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On the Correspondence of Snow and Rime Crystals.*

By

Ukitirô NAKAYA

(Plates I–III)

I. Introduction

Since several years ago the author has engaged in the physical investigations of snow crystals, and for that purpose expeditions to Mt. Tokati were made several times during the winters of 1933–34 and 1934–35. The first report has already been published in this Journal.[1] Half way up the mountain there is a cottage called Hakuginsô and the observations were chiefly made in the neighbourhood of the cottage whose altitude is 1030 metres above sea level. In its vicinity the temperature is normally between $-5°$ and $-10°$C at the beginning of the winter and $-10°$ and $-15°$C in mid-winter, never rising above 0°C, except upon very few occasions, during the four months of the winter. Accordingly rime crystals develop in a beautiful manner on the various exposed objects surrounding the cottage. While observing them by the naked eye and by microscope the author noticed a remarkable correspondence of these crystals to those of snow, which will be described in the following.

II. Correspondence of the Crystal Habits

It is well known that there are two distinct kinds of structure of rime or frost, that is amorphous and crystalline. As for the frost, the amorphous one is produced when the temperature is below but nearly at 0°C, while the crystalline is made at lower temperatures. In case of the rime, the amorphous sort is produced when supercooled watre droplets are frozen fast to some exposed objects, and the crystalline form is obtained when water vapour is condensed by sublimation.[2] The difference can be seen clearly by simple eye observation, as noticed by TSUIJI[3] and by many European meteorologists. In the discussion of the crystal habits, there is

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* Investigations on Snow, No. 5.

1) U. NAKAYA and K. HASIKURA, This Journal, Series II, Vol. 1 (1934) 163.

2) The German terms are sometimes used for the classification of them; that is, "Rauhreif" for the crystalline rime and "Rauhfrost" for the amorphous one.

3) TSUIJI, Journal Met. Soc. Japan, II, Vol. 1 (1933) 109. (In Japanese).

no essential difference between the crystals of frost and rime. In this paper, therefore, the author includes the frost crystal too under the term rime. In any case they are solidified in an amorphous form when they pass through a liquid phase while solidifying, and become crystalline when condensed by direct sublimation.

One example of a microphotograph of amorphous rime is shown in Photo. 6, Plate III, in which one may see clearly that it is made of numerous frozen droplets. For the present this type of rime is disregarded, and in the following only the crystalline rime is dealt with.

Among the rime crystals observed at Mt. Tokati, the most beautiful are those developed on the walls of snow caverns, which are made in natural course under the stumps of trees or in such places. The caverns are of various forms and are of considerable volume, say two or three metres in dimension. Rime crystals grow on the snow walls in various forms, and especially those hung down from the snow ceiling of the cavern show the most beautiful sight. The form of these rime crystals can be classified into four; 1) needle form, 2) feather form, 3) plate and 4) dendritic crystals.

From the crystallographical point of view, each of these rime crystals looks to have its correspondence in the crystals of snow.

1) Needle crystals. The general view of this type of rime crystal is shown in Photo. 1 *a* in natural size. Some of the needles were detached from the wall of the cavern and a microphotograph of them was taken by transmitted light, which is shown in Photo. 1 *b*. It is clearly seen that they are composed of an assemblage of hexagonal columns grown in parallel with each other. The correspondence of this type of rime crystal to the columnar crystal of snow, as shown in Photo. 1 *c*, has already been pointed out by STÜVE,[4] and it seems that there is no doubt as to this correspondence.

2) Feather-like crystals. This type of rime crystal is most often observed at Mt. Tokati. Sometimes it develops to 5 or 7 cm. in length. The general view is represented in Photo. 2 *a*, which shows the plume-like appearance of the crystal very nicely. A microphotograph of a part of this rime is shown in Photo. 2 *b*. As seen in the photograph it is composed of an assemblage of small hexagonal columns as in the case of the needle crystals. These columns are not ararnged in parallel with each other as in the former case, but some columns are attached head-on to the side of the other columns, giving a branched appearance as a whole. The combi-

1) G. STÜVE, Gerland Beiträge zur Geophysik, **32** (1931) 326.

nation of the hexagonal columns in this manner is not rarely observed in case of snow crystals. Two examples are shown in Photo. 2 *c*, which may be considered as corresponding to a unit of combination observed in the case of Photo. 2 *b*.

3) Plate crystals. This type of crystal is usually observed hanging down from the snow ceiling of the cavern as described above. The general view is shown in Photo. 3 *a* in its natural state. The plate is detached from the crystal and examined under microscope, the microphotograph of which is represented in Photo. 3 *b*. Comparing this plate crystal and that of snow as shown in Photo. 3 *c*, it is clearly seen that they are quite similar to each other in their crystal habits.

4) Dendritic crystals. Dendritic crystals are often observed among the crystalline rimes developed on the branches of standing timber when the weather is calm. The general view is given in Photo. 4 *a*. A part of a withered bough is seen in the lower part of the picture, and much dendritic rime develops upwards from that bough. A microphotograph of one of these crystals is shown in Photo. 4 *b*. The correspondence of this type of rime to the ordinary dendritic crystal of snow as shown in Photo. 4 *c* needs no further explanation. The only difference is the lack of minute structure or design in case of the rime crystal. This structure seen in the crystal of snow is caused by the ruggedness of the surface or very narrow canals engraved on the surface of the crystal. When a snow crystal is left in atmosphere saturated with water vapour, being kept far below 0°C throughout, it undergoes a transformation by sublimation, although it does not change its form by melting. The surface energy of the crystal acts to evaporate the molecules from pointed parts or sharp ridges and condense them onto the dented parts. As the result the ruggedness of the surface is flattened, leading to the disappearance of the design on the crystal surface. A good example is obtained in a special kind of snow; sometimes one observes a very soft snow hanging down from the snow ceiling of the entrance of the cavern, which gives an appearance like fragments of picked cotton. The general view is shown in Photo. 7*a* in its natural state. This is not a sort of rime but is an assemblage of snow crystals tangled with each other. The microphotograph is reproduced in Photo. 7*b*, in which one sees clearly the remains of the snow crystal. The form of the crystal is nicely preserved but the structure or design has utterly disappeared. It is without doubt due to the action of sublimation while the crystal is left in the atmosphere for a considerable time. The lack of design in case of the dendritic rime crystal may be explained in the same manner.

5) Another snow-like frost. A remarkable photograph of a frost crystal which is very similar to snow both in its form and structure, was taken by Mr. HATAKEYAMA, the Director of the Magnetic Observatory at Toyohara, south Saghalien. The author is much indebted to him for his kindness in sending the picture with permission for publication. The photograph is represented in Photo. 5 *a*. This frost crystal was found on the wall of a building, standing almost perpendicularly to the wall. A snow crystal similar to this frost is shown in Photo. 5 *b* for comparison. These two pictures will show clearly that the difference between snow and frost crystals exists only in the question of the nuclei.

III. Concluding Remarks

Since the application of the microphotographical method was extended to the study of snow crystals, the copious variety of crystal habits has attracted the attention of many physicists and meteorologists, but the conditions governing the formation of various forms of crystals are not yet clarified. SHEDD,[5] WEGENER,[6] BENTLEY and HUMPHREYS[7] and others agree that dendritic crystals are formed in an amply supersaturated atmosphere and simpler forms are obtained under a less supersaturated condition, but no further conclusion is deduced. The best way for attacking this problem is the artificial production of the snow crystal in laboratory, but at present there is little hope of its success. The correspondence, however, of the habits of snow and rime crystals above described, suggests that the conditions for the formation of a type of snow crystal may be inferred from those for the corresponding rime crystal. The artificial preparation of rime is not difficult and the preliminary experiments have already been performed. The result will be published in the succeeding paper in this journal.

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5) SHEDD, Month. Weather Rev., **47** (1919) 691.

7) WEGENER, Thermodynamik der Atmosphäre, dritte Auflage, Leipzig, 1928, p. 285.

8) BENTLEY and HUMPHREYS, Snow Crystals, New York, 1931, p. 7.

Explanation of Photographs

Pl. I.

1 a. General view of needle rime, Tokati, 1933 XII 27, ×1.
b. Microphoto. „ „ „ „ „ „ „ „ „ „ ×18.6.
c. Corresponding snow crystals, Sapporo 1933, II 24, ×55.
2 a. General view of feather-like rime, Tokati, 1933, XII 27, ×1.
b. Microphoto. „ „ „ „ „ „ „ „ „ „ ×8.7.
c. Corresponding snow crystals, upper—Tokati, 1934, II 10, ×58.8.
lower—Sapporo, 1934, III 9, ×27.1.

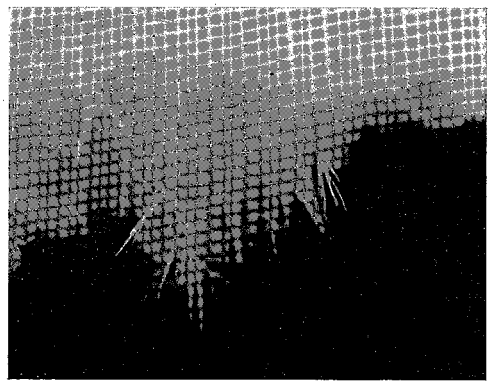
Pl. II.

3 a. General view of plate rime, Tokati, 1933, XII 26, ×1.
b. Microphoto. „ „ „ „ „ „ „ „ „ „ ×6.7.
c. Corresponding snow crystal, Tokati, 1934, II 10, ×36.6.
4 a. General view of dendritic rime, Tokati, 1934, II 9, ×1.
b. Microphoto. „ „ „ „ „ „ „ „ „ „ ×6.2
c. Corresponding snow crystal, Tokati, 1934, II 8, ×14.6.

Pl. III.

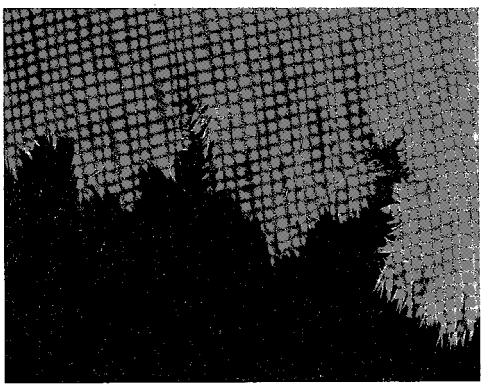
5 a. Snow-like frost, Toyohara, 1935, taken by Mr. Hatakeyama.
b. Corresponding snow crystal, Tokati, 1934, XII 25, ×21.0.
6. Microphoto. of an amorphous rime, Tokati, 1933, XII 27, ×35.9.
7 a. General view of a special kind of snow drift, Tokati, 1933, XII 27, ×1.
b. Microphoto. of the same, ×7.0.

1a



×1

2a



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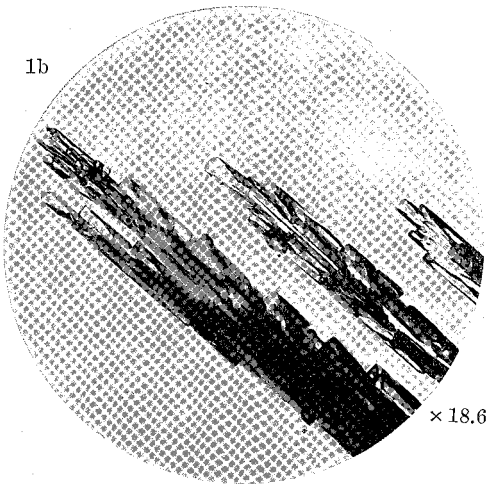
1b



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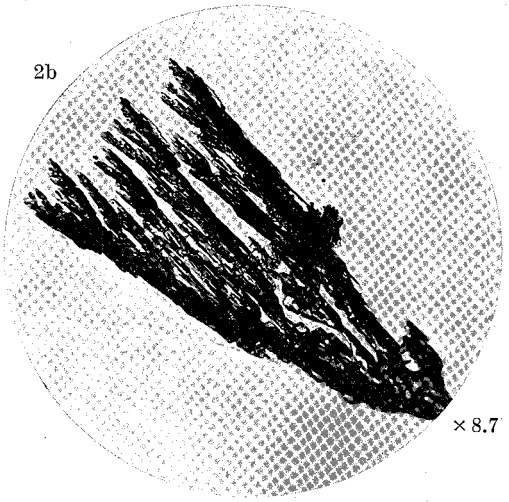
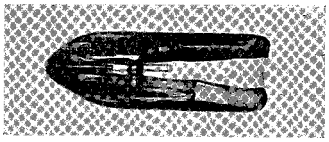
2b

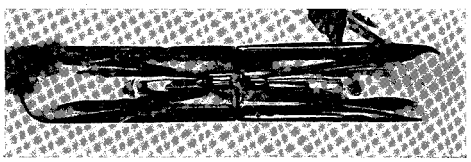


×8.7

1c



×55



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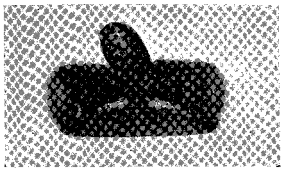

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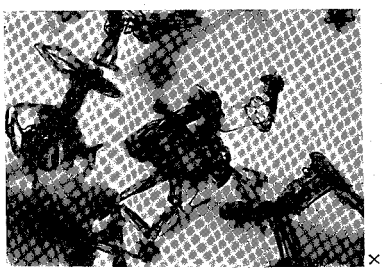

×27.1

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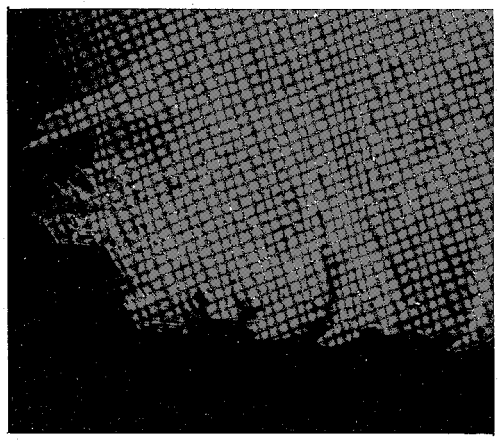
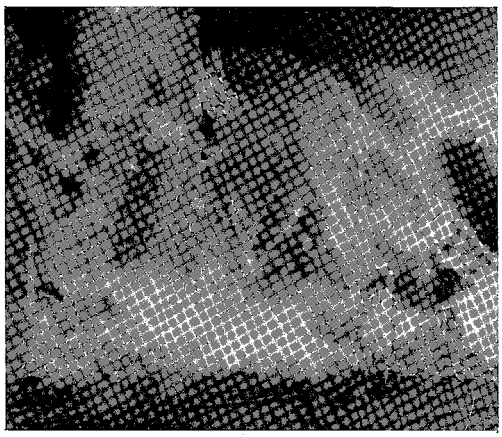
3a



×1

4a



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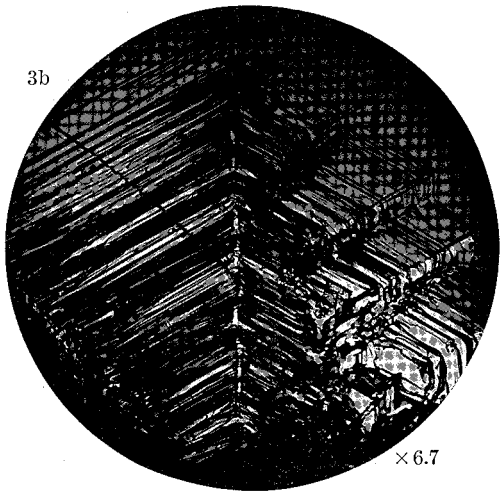
3b



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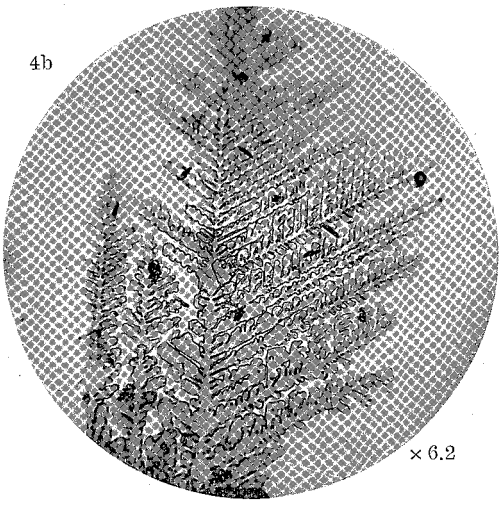
4b



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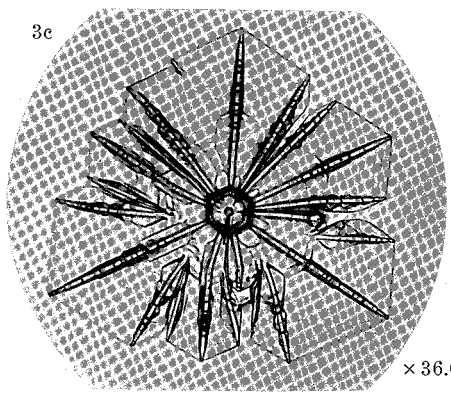
3c



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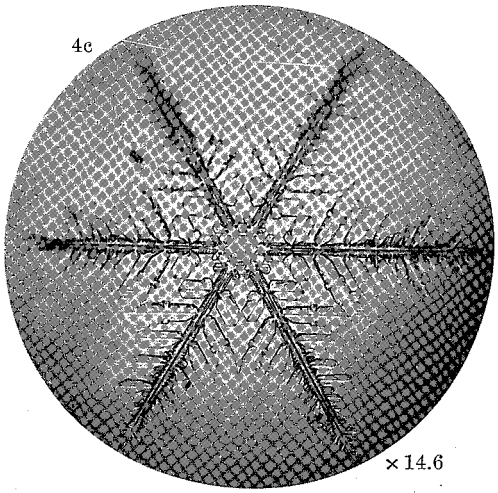

×14.6

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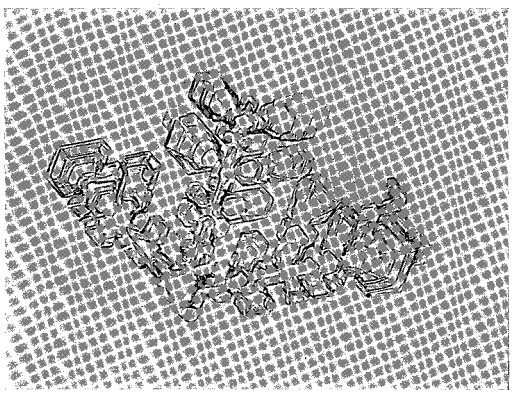
5a



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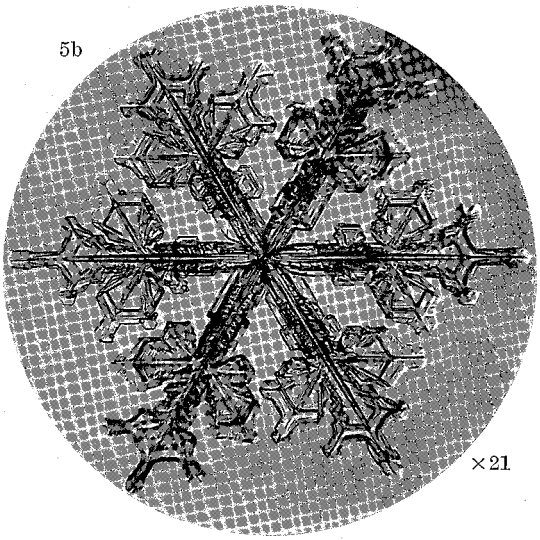
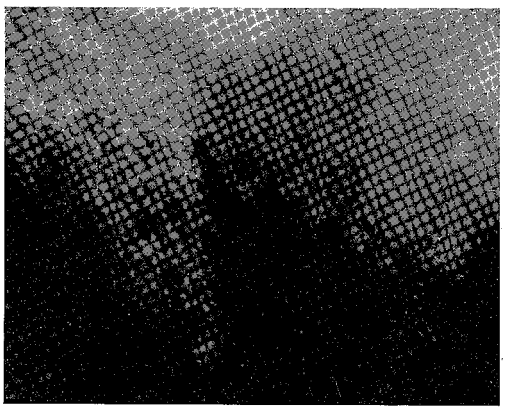


×21

6

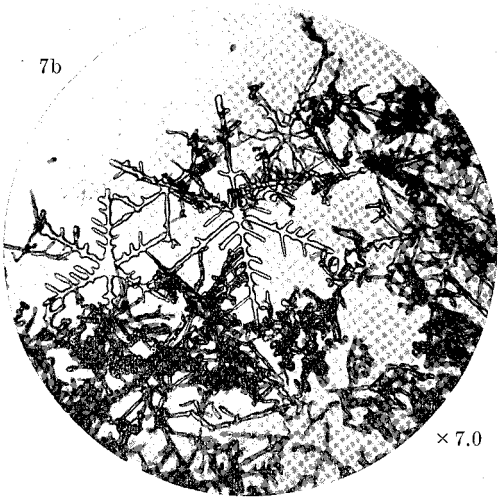
×35.9

7a



×1

7b



×7.0

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