SNOW CRYSTALS OBSERVED AT MAUNA LOA*

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ABSTRACT. The expedition to Mauna Loa in Hawaii was undertaken in the winter of 1956-57 in order to study the nature of snow crystals in the district where the fewest aerosol particles are present. 170 photomicrographs of snow crystals were taken at the summit—13,450 ft. (4000 m.). The varieties of snow crystals were abundant and almost all types hitherto known were observed. The characteristic of the snowfall was the abrupt transition of one type to the other. Many single needles were observed, which were very rare in Hokkaido. Two new types were found; one was a needle composed of many hexagonal columns, and the other an elongated column which is the intermediate state of needle and column. Several photographs were obtained which show the mechanism of formation of ice pellets.

ZUSAMMENFASSUNG. Die Expedition auf den Mauna Loa in den Hawaii Inseln wurde im Winter 1956-57 unternommen, um die Beschaffenheit von Schneekristallen in dem Distrikt zu studieren, in dem sich am wenigsten Aerosol-Teilchen befinden. Es wurden auf dem Gipfel, 4000 m hoch, 170 Schliffbilder von Schneekristallen gemacht. Es gab eine übergrosse Menge von Schneekristallen, und fast alle soweit bekannten Arten wurden gefunden. Das Kennzeichnende des Schneefalles war der plötzliche Übergang von einer Art in die andere. Viele einzelne Nadeln wurden beobachtet, die in Hokkaido sehr rar waren. Zwei neue Arten wurden gefunden; die eine ist eine Nadel, die aus vielen hexagonalen Säulen besteht, und die andere ist eine gedehnte Säule und stellt die Zwischenform zwischen Nadel und Säule dar. Es wurden verschiedene Photographien gemacht, die den Entstehungsvorgang von Graupeln wiedergeben.

THE expedition to Mauna Loa in Hawaii was carried out in the winter of 1956-57. The Slope Observatory there, at 11,130 ft. (3392 m.), belongs to the U.S. Weather Bureau. This observatory is well equipped so that several people can stay there comfortably for a long time. There is another hut near the summit of the Mauna Loa at the level of 13,450 ft., which is called the Summit Unit. This Summit Unit also belongs to the U.S. Weather Bureau. This is a small hut, 8 ft. × 10 ft. (2·6 × 3·2 m.) in size, and has no living facilities, there being neither heating nor power. We therefore stayed at the Slope Observatory and went up to the Summit Unit for the photomicrography of snow crystals depending on the forecasts of snowfall. The forecasts were very good, and we did not miss any falls of snow.

The expedition was undertaken in order to study the nature of snow crystals in the place where the fewest aerosol particles occur. It was supposed that the shape of snow crystals observable in this "aerosol-free" district might be different from that observed in ordinary places. This expectation, however, was not correct, and almost all types of snow crystals were observed.

The number of condensation nuclei was measured by using the General Electric condensation nuclei meter at various altitudes as well as at 13,450 ft., and it was found that the number of nuclei was very small in this district. The number above about 6000 ft. (1828 m.) was very small on fine days, being 100-200 per cm.^{3}.[1] Seven profiles of the nuclei numbers were made and it was found that the number was fairly large in cloud or fog, and very small in rain or snowfall. The height of the maximum number coincided with the boundary of air masses in the time cross-section made from radiosonde data at Hilo.

Five snowfalls were observed on the summit of Mauna Loa during our stay from 7 December 1956 until 22 January 1957. The two snowfalls of 15 December and 6 January were slight and only a few photographs were taken. The temperature was near 0° C. or a little higher, and it was very difficult to take photographs. Three other snowfalls were observed as a sequence, starting from the evening of 14 January. These three snowfalls I, II and III were caused by one storm, but their nature was different from that in Hokkaido

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with regard to the crystal types. They were fairly heavy snowfalls, and about 170 photomicrographs of snow crystals were taken.

It was found that the varieties of snow crystals were very abundant and almost all types hitherto known were observed at the summit of Mauna Loa. Compared with the data obtained in Hokkaido, the difference lay in the frequency of each type of crystal and the mode of transition from one type to the other.

In order to show the mode of transition of the crystal types during one snowfall, the crystals were classified into 6 kinds; dendritic, rimed dendritic, needles, rimed needles, columnar and irregular crystals. Columns and irregular crystals mostly belong to the initial stage of snow formation. The bullet, the side-plane type and the capped column were included in the group of columns. The elongated columns were temporarily included in the needle type. The frequency of occurrence of each type of crystals is shown in Fig. 1. Fig. 1 (*a*)

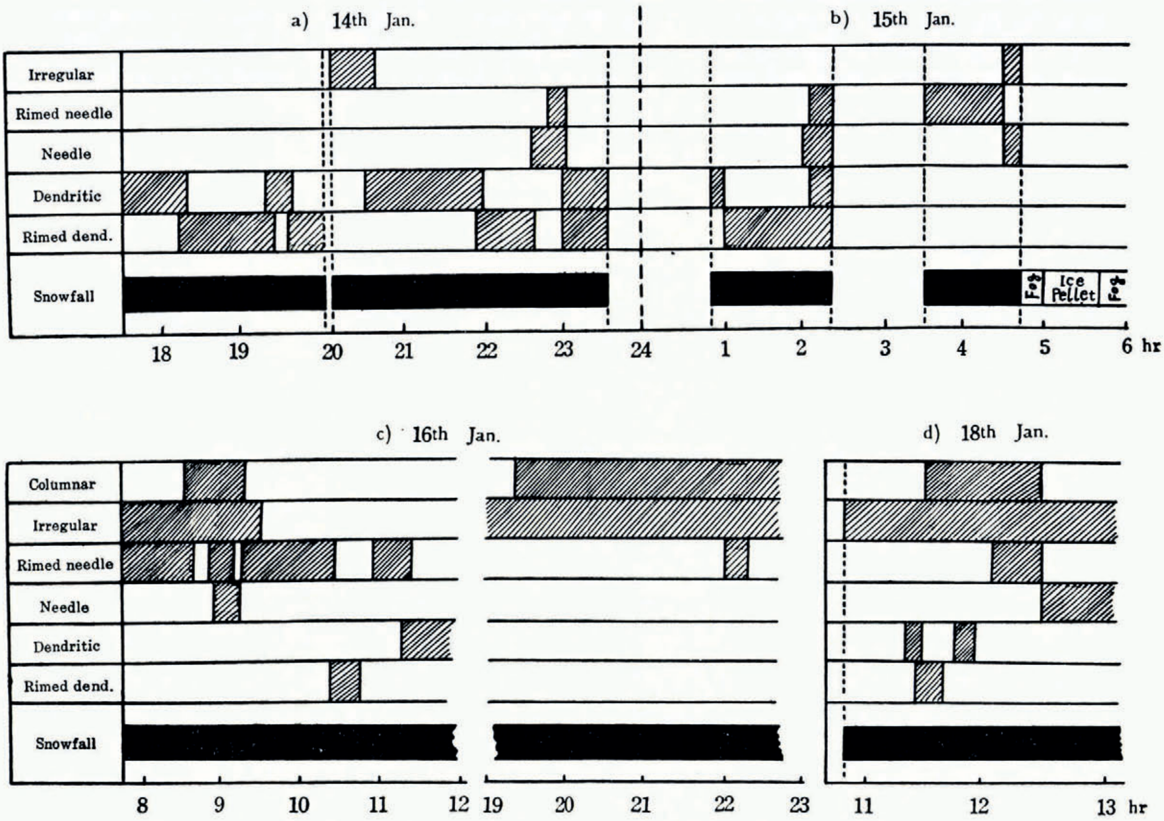

Fig. 1. Type of snow crystal versus time of fall
(a), (b) Snowfall I; 14 January, 17.05 hr., 15th, 04.45 hr.
(c) Snowfall II; 16 January, early morning to midnight
(d) Snowfall III; 18 January, 10.45 hr.

and (*b*) show the mode of change in crystal shape in snowfall I. The mode of transition from the rimed dendrite to the needle and then to the dendrite again, is clearly seen at about 23.00 hr. in Fig. 1(*a*). In Fig. 1(*b*), needles start to be mixed with the dendritic type at about 02.00 hr. and the snowfall ends at 02.20 hr. When the snowfall started again at 03.30 hr., all crystals were rimed needles and they suddenly changed into unrimed needles at 04.45 hr.

In the case of the snowfall III, Fig. 1 (*d*), most of the crystals were columns or irregular crystals, and the dendritic or rimed dendritic crystals were added to this "background" for a short time. The transition from the rimed to the unrimed needle of elongated column type occurred rather suddenly at 12.30 hr. These phenomena suggest that the shape of a snow crystal is dependent upon the nature of the air mass.

Ice pellets or frozen rain drops are fairly common in cold climates all over the world. The mechanism of the formation of ice pellets, however, does not as yet seem to have been determined. The supercooled water drop will not freeze until it is cooled below −40° C., and such supercooling is unlikely. Some kind of seeding must therefore have taken place for the formation of ice pellets. In nature the most probable and active seeding material is ice, and it is supposed that the ice pellet is formed by the attachment of a minute ice crystal to a supercooled rain drop, as shown in Fig. 2 (*a*) and (*b*) (p. 367). In the condition shown in the photograph, ice coexists with water and the whole mass must be at 0° C. Let the mass of the drop be M, and that of crystal m, and the temperature $-T°$ C. At the moment of seeding, x gm. of the drop freezes and gives rise to the liberation of latent heat $80x$ calories. This heat will warm the drop and the crystal to 0° C. Taking the specific heat of ice as unity,

$$80x = T(M+m).$$

$$\frac{x}{M} = \frac{T}{80}\left(1+\frac{m}{M}\right).$$

If the temperature is −10° C. and $m/M = 0{\cdot}2$, $x/M = 0{\cdot}15$. In this case, therefore, 15 per cent. of the volume of the rain drop will freeze at the moment of seeding and the temperature of the system will become 0° C. This system will lose heat by evaporation and convection and become an ice pellet. It might be suspected that this photograph shows the state of melting of an ice crystal, but the photograph showing the attachment of a needle crystal to a rain drop, Fig. 3, will remove doubt on this point.

Fig. 3 is an interesting photograph which shows the mechanism of formation of ice pellets or frozen raindrops, and two photographs showing this mechanism were obtained. Several interesting photographs of needle type crystals were also obtained. Usually the needle crystal has a structure like a bundle of needles, and the single needle is not often observed; among our collection of 3000 photomicrographs of snow crystals obtained in Hokkaido, only three are found. This single needle, however, is frequently observed on Mauna Loa, and there are 14 pictures of them among the 170 photographs obtained. At the summit of Mauna Loa, the ordinary needle crystal with the structure of a bundle of single needles was much less frequently observed than the single needle.

Two pictures of needle crystals showing a strange structure were obtained. One example is reproduced in Fig. 4. Here many small hexagonal columns are attached side by side to a needle crystal. This type is different from the rimed needle and had not been observed previously among natural snow crystals, but a similar structure is found in the artificial snow crystals made in a diffusion cloud chamber.

In former investigations the difference between the needle and the columnar crystal had not yet been determined. Both of them are developed in the direction of the principal axis and have a hole at each end. Some people distinguished the needle from the column by the ratio of the length to the thickness. For example, elongated columns are grouped as needles when the ratio exceeds five. From the results of our artificial snow experiments, this view is not considered to be adequate, because the conditions of formation are quite different for the needle and the column.[2] In the course of the observations at Mauna Loa, a new type of crystal was found, which is an intermediate state of the column and the needle. One example is shown in Fig. 5. From the shape of the crystal it is difficult to distinguish the elongated column from the needle. The crystal of the type shown in Fig. 5 is obtained with artificial snow crystals which are made in the atmosphere with a trace of vapours of strong polarity.[3]

With respect to the other types of crystals: the dendritic, broad branch type, column, side planes, spatial assemblage of plates, etc., no essential difference is observed from those observed in Hokkaido.

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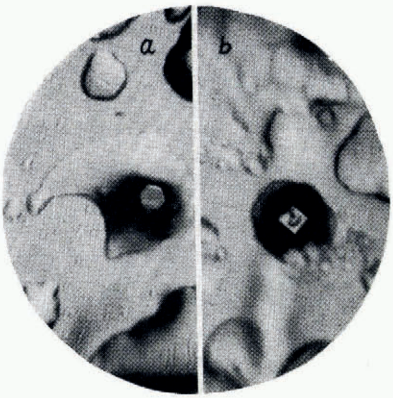

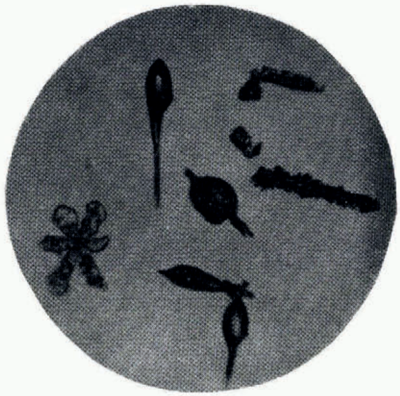

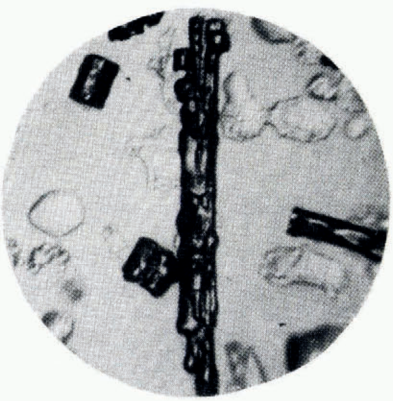

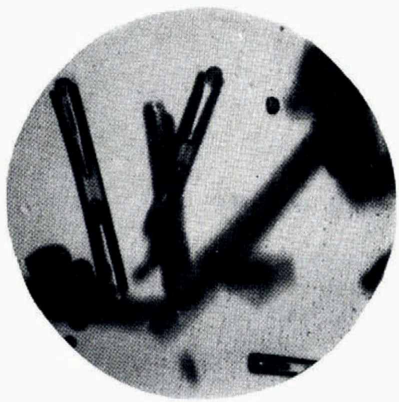

Fig. 2 (a). (b) (top left). Ice crystal captured in a rain drop (×c. 42)
Fig. 3 (top right). Needle crystal captured in a rain drop (×40)
Fig. 4 (bottom left). Needle crystal composed of hexagonal columns (×85)
Fig. 5 (bottom right). Elongated column (×80)