Observation on the Shapes of Snow Crystals in the South Pole Region in the Summer

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夏季の南極点付近における雪結晶の観測

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要旨：1968年9月から1969年2月にわたって行なわれた，昭和基地-南極点往復調査旅行の際，6地点でレプリカ法による雪結晶の観測が行なわれ，その内観測地点903 (87°20′S, 39°52′E), Pole, 771(82°48′S, 40°32′E) の3地点できれいなデーターがとれたので解析を行なった．その結果，すべての地点で観測時の気温(−26°～−30°C) から推定されるように，結晶形は単砲弾，砲弾集合，角柱，側面結晶が多かった．しかし，同じ地点でも観測時間の相違によって，砲弾結晶と角柱結晶のみの場合と，側面結晶のみの場合があり，これは両者の過飽和度の差によるものと考えられた．単砲弾の c-軸の長さは同じ南極での Gow(1965) の観測よりかなり長く，菊地 (1968) の北海道の値とほぼ同じであったが，軸比 (c/a) はかなり大きな値を示した．

また昭和基地で菊地 (1969, 1970) によって発見されたと同じような図6に示す畸形雪結晶がいくつか発見された．

1. Introduction

Concerning the shapes of snow crystals, it is recorded that interesting changes in snow crystal habit occur at about −40°C or lower in air temperature (WEICKMANN, 1948; KLINOV, 1960; SHIMIZU, 1963; HIGUCHI, 1968). For instance, SHIMIZU reported that a "Long Prism" snow crystal was discovered within the temperature range from −30°C to −45°C at Byrd Station (80°00′S, 120°00′W), Antarctica. And, the snow crystal was artificially reproduced by KOBAYASHI(1965) in his small diffusion cold box using thermoelectric cooling panels.

Recently, one of the authors discovered ten or more kinds of hitherto unknown and peculiar shapes of snow crystals during the wintering at Syowa Station (69°00′S, 39°35′E), from the beginning of February, 1968 to the end of January, 1969, especially till September 1968 (KIKUCHI, 1969; 1970). Moreover, it was worthy

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of note that the minimum temperatures of growth of peculiar shapes of the crystals in the clouds, estimated from radiosonde records, were higher than $-35°C$ in almost all the crystals. This paper describes the shapes of snow crystals observed during the traverse from Syowa Station to the South Pole and during return trip, covering a period from September 1968 to February 1969, especially in the South Pole region.

2. Method of Observation and Analysis

The specimens of the snow crystals were collected on glass slides (6 cm × 9 cm) coated with replica solution (1.5 %) at arbitrary time during the traverse. The images of the replicated snow crystals of each glass slide were enlarged five times on photographic papers. The lengths of a-and c-axes of each crystal were measured. Peculiar shapes of the crystals on glass slides were examined by means of photomicrographs.

An example of the snow crystals collected and replicated on a glass slide is shown in Fig. 1.

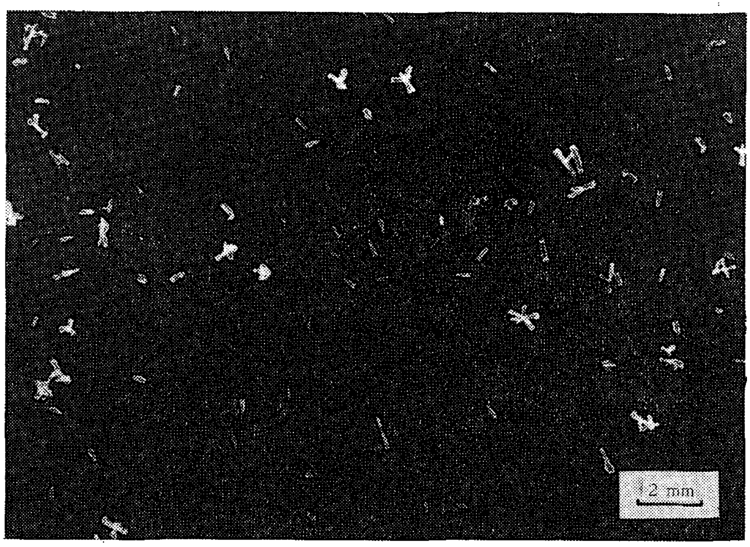

Fig. 1. A typical example of a replica of the snow crystals observed at the South Pole, 0315 LMT, 23 December 1968.

3. Results

Replication of the shapes of snow and ice crystals was carried out at six stations, namely, four on the way to the South Pole, Sts. 885 (86°43′S, 39°46′E, 3030 m in height), 903 (87°20′S, 39°52′E, 2933 m), 927 (88°08′S, 40°53′E, 2859 m) and 938 (88°31′S, 40°58′E, 2819 m), at the South Pole, and at St. 771 (82°48′S, 40°32′E, 3370 m) on the return trip. The snow crystals at St. 903, South Pole and St. 771 were replicated very well and the analyses were done at these stations. The air temperature at the time of the observation was −27°, −30° and −26°C at these stations. The main shapes of snow crystals at the stations were bullet, combination of bullets, column and side planes which were expected from the crystal shapes and its growth temperature (MAGONO, KIKUCHI and YAMAMI, 1971).

3.1. Occurrence of four different shapes of snow crystals

As described above, the main shapes of snow crystals were bullet, combination of bullets, column and side planes. Although it was assumed that single bullets are a result of disintegration of the combination of bullets during their descent (KIKUCHI, 1968), a single bullet was treated as one crystal in counting the numbers of different shapes of snow crystals. The result at each station is shown in Fig. 2. Two observations, early in the morning and afternoon, were made on 23 December 1968 at the South Pole and at about 0800 and 1100 LMT at St. 771. These results are also shown in Fig. 2. The N in the right hand column in the figure means the sampled population in each group. As obvious in the figure, there are two distinct cases, one is that the greater part of the crystals consists of bullets and columns, while the other comprises only side planes. This tendency was seen at both stations, the South Pole and St. 771. At the South Pole, only 5% side planes were observed in the early morning, but in the afternoon the ratio increased to 90%. At St. 771, on the other hand, 80% side planes were recognized in the morning observation and none in the afternoon. The discrepancy of the ratio will be explained by the difference in the supersaturation with respect to ice surface between the crystals of bullet and columnar types and those of side planes type (MAGONO, KIKUCHI and YAMAMI, 1971), that is, the grade of the supersaturation of the crystal of side planes is higher than other two types of crystals

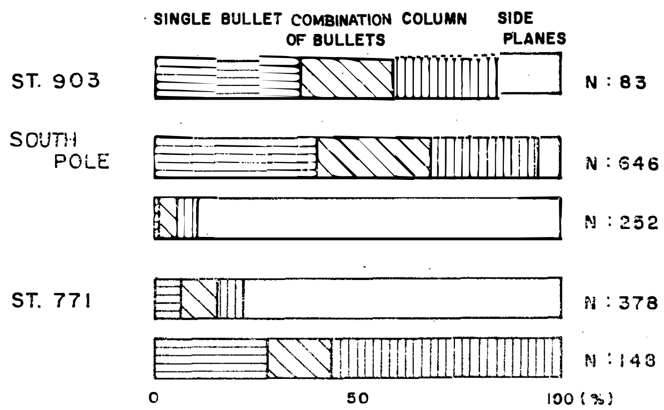

Fig. 2. Percentage of the four different shapes of snow crystals.

in the nearly same range of temperature.

3.2. Length of c-axis of single bullet and column

The length of c-axis was measured to compare with the results of the obser-

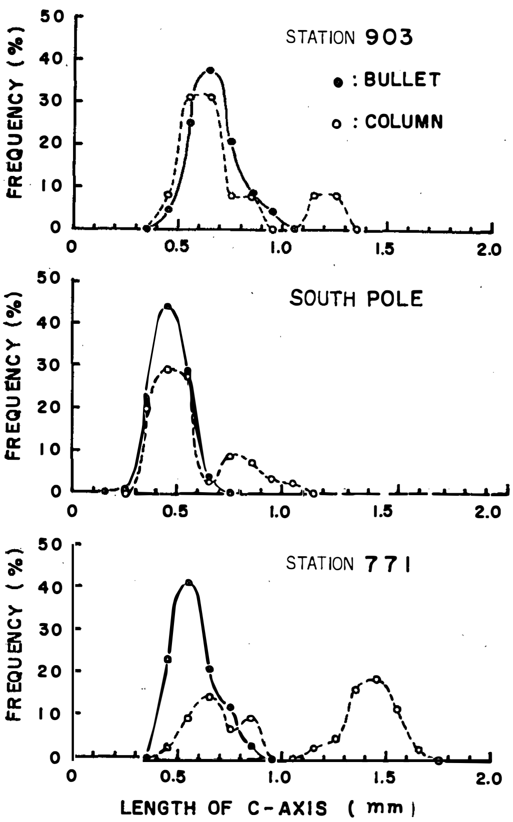

Fig. 3. Frequency distributions of the lengths of c-axes of the snow crystals of bullet (●) and columnar (○) shapes at three observation stations (St. 903, South Pole and St. 771).

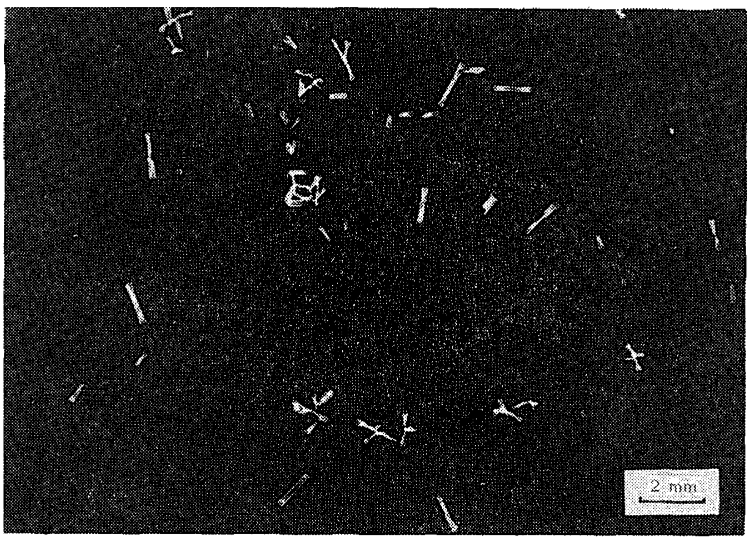

Fig. 4. A typical example of a replica of the snow crystals observed at St. 771, 0745 LMT, 8 January 1969.

vations in Antarctica (Gow, 1965) and in Hokkaido (KIKUCHI, 1968). Only single bullets were used in this measurement, excluding combination of bullets (two or more combined bullets). The results at three stations, St. 903, South Pole, and St. 771, are shown in Fig. 3 in the form of frequency distribution with respect to the length at an interval of 0.1 mm. In Fig. 3, the black dots connected with solid lines are the bullets and the circles connected with dashed lines are the columnar crystals. It is clear in the figure that the bullets at all stations show a nearly normal distribution. On the other hand, the distribution of the columnar crystals show two peaks at all stations, especially at St. 771. A typical example of the difference of the crystals at St. 771 is shown in Fig. 4. The mode of distribution suggests that there existed two layers of clouds in the upper atmosphere, and that the both shapes of the crystals grew at the same time in the lower cloud layer. This expectation is understood that the first peaks of the columns coincided with the peaks of the bullets.

The mean length of c-axis of bullets was 0.66 mm, 0.45 mm and 0.57 mm at St. 903, South Pole, and St. 771 respectively. These values were larger than that of Gow (1965), 0.4 mm in Antarctica, but except the value at the Pole, were approximately similar to that of KIKUCHI (1968), 0.59 mm in Hokkaido. In the meantime, the mean length of c-axis of columns at those stations was 0.72 mm, 0.54 mm and 1.10 mm, respectively, which were larger than that of bullets. At the South Pole, the mean lengths of the column and bullet were the shortest at the three stations. At St. 771, the mean length of c-axis of the column was 1.10 mm and maximum length was 1.8 mm.

3.3. Axial ratio (c/a) of single bullet and column

Axial ratio (c/a) of single bullet and column at St. 903, South Pole, and St. 771 are shown in Fig. 5. In the figure, the frequency distribution in percentage is put on the ordinate, and the axial ratio at an interval of 0.5 is on the abscissa. Although the distribution curves are not normal in comparison with the distribution curves of the lengths of c–axes in both crystal shapes at all stations, the calculated mean value of the bullets was 4.3, 3.5 and 3.8 and that of the columns was 4.8, 3.7 and 6.5, at St. 903, South Pole, and St. 771, respectively. Each value of the bullets was larger than that of Hokkaido (KIKUCHI, 1968), 3.2. The maximum value of the axial ratio of the column at St. 771 was 12.5, which is shown in Fig. 4. However, no "Long solid column or Long prism" observed by SHIMIZU (1963) at Byrd Station was discovered in the present observation.

3.4. Peculiar shapes of snow crystals

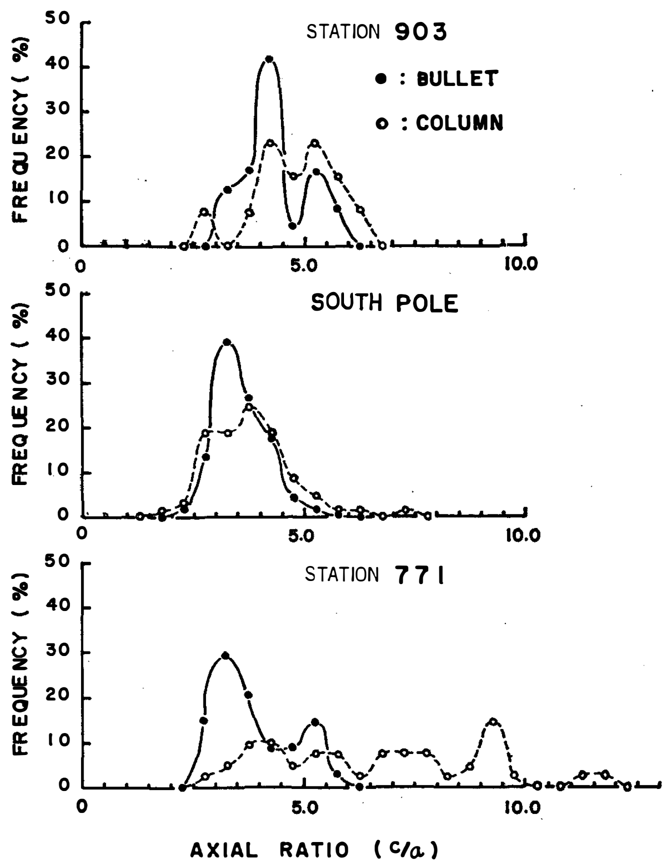

Fig. 5. Frequency distributions of the axial ratios (c/a) of the snow crystals of bullet (●) and columnar (○) shapes at three observation stations (St. 903, South Pole and St. 771)

KLINOV (1960) reported a number of shapes of snow crystals in Siberia which were observed when the temperature was very low ranging from −30° to −57°C near the ground surface. They were formed by radiation cooling associated with steep surface temperature inversion. Some of them were peculiar and hitherto unrecorded shapes. Recently, one of the authors discovered more than ten unknown and peculiar shapes at Syowa Station (KIKUCHI, 1969; 1970). Furthermore, some of them were observed near Sapporo, Hokkaido in 1970 (KIKUCHI, 1971). Some examples of the peculiar shapes found on glass slides in this observation are shown in Fig. 6.

The crystals of Figs. 6 (a)–(c) were observed at the South Pole station and at St. 771. The crystal of Fig. 6 (a) is a rectangular side plane of a part of "Combination of bullets and a rectangular side plane" as shown in Photo 23 in Plate 4 (KIKUCHI, 1969). As the point at which the crystals are combined is very frail, the crystals would be detached from the combination of bullets during the descent. Fig. 6 (b) is the same crystal shape of "Bullet with a side plane" as that in Photo 22 in Plate 4 (KIKUCHI, 1969). The crystal in Fig. 6 (c) was not found at Syowa Station. But there are some of the same crystal in KLINOV's book

(1960), for instance, Photos 15 and 23 in Fig. 19 and Photos 17 and 18 in Fig. 20. Recently, similar crystals were observed at Barrow, Alaska (HIGUCHI, 1968). It is worthy of note that the surface air temperature in our case was approximately −30°C and in the case of Siberia it was between −49°C and −56°C. The crystal of Fig. 6 (d) is the same shape of "Assemblage of periodic scrolls with side planes" in Photo 26 in Plate 5, and Fig. 6 (e) is "Simple tetragon" in Photo 14 in Plate 3 (KIKUCHI, 1969). A rectangular shape on the right side in Fig. 6 (f) is unclassified. Figs. 7 (a) and (b) are minute columns and minute hexagonal plates, and Fig. 7 (c) is a column with a hollow at one end, observed at the South Pole. Fig. 7 (d) is a kind of "Long solid column" (MAGONO and LEE, 1966). This crystal was reproduced from Fig. 4. Figs. 7 (e) and (f) are the top and basal views of the same skelton crystal. The crystal is not classfied.

4. Concluding Summary

As expected from the temperature ranges at the stations in which the replication of snow crystals was carried out, the greater part of the shapes of snow crystals were bullets, combination of bullets, columns and side planes. However, depending upon the localities and the time of observation at the same station, there were two distinct cases, namely, the case where bullets and columns are predominant and the other case that comprises only side planes. This discrepancy in the occurrence of crystal shapes was ascribed to the difference in supersaturation with respect to ice surface between the crystals of bullet and columnar types and those of side planes. But we could not discuss further about the discrepancy because no data of the upper atmosphere were available at the observation stations.

Concerning the length of c-axis of single bullet and column, the pattern of the frequency distribution was different from each other; the distribution of the bullet was nearly normal and the other had two peaks at all stations. From this fact, it was conjectured that there were two layers of clouds in the upper atmosphere. The mean length of c-axis of the single bullets was larger than that of GOW (1965), 0.4 mm in Antarctica, but approximately similar to that of KIKUCHI (1968), 0.59 mm in Hokkaido. However, the mean axial ratio of the bullets was larger than that of Hokkaido.

A few kinds of unknown and peculiar shapes of snow crystals discovered at Syowa Station by one of the authors (KIKUCHI, 1969; 1970), were also found in replica samples collected at the South Pole and St. 771. Their examples were shown in Fig. 6.

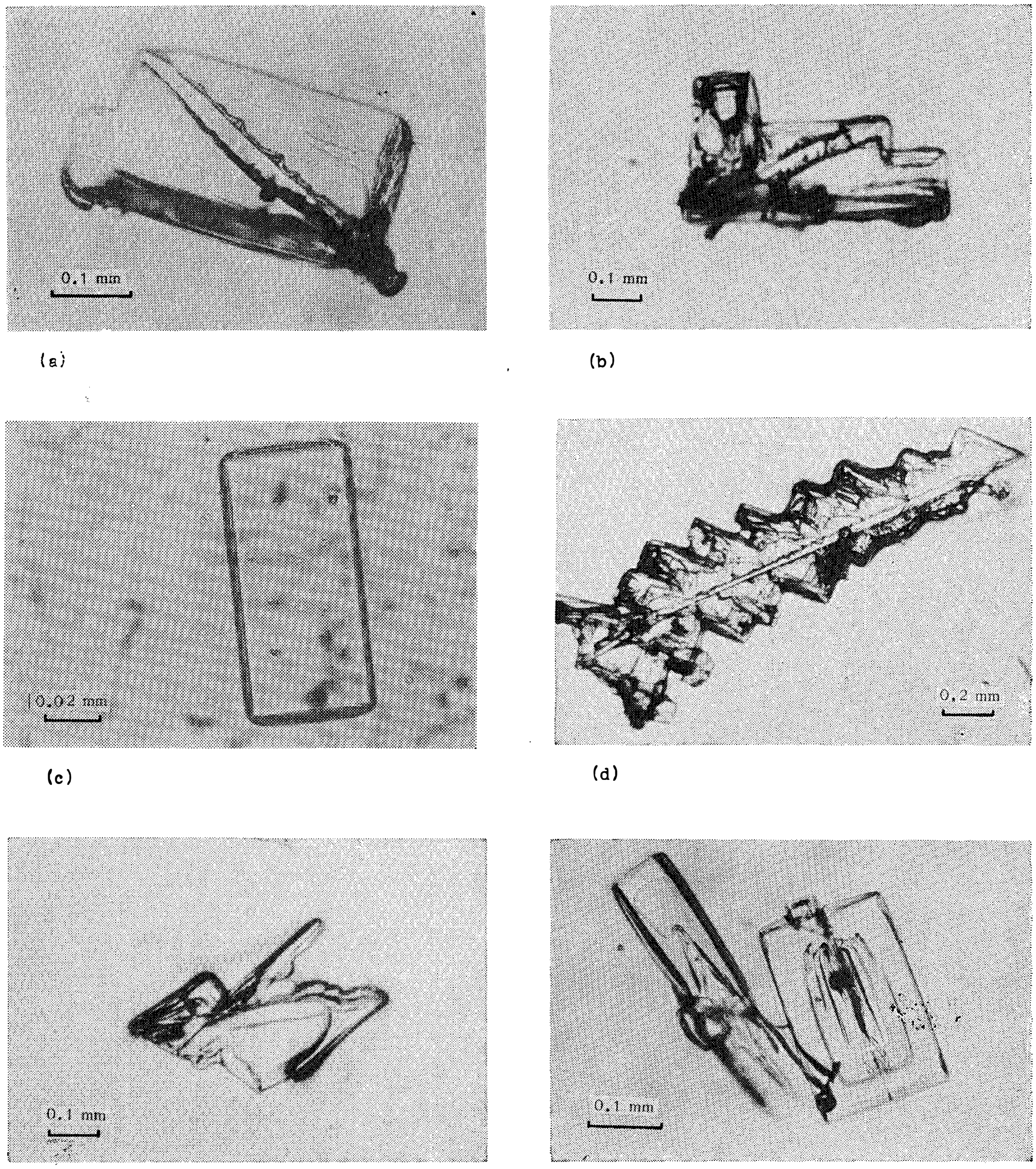

Fig. 6. Photomicrographs of replicas of the snow and ice crystals.

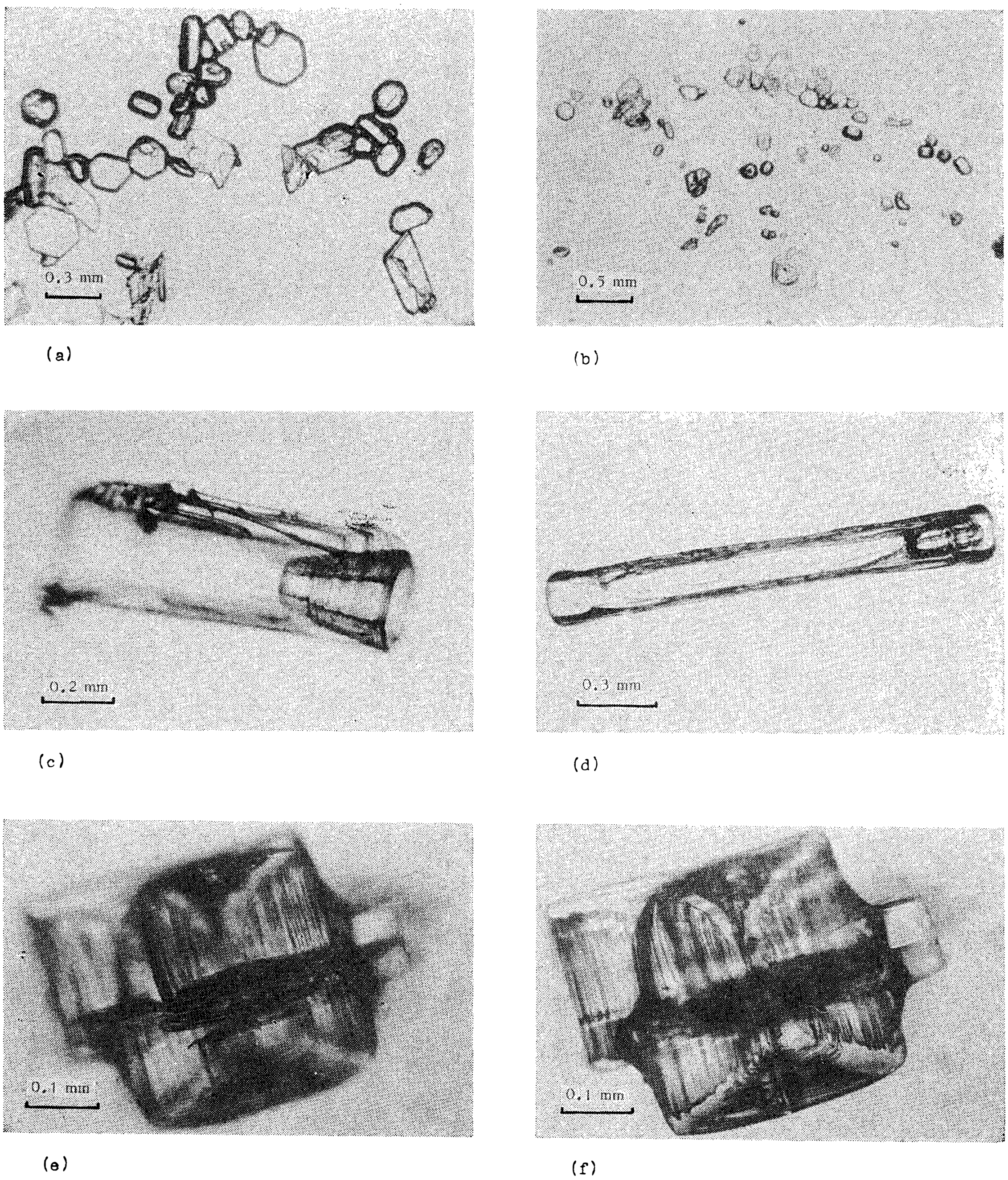

Fig. 7. Photomicrographs of replicas of the snow and ice crystals.

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References

GOW, A. J. (1965): Snow studies in Antarctica. CRREL Research Report, 177.

HIGUCHI, K. (1968): Special features of ice crystals observed at Barrow, Alaska. Paper presented at the meeting of the Meteorological Society of Japan held in Nagoya.

KIKUCHI, K. (1968): On snow crystals of bullet type. J. Met. Soc. Japan, **46**, 128–132.

KIKUCHI, K. (1969): Unknown and peculiar shapes of snow crystals observed at Syowa Station, Antarctica. J. Fac. Sci., Hokkaido Univ., Ser. VII, **3**, 99–116.

KIKUCHI, K. (1970): Peculiar shapes of solid precipitation observed at Syowa Station, Antarctica. J. Met. Soc. Japan, **48**, 243–249.

KIKUCHI, K. (1971): Peculiar shapes of snow crystals of Antarctic type observed at Hokkaido. Geophys. Bull. Hokkaido Univ., **25**, 167–180 (in Japanese with English summary).

KLINOV, F. Ya. (1960): Voda v atmosfere pri nizkikh temperaturakh (Water in the atmosphere at low temperatures). Izd. Akad. Nauk SSSR, Moscow.

KOBAYASHI, T. (1965): Vapour growth of ice crystal between −40° and −90°C. J. Met. Soc. Japan, **43**, 359–367.

MAGONO, C., K. KIKUCHI and N. YAMAMI (1971): On the meteorological conditions for the growth of snow crystals in colder temperature regions, as revealed by radiosonde data in the Antarctica. J. Met. Soc. Japan, **49**, 179–183.

MAGONO, C. and C. W. LEE (1966): Meteorological classification of natural snow crystals. J. Fac. Sci., Hokkaido Univ., Ser. VII, **2**, 321–335.

SHIMIZU, H. (1963): "Long Prism" crystals observed in precipitation in Antarctica. J. Met. Soc. Japan, **41**, 305–307.

WEICKMANN, H. (1948): The ice phase in atmosphere. Trans. 273, Ministry of Supply, London (translation from German).

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