On hollow spiral prismatic crystals of ice on the surface of snow.

By L. Leigh Fermor, D.Sc., A.R.S.M., F.G.S.
Geological Survey of India.

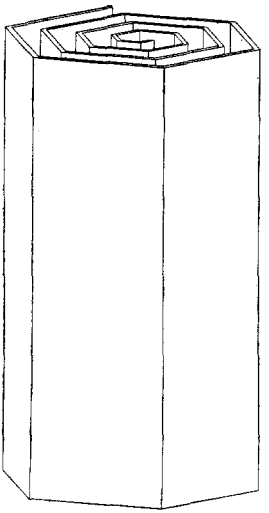
[Read June 16, 1914.]

LAST winter I enjoyed the good fortune of spending some three months at Zweisimmen in the Bernese Oberland of Switzerland, in order to participate in the winter sports. Happily it proved a fine, cold winter of hard frosts and moderately heavy total snowfall. During such a stay in the crisp, dry cold of a snow-mantled world, the manifold and beautiful forms assumed by snow and ice are set before one in a manner impossible in this relatively warm and moist isle with its fleeting glimpses of true wintry weather. According to their size, the streams become frozen up or roofed over with ice, and the waterfalls congealed into cascades of icicles or covered with an icy curtain, behind which a much-diminished volume of water continues to fall. The snow-fields do not remain as when freshly formed, but are subject to constant change. In the earlier hours of the morning, while the sun is still low, the snow surface is dry, crystalline, and but loosely coherent, and the advancing skis of the ski-runner push their way through a sand of brilliant, pure white snow crystals, sparkling like myriads of diamonds, but towards midday and in the afternoon, the intense heat of the sun's direct rays melts the surface of the snow, although the temperature itself remains below zero (Centigrade); and to the ski-runner the snow now feels sticky, often rendering his progress uncertain. As the sun declines and its rays leave the snow, the water wetting the snow crystals or granules begins to freeze again, and by the next morning the surface of the snow has become rejuvenated with a wondrous growth of ice crystals, most commonly with fern-like forms, built, of course, on a hexagonal plan, and analogous to the familiar frost-growths on window-panes, but very much more delicate and intricate, and developed in three dimensions instead of two.

The portions of snow-fields lying in shady situations do not, of course, suffer this diurnal surface melting, except when, during warmer weather,

the temperature of the air rises above zero. During a prolonged spell of fine cold weather, the surface crystals gradually increase in size until the 'fern-fronds' may be as much as one-half to one inch across. These additions to the crystals are derived, it must be supposed, from the moisture of the atmosphere, by direct condensation during the intense cold of night.[1]

But the crystals on the surface of the snow do not always adopt this fern-like habit. Another habit is that which forms the subject of this



Crystal of ice.

note, in which the entire surface of the snow in shady situations may consist of a *cheval de frise* of small hollow hexagonal prisms, composed each of a thin sheet of ice coiled round the vertical axis in a hexagonal spiral parallel to the faces of a hexagonal prism. This is the habit illustrated in the accompanying figure. These prisms range in size from perhaps $\frac{1}{4}$ to $\frac{3}{4}$ inch in length, with a maximum diameter of $\frac{1}{8}$ inch. This gives but a small thickness to the walls of a prism containing three or four coils, and it will easily be understood that an ordinary pocket-lens is not powerful enough to permit the determination with certainty

[1] Temperatures as low as $-12°$ to $-17°$ C. at 8 a.m. were common at Zweisimmen, which lies in a valley at only 945 metres, or roughly 3,000 feet, above sea-level. It may be presumed that still lower temperatures would be recorded on the surrounding mountains.

of the nature of the terminating faces. Consequently, although in the figure the prism is represented as terminated by the basal plane, I cannot assert the invariable absence of other faces. The ratio between length and breadth shown in the figure is, perhaps, an average one, but the prisms may be either more slender or more squat.

It is difficult to indicate any particular condition, either physical or meteorological, as determining the formation of these hollow prisms rather than the commoner fern-like growth, but it may be of interest to record the situation of the largest field of hollow prisms noticed.

On December 4, 1913, before the winter's snow and frost had finally established themselves, I walked to Lenk, some eight miles from Zweisimmen, and thence onwards towards the Simmen Fall at the head of the valley of the Simme. The portion of this valley between Lenk and the fall, a distance of about $2\frac{1}{2}$ miles, lies at about 1,100 metres above sea-level, is flat, and occupied by fields and the hamlet of Obeeried. The final mile or so of this portion of the valley lies in the shadow of the Wildstrübel mass, a section of the Oberland range rising to heights of over 3,000 metres; at 2 p.m. Oberried was in shade and, according to an inhabitant, does not see the sun for some three months in the winter. At the time of my visit the fields of Oberried were occupied by a continuous sheet of snow several inches thick, although at Lenk and Zweisimmen all the previously-fallen snow had been melted or evaporated away. I had been at Zweisimmen since the 21st of November, and there had been several falls of rain in the interval, with very little snow. But a fairly heavy fall of snow had taken place a few days before my arrival, and it is probable that the main mass of the Oberried snow dated from this early fall, and had been protected from melting by the Wildstrübel mass, which seemed to me not only to shade the snow from the direct rays of the sun, but also to ensure a lower air temperature than at Lenk only $1\frac{1}{2}$ miles away. This snow-field had, therefore, probably been in existence for some $2\frac{1}{2}$ to 3 weeks at the time of my visit, but had doubtless received small additions of snow corresponding to rainfall elsewhere. Wherever I examined this field it was covered with a bristling growth of the hollow hexagonal prisms noticed above. On continuing my walk past the Simmen Fall, and rising over 1,000 feet up the Ammerten Pass, through ever-deepening snow, I found the snow universally surfaced with the prismatic growth, and everywhere in shade. The prismatic growth must have been formed since the last fall of snow, which probably took place only a few days before my visit, and, in the absence of diurnal melting, the water required must have been drawn from the atmosphere.

Later in the season I often noticed limited areas of this prismatic growth, usually in the shade of trees, but was not able to assign a reason for its formation, instead of the commoner fern-like growth, which is found both in the shade and in the sun.

The probability that both prismatic and fern-like growths are largely due to abstraction of moisture from the atmosphere seems to be indicated by the fact that they both form as hoar-frost on twigs and branches bared of snow by a previous thaw ; these, if situated in the shade, escape a diurnal melting, and continue to grow day by day, so that in two or three days twigs become coated with a bristling array of hollow prisms or a feathery growth of 'fern-fronds'.

The manner in which the surface of a snow-field may grow during a snow-drought was well shown in a field at Zweisimmen, where people had written their names in the snow with a walking-stick by the side of a path leading to the skating-rink. The act of writing had ridged up the displaced snow along the edge of the letters nearer the path, and during a prolonged spell of fine weather the ridged-up portions increased gradually in height, so that writing originally about an inch deep became bordered by a raised ridge of about the same height, which doubly emphasized the writing. This field was in the sun, but the weather being very cold the amount of snow melted in the day was small, and probably balanced by the growth at night. The water doubtless tends to sink into the snow during the day, but, later, any still liquid water must be sucked up by capillarity to the growing ridges, to be accentuated still further by moisture condensed from the atmosphere in greater abundance on the projecting ridges than on the flat surface of the surrounding snow.

There is a considerable volume of knowledge concerning the forms of newly-fallen snow crystals, of which many hundreds of varieties have been figured by various authors, as for example by William Scoresby,[1] by G. Nordenskiöld,[2] and by W. A. Bentley.[3] None of these resemble at all closely the crystals referred to in this note, which is not surprising, when it is realized that the hollow prisms are related in mode of formation to hoar-frost rather than to crystals of newly-fallen snow. Indeed the forms of hoar-frost seem to have been much less studied than snow crystals. However, I have succeeded in finding one comparable case. Dr. Karl

[1] W. Scoresby, 'An Account of the Arctic Regions,' 1820.

[2] G. Nordenskiöld, 'Communication préliminaire sur une étude des cristaux de neige.' Bull. Soc. franç. Min., 1893, vol. xvi, pp. 59–74.

[3] W. A. Bentley, Nature, 1902, vol. lxv, p. 234.

Grossmann and the late Mr. J. Lomas[1] have given an account of varieties of hollow pyramidal ice crystals formed as hoar-frost—i.e. by condensation direct from the atmosphere—in (1) the lava cavern of Surtshellir in Iceland; (2) as ordinary hoar-frost in the north of England; (3) on the under surfaces of ice crusts on ruts and ponds; and (4) in refrigerators. These crystals are commonly hollow hexagonal pyramidal hoppers attached by their points, with the open ends pointing into the enclosed air space or to the open sky, according to circumstances. Writing of the hoar-frost noticed in various parts of Yorkshire, Lancashire, and Cheshire, in Christmas week 1892, the authors say: 'A spiral arrangement was noticed in some cases, and occasionally a double spiral resembling the helix of an Ionic capital.' This latter variety is figured, and it is seen that the spirals are pyramidal and not prismatic. On examination the authors found that these various types of hopper-shaped crystals were not really hexagonal pyramids, but that each triangular face was built up of a stepped alternation of faces of the hexagonal prism with the basal pinacoid, the very forms recognized in the spiral prisms of Switzerland here described. These authors regard the hopper-shaped crystals as starvation crystals, the pyramidal expansion of the hoppers being due to the fact that the interiors of the hoppers attempt to draw their moisture from only a limited volume of air compared with that adjoining the exterior of the crystals. Our Swiss hexagonal prisms must be regarded as another form of starvation crystal.

In the present paper only two general forms of snow growths have been referred to, but others exist, and it would probably be well worth the while of a mineralogist visiting Switzerland or Scandinavia during the winter to take with him a microscope for crystallographic study.

[1] K. Grossmann and J. Lomas, 'On hollow pyramidal ice crystals.' Nature, 1894, vol. l, pp. 600-602.