or the submarine plateau from which they rise. The axis of the latter plication seems to be continued on to the Carrara Mountains, where the crystalline series is again thrust up, and we find a region of very marked disturbance.*

But enough for the present. Many details of interest must be left for the third and last lecture; to-day I have only attempted to trace in broad outline the development and sculpture of the Alps. I will merely say in conclusion that, though I have been forced to speak, for the sake of clearness, of the *dates* of great disturbances, I do not consider these to have been in any way sudden. The uplifting of any part of the Alps was probably a slow process, occupying thousands of years, only there appear to have been periods, however long, of steady upheaval, perhaps with some corresponding depression in the area immediately beyond, followed by periods, not of absolute, but of comparative, repose.

On Some Effects of Lightning on Crystalline Rocks.

By J. ECCLES.

(Read before the Alpine Club, June 5, 1888.)

Although the occurrence of vitrified lightning tubes in sand on the coast of Cumberland, in North Germany, and elsewhere, is widely known, it is singular that the action of lightning on solid rock, in spite of its much more frequent manifestations, should have received so little attention.

When Bourrit, in 1784, made his first attempt to ascend Mont Blanc, two of his guides detached themselves from the party and passed beyond the summit of the Aiguille du Goûter. On their return they handed to him some specimens of rock partly covered with blackish glassy bubbles or drops. These were submitted to De Saussure, who, after much hesitation, concluded that the bubbles were due to rapid fusion by lightning. But he was not satisfied with mere speculation. He subjected a piece of crystalline rock to repeated discharges of an electric battery, and found that similar bubbles were produced. This is the first recorded observation of what is now called 'fulgurite' on solid rock.

These vitreous bubbles or beads are a pure natural glass caused by fusion of certain constituents of the rock. As a rule, the effects of fusion are superficial, and the rock appears as if it had been splashed with larger or smaller (more often smaller) drops of a pitchy-coloured or greyish-white liquid.

The specimens exhibited (No. 1) were obtained by me in 1870 from some lumps of rock which just appear through the snow near the summit of the Dôme du Goûter—probably the same locality where De

---

* This statement is not made in haste or in ignorance of the recent assertions of certain geologists, whom I believe to have fallen into a very common error.

Saussure's specimens were obtained. I found here small pieces of stone, which had been detached, actually cemented together by the fused glass.

The colour of the glass varies according to the nature of the stone. The darker varieties, which are the more easily detected, owe their blackish or dark-green colour to the presence of mica or hornblende, whereas the lighter kinds are mostly felspathic. Although the lighter-coloured fulgurites are less frequently observed, this, as is remarked by Professor Albert Heim, is not due to their less frequent occurrence.*

Sometimes both light and dark varieties are found on the same rock specimen, in which case the surfaces respectively occupied by each variety correspond almost precisely with the alternations of mineral constituents.

I have found these fulgurites on many of the peaks of the Pennine Alps, and the chain of Mont Blanc, and on several of the Oberland peaks. Professor Heim, in the paper previously referred to,† incorporated certain observations by Herr S. Simon on the occurrence of fulgurites in the Bernese Oberland and Bernina groups, and the last-mentioned gentleman, who has made a much more minute search than previous observers, states that there is scarcely a peak of crystalline rock in the Oberland group which does not show examples of them. A very interesting fact is recorded by Professor Heim. In 1868 he found many specimens on the summit of the Pizzo Centrale, composed of hornblende-schist, none however being found at a greater distance than three mètres below the summit. He collected all the specimens and took them away, but on revisiting the peak in 1875 he found a fresh supply. All these again he carried away. In the interval between these visits, however, a stone man had been erected by the St. Gothard engineers, and an iron post placed therein, which appears to have stopped the formation of the fulgurites, as subsequent visits were entirely unproductive.

Before leaving this branch of the subject, I will quote from a paper contributed to the 'Quarterly Journal of the Geological Society,' May, 1885, by Mr. Frank Rutley, F.G.S., Lecturer on Mineralogy in the Royal School of Mines, on some specimens which I had submitted to him.

On Fulgurite from Mont Blanc; with a Note on the Bouteillenstein, or Pseudo-chrysolite of Moldauthein, in Bohemia. By Frank Rutley, Esq., F.G.S.

An interesting paper by Mr. J. S. Diller, of the United States Geological Survey, upon fulgurite from Mt. Thielson in Oregon, appeared in the 'American Journal of Science,' vol. xxviii. Oct. 1884, in which allusion was made to the effect of lightning upon hornblende-schiste on the summit of Mont Blanc, as noted by De Saussure.

On reading this, I remembered that some years ago Mr. James Eccles gave me two or three small specimens showing evidence of fusion on their sur-

* *Jahrbuch des Schweizer Alpenclub*, 1885-6, vol. xxi. pp. 342-357.

† *Notizen über Wirkungen des Blitzschlages auf Gesteine*, pp. 345-352.

faces, which he at the time considered to be due to the action of lightning. They were collected by him on the summit of the Dôme du Goûter from small peaks of rock rising out of the snow at a height of 14,000 feet above the sea-level. These peaks form part of the chain of Mont Blanc. The fragments are small and consist of hornblende-gneiss; for they contain some felspar, and one of the specimens is traversed by coarse irregular foliations of felspar. Mr. Cuttell has made several attempts to prepare a section through this specimen with the thin fulgurite film adhering to it, but unfortunately failed, the fulgurite crumbling away in each trial. The cuts made through the specimens at various points show, however, that the fulgurite is quite superficial, no trace of fusion being visible below the original surface when the cut surfaces are examined with a lens. Indeed there appears to be no alteration of the rock from the electric flash, except on the actual surface itself, where a number of globules, sometimes in the form of attached spheres, sometimes in quite irregularly fused pellets and blotches of brownish-black and of white glass, have been formed. The latter is the frothy glass or enamel resulting from the fusion of felspar, while the dark glass is due to the fusion of hornblende. Upon one piece the surface is fretted and blistered over an area of about half a square inch. Some of the globules have minute holes from which gas has escaped; while others have been inflated into thin, spherical, or irregularly blistered bubbles. The dark glass is tough, some pressure being needed in order to detach small pieces from the broken bubbles. Fragments of these bubbles, when examined under the microscope with high powers, appear to be absolutely structureless and to contain nothing but a few small gas-bubbles. In this respect the glass corresponds precisely with the Mt. Thielson fulgurite described by Mr. Diller, for there is no trace of crystallisation-products in either case. On the surface of one of the specimens three or four glass-bubbles, each about the eighth of an inch in diameter, adhere to the rock quite close together, while from them a series of minute globules of glass appear to be scattered in a somewhat radiating manner, some of them being connected with the larger globules by a thin fretted trail on the surface of the rock, indicative of the sputtering of the fused material from the point struck by the lightning. The blow-holes of the glass vesicles from which the gas has escaped show an involution of the vesicle-wall around them, as though each hole had been formed by a wire pressed into the bubble while hot. This involution of the vesicles around the blow-holes is possibly due to fusion, cooling and contraction taking place with extraordinary rapidity. That the cooling of the glass was unusually quick is proved by its freedom from crystallites. Fulgurites, on this account, are probably the purest natural glasses ever formed.

The edge of a thin splinter of the rock taken from this specimen fused with intumescence, before the blow-pipe, to a dark glass similar to that of the fulgurite-globules.

The dark and the white glass globules do not, as a rule, appear to have mixed. They are often distinct, even when in contact, showing a clear line of demarcation between the two different kinds. Some instances may, however, be seen in which the dark shades off into the white glass. The fusion of both the hornblende and the felspar must have been so instantaneous, and the cooling so unusually rapid, that the fused surface of each crystal solidified almost exactly *in situ*, except where a sputtering of the molten matter was caused, either by the force of the electric shock or by sudden disengagement of gas from the fused material; for, in presence of such intense heat, the difference in the respective fusibilities of the hornblende and felspar cannot be taken into account.

But these glassy bubbles and splashes, although the most common, are not the only effects which lightning produces on crystalline rocks.

Alexander von Humboldt found on the summit of the volcano Toluca, in Mexico, small tubes, about three inches long, which had been pierced by lightning, and the inner surfaces of the tubes had been perfectly vitrified. The rock was a kind of trachyte.*

But the most remarkable find was that of Abich, the Russian naturalist. In a letter to Haidinger, in 1869, given at length in the 'Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften' (Wien, lx. v. 155, 1870), he describes phenomena observed by him on Lesser Ararat, in rock which he calls Hornblend-Audesit, and of this description I give a partial translation:

On pinnacles of lightish-brown rock on the higher declivities are found dark vitrified patches resembling the droppings from pitch torches. Here also the lightning bursts through the rock and makes narrow tubes of the diameter of a small quill, the inner surfaces of which are coated with a dark green glassy scoria or slag. These increase in quantity towards the summit, where their frequency is such as to produce an actual modification of the rock itself, which may appropriately be called a Fulgurit-Audesit. The fulgurites, in the form of worm-shaped channels 'mit geflossenen oft halb getropften Rinden,' burst through the rock in such a manner and are so closely crowded together that the rock itself is changed from a compact stone with micro-crystalline structure into a cavernous incomplete melted product which may be compared in appearance with wood which has been completely destroyed by teredo boring.

Last year I found, on the summit of Monte Viso, lightning-tubes similar in many respects to those found by Abich on Lesser Ararat. There is, however, one rather important difference—viz. the absence of any structural change in the rock by the penetration of the lightning, which may be partly accounted for by the probable greater compactness and hardness of the Monte Viso rock, which much resembles the 'grüne Schiefer,' and partly by the much less frequency of the tubes themselves, of which a prolonged search did not enable me to find more than forty. The formation of these tubes, indeed, seems to produce no more effect on the rock itself than does that of the glassy bubbles before described. A certain proportion are, in my opinion, not true tubes, but rather semi-tubular channellings of the rock by the lightning. I suspect also that in many cases the lightning has taken advantage of some slightly open joint, or has run along the surfaces of a cleavage plane, between which it has inserted itself at some point where the opposing surfaces were slightly open, or just on the point of opening, and while forming a perfect tube has at the very same moment rent asunder the adhering surfaces of the planes and thereby split the tube in two longitudinally.

Of the specimens exhibited, the largest is probably an example of both modes of action—the tubes on the chief surface have once been perfect, and produced by the lightning working between planes, one surface of the plane being split away; whereas the continuation of the tubes round the corners of the stone and on its opposite surface is the

* *Kosmos*, vol. iv., part i., note 531, Sabine's translation.

effect of external channelling. It appears to me to be more difficult to attribute the origin of the ramifying tubes on the chief surface simply to the action of lightning falling directly on the outside of the stone.

Although I made a very careful search, I could find no more than two tubes in all in which the circumference remained complete at any point, and these were in rock so solid that I could not detach them without destroying them. In both these cases the rock was pierced nearly at right angles to the cleavage.

I am not aware that these tubes have previously been observed on any of the peaks of the European Alpine system, and no record of such observation is to be found.

Isolated from other mountain groups, and towering far above any of the other peaks of the Cottian Alps, Monte Viso occupies a position exceptionally favourable to the display of electric energy, and the existence of the tubes may be due to this energy having been here on a greater scale than elsewhere in the Alps. But so far this supposition rests too much upon purely negative evidence, and before concluding that such tubes as have been found on Lesser Ararat and Monte Viso do not exist in the main chain or other groups of the Alps, a much more careful and systematic search than has hitherto been made is required. It is quite possible that similar phenomena, not at the time expected, or possibly even not looked for, may have escaped observation during a too hasty search, and that a good find of the bubble-like fulgurites may have drawn attention from the more interesting tubes. This may easily have happened on more than one occasion in my own experience.

I commend the search for evidences of lightning action to all fellow-climbers, and suggest the careful examination of the summits of all well-isolated rock-peaks, such as the Matterhorn, Dent Blanche, Finsteraarhorn, &c. The area of search is always circumscribed, and the fulgurites will not be found *in situ* more than a very few feet below the summit or the final ridge, but the *débris* accumulated at the bases of all pinnacles on the summit ridge should be carefully searched.

Sunburn.

By R. L. BOWLES, M.D.

In conversation with an Alpine friend it was suggested to me that some observations I had made during my many holidays among the Alps would be interesting to the readers of the 'Alpine Journal,' and he expressed a hope that I would string them together in the form of a paper.

These observations are more or less of a scientific character, but have no pretension to scientific accuracy. As my wanderings among the Alps have always (except on one occasion when I paid a visit to Davos in winter) taken place in June and July, I have been neces-