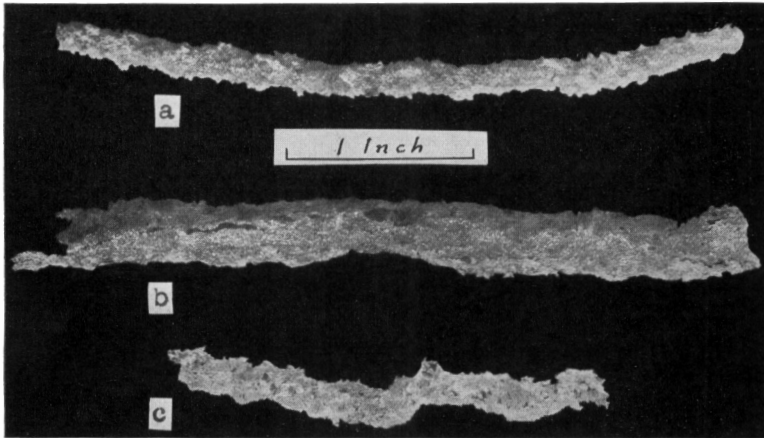


Fig. 4. Fulgurites with lace-like Walls (b, c).

or peppered with gray or black areas, but commonly the glass is uniformly colorless, grayish, or black.

The thickness of the wall varies from several millimeters to paper thinness, and walls of some tubes are discontinuous or lace-like (Figs. 4b, 4c). No relation seems to exist between the size of the tube or its bore and the thickness of the wall, for tubes of large diameter may have thin walls.

The diameter of the fulgurites collected by the writer ranges from one-eighth of an inch to about one inch, averaging three-eighths of an inch. Tubes three inches or more in diameter have been reported (60). Considerable variation in diameter in the same tube is common, brought about by enlargement (Figs. 5a, 5b, 5c, 5d) or constriction of the tube, with or without corresponding change in diameter of lumen or bore.

While downward tapering is reported, the writer has ex-

cavated a number of fulgurites 15 to 25 feet without noting any marked decrease in size.

In general the lumen is roughly circular, and conformable to the outer surface; but ridges, spines, and wings may have no corresponding interior irregularity. In many fulgurites compression of the walls took place before solidification of the glass, giving a flattened cross-section. Compression may be limited to a portion of a tube, and in closely adjacent fulgurites

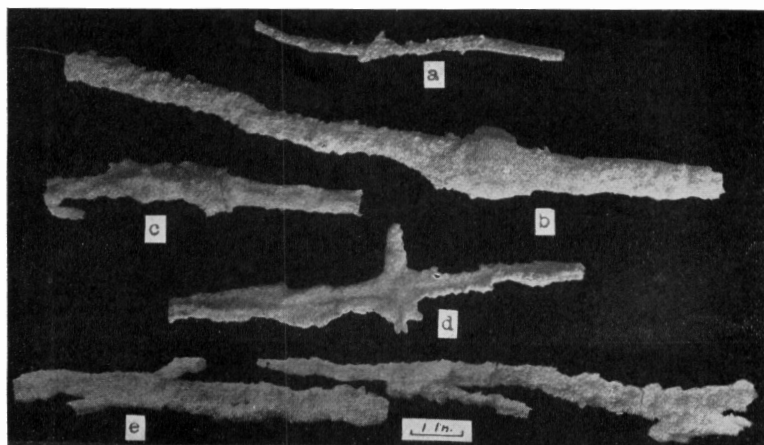


Fig. 5. Fulgurites with tube enlargements (a, b, c, d) and a tube (e) which branches and the branches reunite.

one may be compressed and the other not. In several instances where tubes paralleled the inclined bedding planes of the enclosing sand, cross-sections were found to be oval or rectangular, with short axis normal to the bedding planes. While not evident from the photograph, Fig. 4b is oval in section.

LENGTH AND POSITION OF THE TUBES.

Fulgurites 20 to 30 feet in length are common in the areas examined by the writer and tubes as much as 60 feet below the surface of the sand have been collected from the Foster pit at Dixiana, South Carolina. While the tubes usually follow a tortuous though roughly vertical downward course through the sand, variations of this course are worthy of note.

Many tubes branch and rebranch, with outward divergence of the branches, or occasionally the branches may follow nearly parallel courses for a few inches and reunite as shown in Fig. 5e.

In some fulgurites, apparently limited to the smaller tubes, the course parallels the bedding of the sand. For the larger tubes inclined positions, either for parts of the course or all of it, without any definite relation to the bedding of the sand occur. Barrows (12) reports a tube running at an angle of ten degrees to the horizontal for the entire length recovered. A large tube found by the writer was nearly vertical except for four inches where it followed a horizontal course, the change from vertical to horizontal and from horizontal to vertical being accomplished by right angle turns.

A zone of reddish sand, usually less than one-quarter of an inch thick, though occasionally three or four inches (69), commonly surrounds the fused material. In passing downward, due to dissipation of energy associated with the lightning discharge, smaller and smaller amounts of sand are fused, forming discontinuous walled tubes, or merely reddish streaks in the sand. The fusion may end abruptly when a conducting or wet layer is encountered. The bulbous terminating sacks reported from Nebraska (10) have not been found in the Coastal Plain.

OCCURRENCE.

Because of their fragility, fulgurites are usually found only where the sand has not been much disturbed; thus they are seldom found in cultivated fields. In areas where the soil is lacking or has been removed, a small amount of erosion leaves the tubes projecting or pieces lying on the surface. These conditions commonly occur where the overburden has been removed and on slopes into sand pits.

The sand pits from which the writer's collections of fulgurites have been made are located in the Cretaceous sediments which outcrop in a broken fringe of hilly topography along the inner margin of the Coastal Plain. Sand, clay, and gravel make up the formation, but the sand pits are generally located where the sands are thick and clay lenses thin or lacking. The sands are fine to coarse in texture, composed mostly of quartz, and commonly cross-bedded.

The pits from which the largest collections have been made

are most actively operated and have also been more carefully and frequently examined. The following table summarizes the collections made from the pits.

Pits	Fulgurites		Total
	In Place	Stray Pieces	
Lexington Co., S. C.			
Summit Pit	5	0	5
Rose Pit	11	3	14
Hoefer and Ehrlick Pit	22	5	27
Foster Pit	19	5	24
Wilson Pit	12	2	14
Richland Co., S. C.; Pontiac Pits	4	3	7
Davis Pit	2	2	4
Chesterfield Co., S. C.; McBee Pit ..	1	3	4
Moore Co., N. C.; Aberdeen Pit	2	0	2
Total	78	23	101

The total area of the pits examined would amount to several hundred acres, but in each pit only a small part of the total area is favorable for the discovery of fulgurites. A density of several fulgurites per acre is thus indicated for the areas examined. The fact that fulgurites occur in all the pits examined, together with the wide distribution of the pits suggests that fulgurites are common throughout the Sand Hill Belt.

ORIGIN OF TUBES.

It is a matter of common observation that lightning frequently strikes the earth's surface; but only where the surface materials are sandy are sand fulgurites formed. Many observers (23, 53, 54, 64, 78, 79, 80, 82) have noted the surface markings and killing of vegetation by lightning.

Lacroix (57, 58) has pointed out that in the Pyrenees rocks rich in iron minerals appear more susceptible to being struck by lightning, and exposed points such as mountain peaks, are known to be more frequently struck. Neither of these factors can explain the abundance of fulgurites in the Coastal Plain, since the Sand Hills are not outstanding topographic features, nor is the composition of the sands exposed in the pits such as to attract or conduct lightning.

Three factors without doubt play an important part in causing the abundance of fulgurites in the Coastal Plain. The purity of the sand together with the good drainage which keeps the sand relatively dry, results in favorable conditions for fulgurite formation when lightning strikes. Also the

formation of fulgurites has probably taken place over a long period of time.

The length of the tubes depends on the intensity of the lightning discharge and the thickness of the sand layer, which acts as a dielectric. A discharge of low intensity may be gradually dissipated in the sand while one of high intensity may pass through many feet of sand before the discharge is grounded. The ground-water table or a wet stratum determines the downward limit of fulgurite formation.

The path followed by the lightning through the sand is in general like the path of lightning in the atmosphere between cloud and earth, some discharges following a single path and other discharges following branching and rebranching paths, in each case the discharges follow the paths of least resistance. Most irregularities of the course in the ground are no doubt due to differences in resistance to passage of the discharge, resulting from changes in composition, moisture content, compaction, etc., of the sand. Thus inclined bedding may divert the course, as has been observed for several smaller tubes. Small differences in conductivity would probably be of greater influence for the smaller discharge than the larger discharge.

The occurrence of fulgurites in groups was long ago explained by Darwin (25) as being due to the branching and rebranching of lightning before reaching the ground. Several fulgurites in line may be a result of shifting of the point of strike due to drift of path of discharge with the wind.

Three explanations of the tubular form of the fulgurite have been offered: Either the lumen is due to expansion of the moisture present in the sand, or it is due to the expansion of the air along the path of the discharge, or it results from a mechanical thrusting aside of the sand which is then fused around the hole made. As there is theoretically no mechanical force associated with the passage of an electrical discharge, the opening made must be due to expansion of air and moisture, and in dry sand largely the expansion of air, along the path of the discharge. The amount of sand melted depends on the energy expended in the form of heat, the melted material taking a cylindrical shape due to surface tension. The diameter of the tube is determined by the amount of expansion of air and moisture along the path of the discharge, which, when great in proportion to sand melted, produces a large-bored thin-walled tube. The collapse of some tubes before solidifica-

tion of the glass is probably related to length of time during which discharge takes place, i.e., the rate at which energy is dissipated, and ease of relief of expansive force, since a short-timed discharge produces quick expansion and release of pressure before congealing of melted material. Swellings in the tubes may be due to less resistance to expansion by the wall material or to greater porosity allowing larger amounts of air and moisture in the sand. Obviously difference in composition of the sand would influence the amount of sand melted.

Fielder (33) long ago noted that the tubes were broken before excavation, often into smaller pieces for the thicker walled tubes, and he accounted for this fracturing by shrinkage of the glass on cooling. No doubt settling of the sand and earthquake tremors account for some of the fracturing. In most instances the tubes suffer additional fracture while being excavated. The longest piece the writer has recovered is about 14 inches.

ARTIFICIAL FULGURITES.

The first serious experiments on the production of artificial fulgurites were carried out by Rollman (70) in 1868, although experiments had been made as early as 1828 (15). In 1909 Butcher (22) made tubes up to 9.5 mm. long and 0.5 mm. in diameter by passing a spark through powdered glass and resin placed in a hole in a block of paraffin wax. The conclusions were that the tubes result from fusion around a column of air in which the spark passes; that the length and thickness of the tube depends on the energy and character of the spark; that the difference between thick- and thin-walled tubes was probably due to a difference in the sharpness of the flash and the resulting explosive effect, which effect, when great and the quantity of material melted small, produces a large-bored thin-walled tube.

As far as known no subsequent systematic experimentation in the production of artificial fulgurites has been carried out. This is unfortunate, considering the fact that now electric discharges of much greater energy content can be produced, even approaching actual lightning conditions. A systematic investigation should reveal the influence of composition of sand, size of sand grain, moisture content, and many other varying conditions on the character of the artificial fulgurite, and through comparison of the artificial fulgurites with those

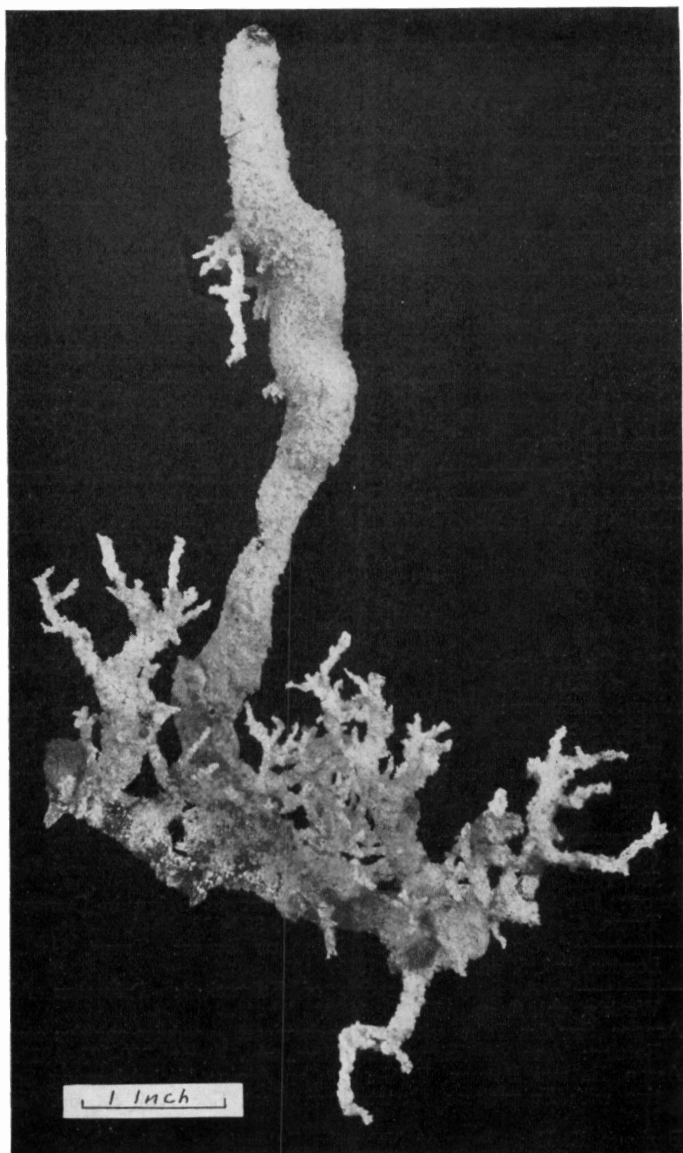


Fig. 6. Artificial Fulgurite made by passing electric current into grounded ten-quart pail of sand. (Courtesy General Electric Company, Pittsfield, Mass.)

produced by lightning, much information about the lightning discharges which strike sand might be learned.

A few artificial fulgurites have been made by the General Electric Company by passing high voltage discharges into sand. Mr. K. B. McEachron has kindly furnished a photograph (Fig. 6) of one artificial fulgurite they made by passing the current from an electrode suspended over a grounded ten-quart pail filled with a fairly clean mixture of quartz and feldspar.

Occasionally when high tension wires are grounded conditions are favorable for the production of artificial fulgurites. Mr. E. B. Eckel has given the writer information about the production of fulgurites ranging from one-tenth of an inch to three inches in thickness and up to two and one-half feet in length, which were formed when a high tension wire came in contact with the ground, thereby causing a current to discharge into granitic debris for about 12 hours near Boulder, Colorado.

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