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Citation	Journal of the Faculty of Science, Hokkaido University. Series 7, Geophysics, 5(1), 21-28
Issue Date	1977-02-05
Doc URL	http://hdl.handle.net/2115/8694
Type	bulletin (article)
File Information	5(1)_p21-28.pdf

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[Journal of the Faculty of Science, Hokkaido University, Ser. VII (Geophysics), Vol. V, No. 1, 1976]

Remeasurement of the Axial Angle between Spatial Branches of Natural Polycrystalline Snow Crystals

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(Received Oct. 30, 1976)

Abstract

Remeasurement of the axial angles between spatial branches of natural snow crystals, that is to say, spatial dendrites, radiating assemblage of dendrites, combination of bullets and side planes, was carried out in the Cloud Physics Observatory, Hokkaido University at the top of Mt. Teine (1,024 m msl), Hokkaido in the two winter seasons of 1974 and 1975. As a result, it was found that all shapes had remarkable peaks around 70° in their distribution frequencies. The result was exactly the same as pointed out by Lee (1972). Although Lee had concluded that almost all snow crystals of radiating assemblage of dendrites were composed of two planes of dendritic crystals, however, about half of this type were composed of three or more planes.

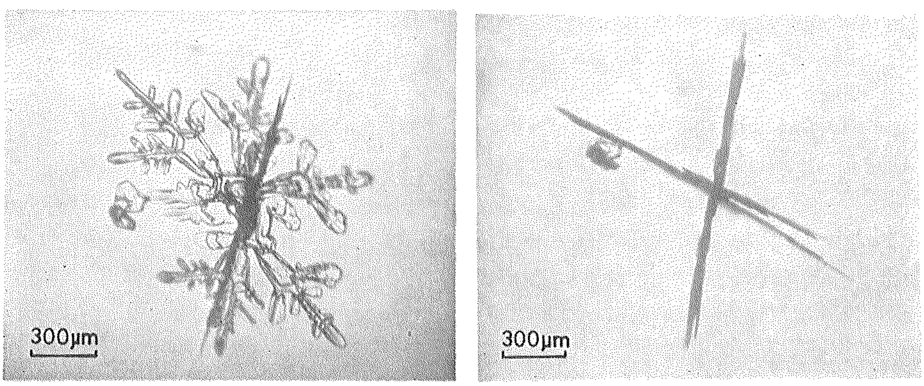
1. Introduction

Recently, considerable interest has been shown in the mechanisms of origin of polycrystalline snow crystals, namely, spatial dendrites, radiating assemblage of dendrites, combination of bullets etc. One of the authors[1] carried out a statistical treatment of cases of combination of bullets and concluded that the combination of bullets grew from frozen cloud droplets with many spicules which were produced by sudden freezing of supercooled cloud droplets and a single bullet was a result of the disintegration from the combination of bullets during their descent. Further, he found that the percentage of number of the combination of bullets combined from bullets lower than four was 85% or more. However, he did not treat the angle of *c*-axes between bullets. Lee[2] carried out careful measurements of the angles between spatial branches of natural polycrystalline snow crystals under a microscope utilizing a universal stage at the top of Mt. Teine, Hokkaido. And he found that the predominant angle varied according to the crystal shapes of polycrystalline snow crystals, however, the highest peak in the distribution of the angle was recognized around 70° in all types of spatial dendrites, radiating assemblage of dendrites, side planes and combination of bullets. Further, he found that the *a*-axes of spatial branches are common to those of the basal plane of the snow crystal. On the other hand, in laboratory experiments, Higuchi and Yosida[3], Magono and Aburakawa[4] and Aburakawa and Magono[5], grew the crystals of prisms and dendrites from frozen droplets on ice substrata. The peaks of the measured angle between *c*-axis of ice crystal and that of the substrate in the case of Higuchi and Yosida[3] were approximately 20°, 30°, 60° and 90° and in the case of Aburakawa and Magono[5] approximately 80° at –20°C and –28°C and the range was between 40° and 50° at –10°C. As summarized above, it may be seen that there is a difference between observational and experimental results. In order to carry out a more detailed experiment on the orientations of frozen water droplets, remeasurement of the angle between spatial branches of polycrystalline snow crystals are required.

2. Method

The measurement of angles between spatial branches of natural snow crystals was carried out in the Cloud Physics Observatory, Hokkaido University at the top of Mt. Teine, Hokkaido in two winter seasons of 1974 and 1975.

Measurement apparatus and procedure was the same as Lee's[2], that is to say, natural falling snow crystals were collected on a regular glass slide and the glass was moved onto a universal stage fixed to a microscope. The first photograph was taken in original state on the glass slide as shown in Fig. 1(a). Next, by adjusting the universal stage, an exact crosssection of two planes was obtained as shown in Fig. 1(b). In the case of radiating assemblage of



(a) (b)

Fig. 1. Radiating assemblage of dendrites composed of two planes (a) and crosssection under a universal stage (b).

dendrites, as pointed out by Lee[2], the crystal was composed of two planes of snow crystals. Therefore, the measurement of angle between two planes was quite easy. However, about half of the examples of crystals were composed of three or more planes as shown in Figs. 2 and 3. The angle of all samples was measured on photographs at a room temperature laboratory after descending from the mountain.

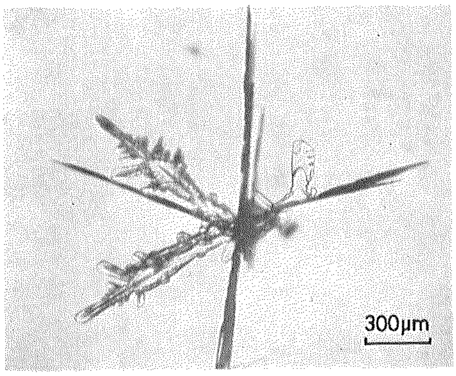


Fig. 2. Radiating assemblage of dendrites composed of three planes.

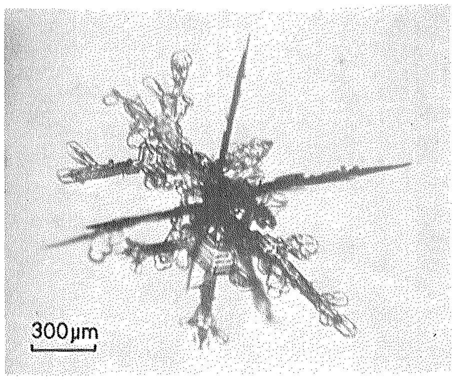


Fig. 3. Radiating assemblage of dendrites composed of three or more planes.

3. Results

The measurement of the angle was made following four shapes of snow crystals; radiating assemblage of dendrites, spatial dendrites, side planes and combination of bullets. Sample populations of spatial dendrites and combination of bullets in this measurement were larger than the previous one[2]. The distribution of plane angle between spatial branches of radiating assemblage of dendrites is shown in Fig. 4 in the form of frequency. The ordinate shows the number of snow crystals measured, and the abscissa shows the plane angle in two degrees respectively. The numeral on the right side of the schematic description on the upper part in the figure shows the sample number of snow crystals measured. As may be seen in the figure, there was a remarkable peak around 70° distinctively as pointed out by Lee[2]. Further a small peak was seen around 40°. This is nearly the same angle of 39° as in the previous one. However, a small peak at 56° by Lee[2] was not recognized but was included in the distribution with the peak of 70°. The example of the snow crystal of spatial dendrites is shown in Fig. 5. There was only a sharp

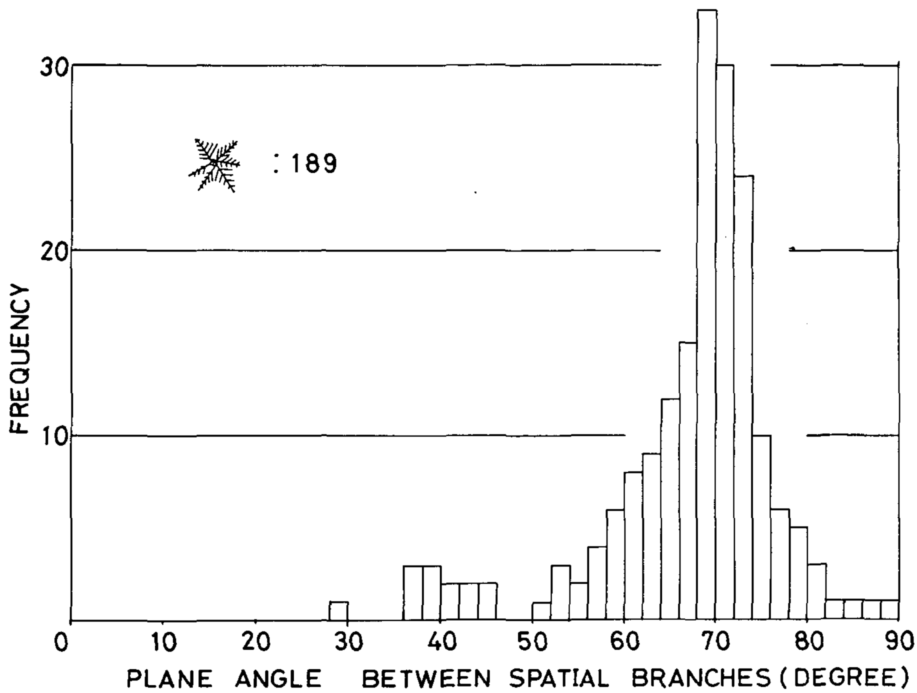


Fig. 4. Distribution of plane angle between spatial branches of spatial dendrites.

peak at 70° and the distribution was restricted to a small range between 60° and 80° except in only a few samples. Although the sample population was larger by 40% than the previous observation[2], the tendency of distribution was nearly the same with that. Fig. 6 shows an example of side planes. Sample population in this case was very small, however, the same tendency of distribution was estimated. The last example of the combination of bullets is shown in Fig. 7. Although, in the case of Lee[2], the sample population was very small and the distribution was widely scattered, in this example, a relatively remarkable peak was recognized around 70°. Further, there were some peaks with smaller angles than 70°, however, they were not clear because the sample population was not large.

4. Conclusion

Remeasurement of the angle between spatial branches of natural polycrystalline snow crystals, radiating assemblage of dendrites, spatial dendrites,

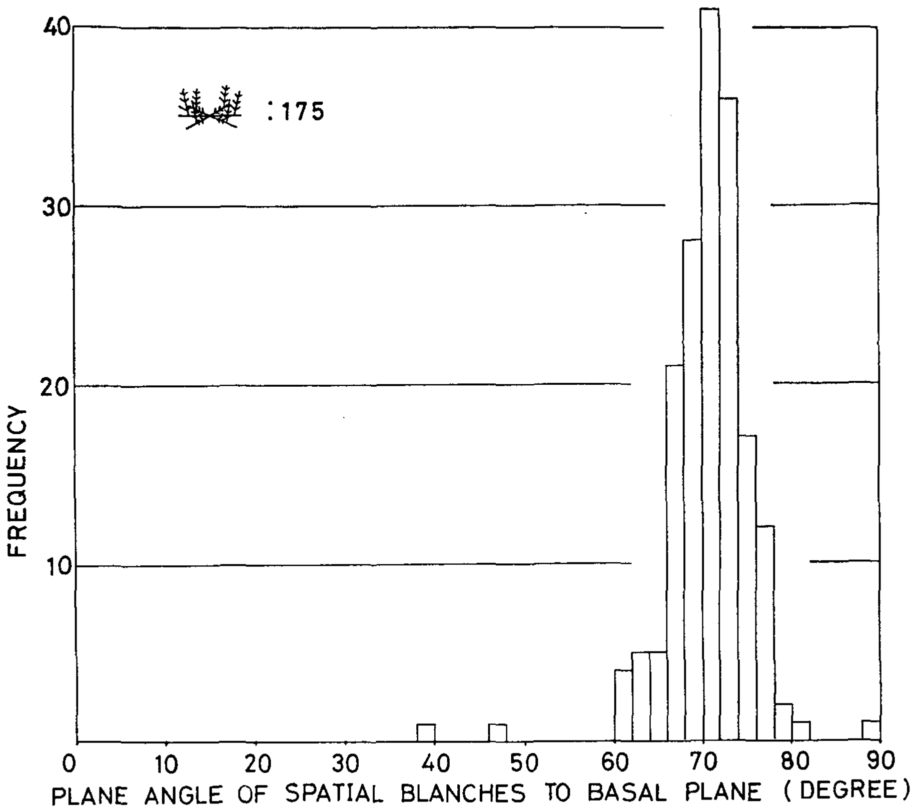


Fig. 5. Distribution of plane angle of spatial branches to basal plane of radiating assemblage of dendrites.

side planes and combination of bullets was carried out. As a result, it was found that all of them had remarkable peaks around 70° in their distribution frequencies. The result was exactly the same as that pointed out by Lee[2] previously. And, especially, this tendency was clearly defined in the shape of spatial dendrites. In the case of radiating assemblage of dendrites, it was estimated that there were other small peaks around 40° and between 50° and 60°. Although Lee[2] had concluded that almost all snow crystals of radiating assemblage type were composed of two planes of dendritic crystal, however, about half of this type were composed of three or more planes as shown in Figs. 2 and 3. In the cases of side planes and combination of bullets, it was recognized that there were the same tendencies with peaks around 70°. As to this 70°, Lee[2] developed the matching theory and Iwai[6] introduced

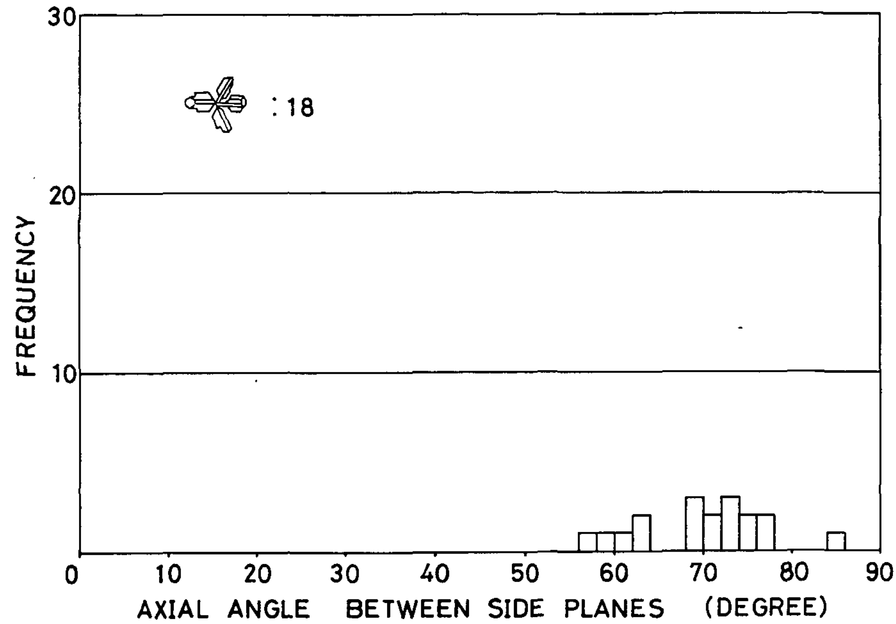


Fig. 6. Distribution of axial angle between different axes of side planes.

the idea of penetration twin theory. Qualitatively, it is considered that the matching theory would be suitable for the shape of spatial dendrites, on the other hand, the penetration twin theory would be suitable for radiating assemblage of dendrites and crossed plates. Recently, Kobayashi and Furukawa[7] developed a coincidence-site lattice theory and they compared their theoretical results with angles between neighboring c-axes of combination of bullets based on numerous photographs collected from books and articles by Bentley and Humphreys[9], Nakaya[10], Клинов[11], and Gow[12] (Kobayashi et al.[8]). As a result, they noted that the observed peaks of an angle between c-axes were 90°, 70°, 65° and 55°. And further they pointed out that these angles were in good agreement with the angles predicted by the twinning relation in ⟪$10\bar{1}2$⟫, ⟪$30\bar{3}4$⟫ or ⟪$30\bar{3}8$⟫, ⟪$10\bar{1}3$⟫ and ⟪$10\bar{1}1$⟫ twins[8]. Comparing their observed frequency with our results shown in Fig. 7, it is recognized that a good agreement among them was seen with the exception of the case of 90°. Furthermore, they proposed an idea of penetration twins into one of the growth mechanisms of combination of bullets. In this case, the most probable twinning relation is ⟪$30\bar{3}4$⟫ and ⟪$30\bar{3}8$⟫ twins for the angle

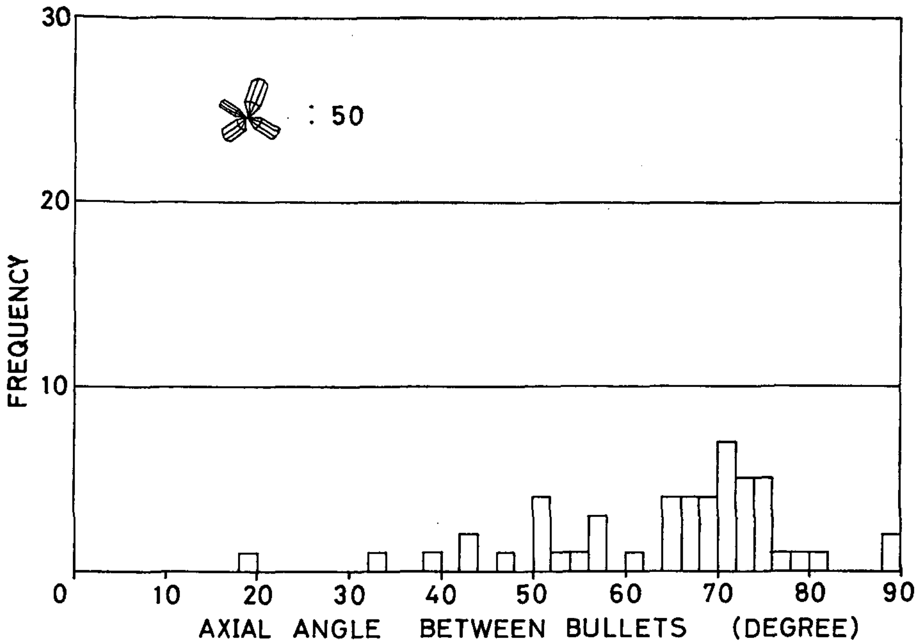


Fig. 7. Distribution of axial angle between bullets of combination of bullets.

between c-axes of 70.3° and 109.2°. Two ⟪10$\bar{1}$2⟫ twins have another possibility and the angle is 93.1° in this case. The authors, recently, obtained some examples showing penetration twins in their freezing experiment of supercooled water droplets. And the angle between their crystals showed a range between 66° and 72° to 13 out of 18 examples[13]. In any event, the remarkable angle of 70° may be solved by the development of theory and by careful laboratory experiments in the near future.

Acknowledgments: The authors express their hearty thanks to Prof. C. Magono, Department of Geophysics, Hokkaido University, for his discussion on this study. The expense of this study was defrayed by the Educational Ministry of Japan.

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