Art. VI.—On a Noteworthy Case of the Occurrence of Ice in the Form of Non-Crystalline Columns.

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On the morning after the first sharp frost of the present winter, the ground in front of the Dalhousie College Building, to the extent of about 60 square yards, was found to be covered with little columns of ice springing from apertures in the frozen earth. They were irregularly distributed, occurring in groups separated by interspaces which were in most cases narrow, and were either without columns altogether or had only a few isolated ones. The ice columns themselves varied in length from half an inch to two inches. They were for the most part roughly circular in section with diameters ranging from one-tenth to one-third of an inch in different columns, but practically uniform throughout the whole length of any one column. The section of any one column was in general the same at all points of its length, and they had thus the appearance of being striated longitudinally. Many of them carried little pebbles on their summits, and still more carried fragments of frozen earth. The ice of which they were composed was not transparent, but had a white appearance similar to that of compressed snow, or of ice traversed by innumerable tiny fissures. They sprang from the frozen earth at no uniform inclination to the vertical, but in the great majority of cases they curved upwards, so that their upper parts were less inclined to the vertical than their lower parts.

The occurrence of ice in this form after a sudden frost is familiar enough in our changeable climate, and must probably be common in other countries with similar climatic conditions. But so far as I can ascertain, this mode of ice formation does not seem to have been adequately described or its peculiarities to have

been explained. Attention was drawn to the occurrence of ice in crystalline columns rising from the soil and bearing pebbles and earth on their summits, by Sir David Brewster,* but the columns referred to above, were distinctly non-crystalline. In the earlier volumes of Nature (vols. XXI, XXII, XXV, &c.,) there is a long series of communications describing and discussing peculiar forms of ice, but for the most part they refer to the familiar occurrence of ice in the form of filaments springing from rotten wood or from a porous, clayey soil. The only description of the mode of ice formation referred to above, which I have been able to find is by J. D. Paul.† He describes ice as occurring in bundles of little rods rising from the frozen soil and carrying dirt and pebbles on their summits. He also mentions their being curved, but does not refer to any uniformity in the direction of their curvature. Nor does he give any explanation of the phenomena which he observed.

I have frequently observed this mode of ice formation in Nova Scotia, and in most respects the present case is similar to others which have come under my notice. But my attention was never before directed to the fact of the upward curvature of the little columns. And it is this observation, together with the simplicity of the conditions under which, in this case, the little columns were produced, which have led me to bring the matter before the Institute.

A short time before the date of the occurrence referred to, the ground in front of the College building, which had become quite hard through the trampling of many feet, was covered with a thin coating of loose pebbly soil for the purpose of making it more level. This layer of soil had not been rolled, and had been but slightly walked over, when several days of heavy rain ensued. As the hard soil underneath prevented the escape of the rain, the loose soil must thus have become quite saturated with water. Then came one of our sudden changes of temperature. The wind whirled round from the south to the north-west, and the temperature fell from many degrees above, to sev-

**Edinburgh Journal of Science*, N. IX., p. 122, and Poggendorff's Annalen, Bd. VII., p. 509.
† Nature, Vol. XXXI, p. 264.

eral below, the freezing point. I do not know what the exact variation of temperature was ; but the change was so great and so sudden, that while the layer of soil was still saturated with water, its surface must have begun to freeze. Owing to the expansion of the water on solidification, a continuation of the freezing would result in a slight elevation of the crust thus formed, until the thinner parts of the layer of loose earth had been frozen quite down to the hard ground underneath. This layer would thus become divided into little patches, with completely frozen interspaces, and its crust would be prevented from further elevation as a whole. A continuation of the surface radiation, resulting in the freezing of a portion of the water in any of the spaces in which it must now be enclosed, must, owing to the expansion of the freezing water and the rigidity of the enclosure, raise the pressure throughout this space and in the frozen crust. The rise of pressure would of course be accompanied by a lowering of the melting point, and at those parts of the crust at which the pressure was greatest the melting point might be reduced to the actual temperature of the crust. At any such part, therefore, the ice would partially melt and be driven outwards, carrying with it the earthy portion of the crust, and, through the aperture thus produced, the ice would continue to be protruded so long as freezing continued.

That a column of ice formed in this way would have, in general, a section of the same form throughout, is obvious. That the ice would likely be opaque, follows from the fact that the protrusion of a column of so brittle a substance must result in the formation of innumerable cracks and fissures, giving it the appearance of compressed snow. The presence of these cracks enables us also to explain the upward curvature of the columns. For at the base of any column which is in course of protrusion, melting is going on at various points. At no one point will there be much ice melted, for a slight melting will result in reduction of the pressure. But here and there throughout the base melting will occur. The water thus formed will flow downwards into the little fissures ready to receive it, and filling some of them will then freeze, expanding during solidification. If the axis of

such a column at its base be inclined to the vertical, more water will flow into the fissures of its lower side than into those of its upper side, if we assume the distribution of the maximum pressure and of the fissures to be practically the same throughout. The elongation of the lower side, which will be produced by the freezing of this water, will thus be greater than the elongation of the upper side; and the column will therefore curve upwards. Should the conditions be such that the pressure in the upper part of a column is greater than in the lower part, or should there be comparatively few fissures in the lower part, it may happen that the upper part of such column will receive more water than the lower part, and will undergo consequently a greater elongation, in which case the column will curve downwards; but columns formed under such conditions will be exceptional, and in general therefore it may be expected that their curvature will be upwards.