A CHAPTER ON FOSSIL LIGHTNING.

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THE expression "fossil lightning" may seem somewhat paradoxical, but it is here employed in a figurative sense to designate a condition of things which we have good modern evidence to prove to have been the result of the lightning's flash, myriads of ages gone by. Of late years vitrified sand-tubes have been discovered in Cumberland, in Prussia, South America, Natal, and other places; and these have been very clearly made out as having been directly caused by lightning, and hence they have been called by mineralogists "Fulminary tubes" or Fulgurites. All these would appear, so far as we can ascertain, to have been formed at comparatively a very recent period, and hardly, therefore, deserving of the appellation of "fossil lightning." Nevertheless, as I have come across some examples of such bodies on the surface of the flagstones which form our pavements, and of the antiquity of which there cannot be any doubt whatever, I have no hesitation in making use of the term which heads this chapter.

If I had at one time any scruples upon this point, they were removed whilst attending the instructive lectures so eloquently delivered by that great philosopher and distinguished comparative anatomist, Professor Owen, at the Museum of Practical Geology, in the early part of the last year. He used this expression, in his first lecture on Fossil Birds, when particularly speaking of the various modes in which the evidences of evanescent things become recognisably preserved in rock, as illustrated by meteoric phenomena, footprints, soft and soluble plants, and animals. The "fossil lightning," as exhibited in the British Museum, he lucidly described, and pronounced some of it even to be forked. As further illustrating evanescence, I may for the moment refer to some specimens of rain-prints and shrinkage-cracks on the under side of layers of carboniferous sandstone from Cape Breton (Nova Scotia), figured and described by Sir Charles Lyell, in the Geological Society's Journal and in his "Manual of Geology." The large size of the rain-drops would indicate most probably a vio-

lent shower, lasting but a short period of time, and followed by a gleam of sunshine which was powerful enough to produce a rapid drying of the sand, and the formation of shrinkage-cracks, which, together with the depressions formed by the rain-drops, the latter often so strikingly marked as to indicate the very direction of the shower, became covered by a thin layer of sand on the next flowing of the tide. The shrinkage-cracks and the large drops of rain I have heard described as instances of *fossil sunshine*.

Fulgurites were first discovered by the shepherd Herman in 1711, whose specimens are still preserved in the Museum at Dresden; Hentzen next found them, in 1805, and he was the first to recognise their true nature. They are generally compressed in form, mostly hollow, and taper in their descent into the sand vertically. Some are distinctly furcated, and in many specimens lateral branches, also tubular and from two to three inches long, and not exceeding a quarter of an inch at the point of junction, proceed from various parts of the parent tube. These small branches gradually bend downwards, and assume a more or less conical form, terminating in abrupt and closed points. If the lightning has encountered the resistance of pebbles, or has passed through wet sand, the tube becomes not only contorted and twisted in its course, but is also much flattened and compressed. Mr. Irton found a tube at Drigg, which was hollow for eight or nine inches, then became completely solid without any central perforation, while lower down it again assumed the rugged and tubular condition.*

The extreme diameter (or bore (?) of the lightning) of these tubes is an inch and a half;† the internal cavity is rarely circular, being either triangular, quadrangular, pentangular, oval, or some irregular figure; their length, as stated before, is from a few feet to upwards of forty feet; the thickness of their walls has reached $\frac{1}{10}$ th of an inch, and their largest circumference from two to five inches, as I have determined by actual measurement.

Nearly all the tubes met with have numerous longitudinal furrows and indentations on their external surface, and have not inaptly been

* Trans. Geol. Soc. vols. ii. and v.

† The agglutinating power of the electric fluid sometimes forms a mass of 2½ inches diameter, with a tube above and below it; many such interruptions have been found in the course of a single tube, from the lightning having met with obstacles in its passage.

compared to a shrivelled vegetable stalk, or the bark of certain trees, particularly the elm, the birch, and the cork. These furrows and creases are considered to be the result of the compression of the surrounding loose sand, while the tube was still softened from the effects of the intense heat. Perfectly cylindrical fragments, free from furrows, have, however, been discovered, with a circumference of four inches. By the aid of a small magnifying glass, the external surface of the tube is seen to be covered with a crust of agglutinated sand or quartz, each particle being visibly surrounded by vitreous matter, the grains being also round in form, some having a slightly glazed appearance. The internal surface of the tubes is quite smooth and glassy, and completely vitrified, with a corresponding irregularity of form to that of the exterior. Extreme compression acting on the tube in its soft state, has in some cases caused the opposite sides of many of the furrows to come into contact and be welded together; in this way the tube is occasionally so much flattened as to be obliterated. The internal glassy smoothness is brilliant and porcellaneous, and resembles many mineral substances, particularly opal and hyalite.

The colour of these tubes varies according to the nature of the sand into which the lightning has penetrated. Those from Drigg and La Plata are of a light-drab colour, and, if minutely examined, numerous black specks are seen, with what seem to be air-blebs, or perhaps bubbles of steam. It is the white quartzose grains which have become vitrified in all the specimens, imparting to the tube-mass a sufficient amount of hardness to permit the scratching of glass, and even the striking of fire with steel; they are nevertheless easily broken. All the vitrified tubes from Natal are of a dark ferruginous brown colour, owing to impregnation with iron; the largest of these are not quite so dark as the smaller. In certain localities the tubes have been found, firstly on passing through the soil almost black, then yellowish-grey, still lower of greyish-white, and finally colourless; these variations depending upon the purity of the sand from, or its admixture with, other substances. The electric fusion is not solely confined to the less refractory quartz, but in some instances at Drigg has extended to pebbles of hornstone-porphry, many of which were partly vitrified.

In the foregoing description of "recent lightning," I have confined

myself to those tubes which are hollow ; but, as I have stated, occasionally this character is wanting, and many of them terminate in the solid state, it is only necessary then to mention that even the vertical penetration is characterised by the same peculiarity ; thus of the fulgurites from Natal, very small specimens do not appear to be tubular, but resemble the horizontal cylinders from Dresden.

That the formation of fulgurites, whether recent or fossil, is due to the vitrification of the siliceous matter through which the electric fluid passes, we have clear proofs by our knowledge not only of the meteoric phenomena of the districts in which they are found, but also by the results of various series of experiments which have been from time to time instituted to produce them artificially. In relation to the first, the neighbourhood of the Rio Plata, close to where Mr. Darwin found them, was known to be remarkably subject to electric phenomena ; and the sand-hillocks of Drigg, in Cumberland, from presenting themselves as direct objects to clouds coming from the sea, the marshes of Irt only intervening, are favourably situated for promoting electrical discharges. The experiments made seem, too, very conclusive, and are full of interest. The Drigg-sand consists of quartz and hornstone-porphry, and, when submitted to the action of a powerful blow-pipe, formed a clear glass mingled with olive discolorations resembling the fulgurites.* MM. Hachette, Savart, and Beudant feebly imitated these bodies by the shocks of one of the most powerful galvanic batteries in Paris on powdered quartz, the result being small tubes of an inch in length.† I have experimented upon various kinds of sand with a powerful blowpipe, and have produced glass varying in colour according to the composition of the sand. The majority of light-coloured sands I find to assume a slight rusty colour, on being submitted to a considerable heat, before actual fusion occurs. All these, however, are but feeble evidences of the power of electricity prepared by ourselves, when contrasted with that which constitutes the lightning's flash, the intensity of which can be estimated by the descriptions given of these remarkable bodies. Were any further evidence required to prove these fulgurites to be the result of lightning, it is only necessary to refer to descriptions given of trees struck by the electric fluid, when there have been found at the depth of from

* Trans. Geol. Soc. vol. ii.

† Annales de Chim. et Phy. tom. 37.

twelve to eighteen inches from their roots, melted quartzose matter, and vitrified tubes, of a flattened form with zigzag projections. Our wonder is, that such manifestations of the effects of lightning are really not more commonly noticed than they seem to have been, when we call to mind the observation of Sir Charles Lyell, that "it is probable a moment never passes without a flash of lightning striking some part of the earth."*

In London, the reader may see fulgurites in the Museum of the Geological Society, including specimens from Drigg, from the shores of La Plata, and from Dresden. In the Museum of Practical Geology, Jermyn Street, are specimens from Natal, many of them larger in size than those from Drigg, as also a tray of small ones. The British Museum contains fulgurites from the Tuarie country, Africa; from the vicinity of Dresden; from the Senner Heide, Westphalia; and from Drigg.

Some of those from Africa are dark in colour, and more nearly resemble those I have seen in a fossil state. The fine state of preservation of most of these has been owing, no doubt, to the soft and dry character of the sand around them.

The evidences of the power of atmospheric electricity are at times made fearfully manifest during thunder-storms, when the electric fluid shatters rocks and scatters immense fragments to considerable distances, splitting and tearing up trees, levelling houses, fissuring thick walls, and melting substances which have been looked upon as infusible. Of the last, we have an illustration according to Saussure in the slaty hornblende on the Dôme du Gouté, one of the summits of Mont Blanc; he found in 1787 vitreous blackish beads, of the size of hemp-seed, which were attributed most clearly to the effects of lightning. Ramond observed the entire face of certain rocks on several summits of the Pyrenees, especially the Pic du Midi and Mont Perdu (the latter upwards of 11,000 feet high), and also the rock Sanadoire, in the Puy de Dôme, varnished with a coating of enamel, and covered with vitreous beads, of the size of peas, the result of the same cause; the interior of the rock being found quite unchanged. On the summit of the Pico del Frayle, the highest pinnacle of the Volcano of Toluca,

* Principles of Geology, 8th edition.

in Mexico, upwards of 15,000 feet in height, Humboldt noticed the electric effect of lightning. He brought away pieces of a mass of trachyte pierced by lightning, and glazed on the inside like lightning-tubes; in it the lightning had made cylindrical tubes three inches long, in such a manner that the upper and lower openings could be distinguished apart, the rock surrounding these openings being also vitrified. Arago refers to the vitrification of rock (without tubes), which has been seen at a vertical height of 26,650 feet, over an extensive surface, at the Lesser Ararat and other places.* I possess a specimen of rock from Canada, which (being at the present time mislaid, I cannot therefore say positively what it is, but I believe it to be syenite) is thus covered on its exposed surface by a distinct coating of enamel. Several well-attested facts have been collected by Arago, showing the actual vitrification of stones, bricks, and other bodies, by lightning.

To illustrate the immense power of lightning in splitting and moving large masses of rock, I may be permitted to give the following quotation from the MSS. of the Rev. George Low, of Fetlar, in Hibbert's "Shetland Islands :"—

"At Funzie, in Fetlar, about the middle of the last century, a rock of mica-schist, 105 feet long, 10 feet broad, and in some places 4 feet thick, was in an instant torn by a flash of lightning from its bed, and broken into three large and several small fragments. One of these, 26 feet long, 10 feet broad, and 4 feet thick, was simply turned over. The second, which was 28 feet long, 17 broad, and 5 feet in thickness, was hurled across a high point to a distance of 50 yards. Another broken mass, about 40 feet long, was thrown still farther, but in the same direction, quite into the sea. There were also many smaller fragments scattered up and down."

It is in loose sand that we meet with the silicified tubes produced by lightning in the greatest abundance. Almost any substance is liable to be melted that contains even the smallest portion of siliceous matter.

My friend, Dr. Bigsby, informs me he has seen, many years ago, what he believes to be the effects of lightning in the chalk near Carisbrook, Isle of Wight. These consisted of tubes, perpendicular to

* Humboldt's *Cosmos*, vol. i. and vol. iv.

the surface, which were vitrified and glassy in their interior, and the chalk itself affected for a short distance around them. They were quite or nearly straight; in size, from half an inch to an inch in diameter, and were exposed in a fissure of the chalk. About three feet of these tubes were visible, and then they became lost.

The finest examples of these lightning-tubes which have come under my notice in the London museums are those from Drigg, in Cumberland, in the Museum of the Geological Society, and which have been described in that Society's Transactions. They appear to be the most perfect, although larger tubes have been found at Natal. In speaking of these I shall combine a general description of the whole.

It is in banks, hillocks, or mounds of loose sand, that they are generally met with, sometimes, however, in immense hollows, or occasionally on declivities of mounds of sand. At Drigg they were discovered in the middle of sand-banks forty feet high, between the river Irt and the sea, but projecting above the surface from the drifting away of the sand. These sand-banks are exceeded both in extent and height by those at Eskmeols, in the same county. On the shores of La Plata, in South America, Mr. Darwin found them in the sand-hillocks of Moldonado, which were constantly changing their position from not being protected by vegetation. This circumstance caused them to be found projecting above the surface, as at Drigg, and Mr. Darwin inferred, from finding numerous fragments lying about, that they had at one time been buried at a greater depth.* These occurred in a level area of shifting sand, situated among some high sand-hillocks, distant about half a mile from a chain of hills 400 and 500 feet high. In the Senne, Westphalia, similar tubes were found on the declivities of mounds of sand thirty feet high; but occasionally some were noticed in cavities, described as hollowed out in the heath in the form of great bowls, 200 feet in circumference, with a depth of from twelve to fifteen feet.

The position in which these tubes are found is one of some interest and importance. As usually encountered, they run vertically into the sand, at a varying depth. On the banks of La Plata four sets entered the sand perpendicularly, and one was traced $5\frac{1}{4}$ feet into the

* Darwin's Journal, vol. iii. 1839, p. 69.

sand by Mr. Darwin ; but, as the diameter of the whole was nearly equal, it must have extended to a greater depth. He found one deviating from a right line at a considerable bend, amounting to 33° ; and from this tube two small branches about a foot apart were sent off, one pointing downwards and the other upwards. This is an illustration of the forked character of the electric fluid, which, besides its division into two branches, would seem to have turned back in this case at an acute angle of 26° to the line of its main course. At Drigg many tubes were found dividing into two branches and pursuing a tortuous course into the sand. Some of the tubes gave off several small branches, the diameter of which was not a fifth of the tube whence they sprang ; others, again, deviated almost at right angles, glancing off, as it seemed, by the interruption of a pebble, as in the example figured in the Geological Society's Transactions (vol. v. First Series, pl. 3).

It is looked upon as a fact somewhat remarkable, that quite a number of tubes have been discovered to enter the surface of these sand-hills in comparatively limited areas ; at least, such was the case at Drigg, on the shores of La Plata, and also in Germany. Mr. Darwin counted more than four within a space of sixty yards by twenty. Three were noticed within an area of fifteen yards, upon a single hillock at Drigg ; and the same number were found in an equally limited space in Germany, as described by M. Ribbentrop. In considering this peculiarity, Mr. Darwin believes in the improbability of these tubes being produced by successive and distinct shocks—an opinion in which most persons will concur. Yet, whilst acknowledging the possibility of a division of the lightning into separate branches shortly before entering the ground, as suggested by him, I still think that the electric fluid may have run along the surface of the sand, and then entered it at different spots remotely situated from one another. This view is by no means irrational, when we reflect upon the truly singular peculiarities associated with this wonderful fluid, which may be seen at times to run along the surface of bodies and suddenly disappear. The intensity of its action, too, is oftentimes modified by the amount of resistance offered by substances struck by it. On the other hand, the electric fluid may divide into

several distinct currents, which would enter the surface at the distance of many yards from each other.

The greatest depth to which the electric fluid has penetrated vertically, as demonstrated at Drigg, is forty feet ; but I should be disposed to estimate the length of horizontal fusion at a much greater amount.

The majority of the fulgurites which I have had the opportunity of examining, have entered the sand vertically ; but some, again, ran along the surface of the sand in a horizontal direction. And it is this latter form only that we can expect to meet with in a fossil state. As examples of horizontal recent tubes, I may refer to specimens from Dresden, in the British Museum and in the Museum of the Geological Society. In the former collection the tube is very small, and runs in a somewhat tortuous manner, giving off a small branch five inches long, the entire length being sixteen feet and two-thirds ; but the original must have been very much longer, as this is but a portion of it. This example was presented by Dr. Fiedler, who has published a work on fulgurites in German, to which I have not had access ; but was obtained "on the confines of Holland, in a sandy country ; a shepherd, after having seen the lightning strike a hillock of sand, found, in the very point where it struck, a fulgurite." The Geological Society's specimen is eighteen inches long, and as large as a lead-pencil. Both of these examples are solid, without any internal cavity, and it seems a question in my mind whether actual tubes are ever found in any other than a vertical position. The examples in a fossil state which have come across my notice, and which first drew my attention to the subject, appear to have been found only in the solid form,* and partaking of the horizontal position. There are three flagstones on the eastern side of Tottenham Court Road which contain fulgurites of a lightish colour, running in forked directions. There is one on the eastern side of Russell Square, close to Guildford Street, on the surface of which a dark ferruginous tube of "fossil lightning" runs diagonally across the stone, its diameter being about two lines. I have noticed them in three or four other places in the

* I state this with some reservation, because I have seen a section of what looks like a lightning-tube in a sandstone door-step. It has four irregularly compressed sides, and presents very much the appearance of one of these bodies.

same parish, and feel satisfied they are the actual results of lightning : and whilst preparing this paper, I have come across a flagstone on the northern side of the Marylebone Road, running on the south side of Park Square, Regent's Park (two-thirds of the way towards the eastern end of the square), which contains one of the finest examples I have yet seen. The age of these flags I am unable to determine ; * but at any rate, by thus drawing attention to the subject, I hope it will lead to the discovery and preservation of fossil specimens, even in the oldest sandstones, for there is no reason to doubt the existence of electrical influences at the very earliest ages of our planet.

LOCALITIES OF FULGURITES.

BRITAIN.—Fossil in sandstone flags	Dr. Gibb.
DRIGG, Cumberland	Mr. E. L. Irton.
ESKMEALS, in larger sand-banks near the same place†.	Mr. Richd. Falcon.
LANCASHIRE, coasts of	Greg and Lettsom.
CANISBROOK, Isle of Wight	Dr. Bigsby.
DOVER, Chalk Cliffs ‡	Mr. S. J. Mackie.
GERMANY	M. Ribbentrop.
MASSÉL, Silesia	Herman.
LA SENNE, Heath of Paderbarn, Westphalia	Dr. Hentzen.
NIEBLEBEN, near Halle on the Saale.	
REGENSTEIN, near Blankenburg.	
PILLAU, near Königsberg, Eastern Prussia.	
DRESDEN, vicinity of	Dr. H. K. Fiedler.
TUARIE COUNTRY, Africa.	
NATAL do.	
LAKE OF TWO MOUNTAINS, Canada §	Dr. Gibb.
PINNACLE OF TOLUCA, Mexico	Humboldt.
MALDONADO, Rio de la Plata	Mr. Darwin.
BAHIA, Brazil.	

* These flagstones are probably from the lower carboniferous rocks of Yorkshire ; at least, nearly all London is paved with such flags.—ED. GEOL.

† Near this spot are the remains of an old Roman encampment ; and occasionally coins, with other objects of interest, are turned up.

‡ This instance referred to by Dr. Gibb was a case of a double or furcated perforation in a thick layer of clay covering the Castle Hill at Dover, made by a powerful stream of lightning, which, when a lad, I saw strike the ground at an elevated point. It can scarcely be called a fulgurite, as the clay was only coated on the surface with bluish-grey beads and grains, powdered, as it were, like the bloom of a peach. The perforations forked at about nine inches from the upper surface of the soil, apparently divided by one of the numerous angular fragments of flint which abound in the subsoil, and were of sufficient dimensions for me to put my arm with my walking-stick into them. The branches had divergent directions, as nearly as I can remember, of 30° or 35° on either hand from an imaginary intermediate vertical line. Their forms were irregularly angular, with ridges, as in the fulgurites, but they were of far larger diameter than any of the latter objects I have ever seen.D—S. J. M.

§ When strolling over the sand-banks of the hills at this place, when a youth, I discovered substances which I now believe were these tubes.