



Title	Notes on Irregular Snow Crystals and Snow Pellets
Author(s)	Nakaya, Ukitirô; Sekido, Yatarô; Tada, Motoiti
Citation	北海道帝國大學理學部紀要, 1(8), 215-226
Issue Date	1936-04-20
Doc URL	<a href="http://hdl.handle.net/2115/34456">http://hdl.handle.net/2115/34456</a>
Type	bulletin (article)
File Information	1_P215-226.pdf



[Instructions for use](#)

# Notes on Irregular Snow Crystals and Snow Pellets.\*

By

Ukitirô NAKAYA, Yatarô SEKIDO and Motoiti TADA.

[Pl. I-VII]

## 1. Introduction

In the course of continuous observations of snow crystals during the last three winters, the authors were lead to the conclusion that not all snow crystals which one actually observes are perfect and that they are not simple crystals of hexagonal symmetry as shown in a text-book. On the contrary, those ideal crystals occupy only a small part of the total number of snow particles falling down to the earth. Before proceeding to the general classification of all types of snow crystals observed in the last three seasons, which will be published as No. 8 of this series of investigations, brief explanations will be presented in this paper on some "irregular" crystals that have been rather neglected by most investigators<sup>1)</sup> engaged in this line of research. The snow pellet or the graupel<sup>2)</sup> is also treated in this paper, as the authors found many particles of snow which lie in the intermediate states between the snow crystal and the graupel and, consequently, consider that the graupel is one of the modified forms of snow crystal.

## 2. Crystals with Two, Three or Four Branches

Crystals with three branches or plates of trigonal symmetry are not at all rare, having been reported by many observers, as Dobrowolski, Mûge, Bentley, etc. The plates of trigonal symmetry were observed by BENTLEY in such a large number that HUMPHREYS<sup>3)</sup> proposed in his classification

---

\* Investigations on Snow, No. 7.

1) For example, the famous book by BENTLEY contains about one hundred photographs of those irregular crystals, while more than two thousand of regular plate crystals are reproduced.

2) The German term Graupel will be used instead of snow pellet in this and following papers.

3) BENTLEY and HUMPHREYS, Snow Crystals, New York, 1931, p. 6.

of snow crystals to add a term of trigonal plate to the known hexagonal column and plate. WHERRY<sup>1)</sup> took the system of crystallisation of ice as trigonal from the fact that the crystals of trigonal symmetry are frequently observed.

The authors took many photographs of crystals with three branches at Mt. Tokati, one of which is reproduced in Photo. 1, Plate I. They noticed the fact that many crystals of this sort are observed in a short time interval during a snowfall. At that time the crystals of the irregular form are often observed, being mixed with this kind of snow. On one occasion they observed two similar crystals of this type lying side by side on a receiving glass plate, which suggested that this three-branched crystal may be a component of a twin crystal of hexagonal form. Then they tried, during a snowfall when some three-branched ones are observed, to find the twin crystal among the apparently regular crystals with six branches. It was found that some of the apparently regular crystals could be separated into two three-branched ones by a slight mechanical shock; for example, by poking the centre of a crystal with the tip of a fine splinter. One example of the separated crystal is shown in Photo. 2, and another example will be seen in the pictures of the general classification, report No. 8.

From a simple experiment described above, it is understood that a three-branched crystal is nothing but a component of twin crystal which is developed from two nuclei.<sup>2)</sup> At the initial stage of the growth of a snow crystal, two nuclei happen to attach with each other, one lying on top of the other, and these two nuclei are connected crystallographically, then by chance three alternate branches belonging to one nucleus and the other three branches of the other nucleus begin to develop respectively just earlier than the corresponding ones belonging to the opposite nucleus. Then the supply of water vapour from the surrounding atmosphere to the branches of crystal is chiefly made to the elongated branches so that three branches belonging to one nucleus are fully developed, while the branches of the other nucleus just underneath these developed ones remain in a shriveled state, and vice versa. A twin crystal grown in the manner above described must be composed of two components as shown in Photo. 2, one lying on top of the other in such a way that they represent as a whole an appearance of a regular hexagonal crystal. This sort of crystal is easily

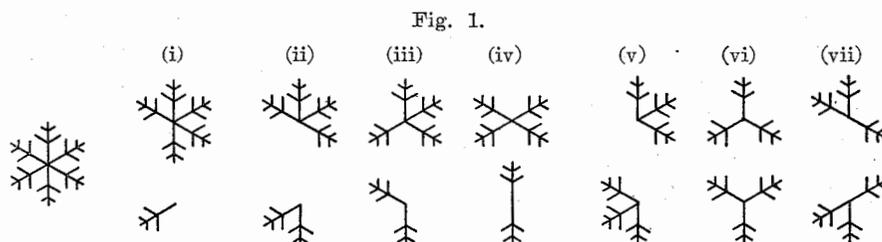
---

1) E. T. WHERRY, *Month. Weath. Rev.*, 48 (1920) 29.

2) The term "nucleus" used in this paper means not only a nucleus of crystal in the literal sense but also a minute crystal at the very initial stage of its development.

separated into its components by a slight external force, giving thus the three-branched crystals in question. Returning to Photo. 1, the relics can be clearly seen of the three undeveloped branches which, according to the theory above described, must be present in any sample. These relics, however, are not always observable, as may be seen in Photo. 9 of the previous report No. 2.<sup>1)</sup> They can be too small to be observed even under microscope, or more probably may be extinguished by the sublimating action of crystal.

From the standpoint of this two nuclei theory, seven pairs of component crystals can be expected, if it is assumed that the initial development of some of the branches is determined by chance. The seven pairs are schematically shown in Fig. 1. As a matter of fact, almost all these component crystals have been actually observed.



- i) A separated single branch is sometimes observed. Photo. 6, Plate I, shows this type of twin crystal before the separation, from which one branch on the left hand side can be separated.
- ii) Two examples are reproduced, Photo. 12, Plate II, and Photo. 69 of the previous report, No. 2.
- iii) One example of the two-branched component of this kind is shown in Photo. 8 of report No. 2.
- iv) This is the typical form of four-branched crystal and many photographs of these crystals are taken; see Photos. 3 and 4 of this paper and Photos. 7, 11, 12 and 13 of report No. 2. Photo. 4 of this paper shows two component crystals separated artificially.
- v) This type is most frequently observed; see Photos. 68, 70 a, b and 71 of report No. 2.
- vi) Photos. 1 and 2 of this paper; see Photo. 9 of report No. 2 and one good example in report No. 8.

1) U. NAKAYA and K. HASIKURA, This Journal, vol. 1, p. 163. That paper will be referred to as No. 2.

- vii) This rather extraordinary form of component crystal is shown in Photo. 5 of this paper, in this case the distance between the two nuclei is observable.

The authors thus consider that the origin of the three or four-branched crystals, which has been long a pending question, is explained by this two nuclei theory.

The origin of a triangular plate may be also explained in the manner described above. SHEDD,<sup>1)</sup> WEGENER<sup>2)</sup> and others agree that a dendritic crystal is first formed in a sufficiently supersaturated zone of the atmosphere and then the space between the skeleton branches is filled up with ice while the crystal is passing through a less supersaturated layer, transforming the dendritic crystal into a plate form having symmetrical patterns inside. As the falling velocity of a plane dendritic crystal is very small, being of the order of 1 km/hour,<sup>3)</sup> there will be sufficient time for performing several stages of transformation before the crystal comes down to the earth surface. According to this view, the triangular plate is a transformed form of one component of a twin crystal.

Some crystals are often observed which have outlines of hexagonal symmetry and patterns of trigonal or digonal symmetry near the central part. This sort of crystal is also explained as having passed through a twin crystal stage in its earlier development.

### 3. Plane Crystals of Irregular Form

- i) *Deformation of the crystal caused by the attachment of another nucleus.*

Sometimes it happens that another nucleus attaches to a point on a half-made crystal and the subsequent development of the crystal is deformed by this disturbance. Six examples are shown in Photos. 7-12, Plate II. In Photo. 7 one sees that, in the earlier stage when the main crystal was a small hexagonal plate, another nucleus attached thereto and in the subsequent course the main and the appendant crystals passed through the same stages of development. In case of Photo. 11, an appendant nucleus attached to the main crystal when the latter had developed into a hexagonal plate of a considerable dimension, the subsequent development having been disturbed to a remarkable extent.

---

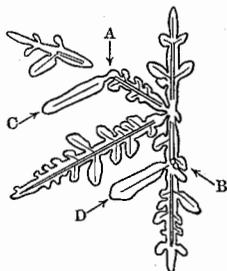
1) SHEDD, Month. Weath. Rev., 47 (1919) 691.

2) WEGENER, Thermodynamik der Atmosphäre, dritte Auflage, Leipzig, 1928, p. 248.

3) U. NAKAYA and T. TERADA JR., This Journal, vol. 1. p. 191, Investigations on Snow, No. 4.

Photos. 9 and 10 are examples showing the case when an appendant nucleus attached to a point on a branch of stellar crystal. It is an interesting phenomenon that in both cases two twigs of a considerable size occur at the point where the nucleus attached, while no such twig is observed at the corresponding points on the other branches. The similar phenomenon is also observed in the case of Photo. 12. In this case the appendant nucleus is very small and is only noticed by a close examination of the original crystal. Two distinct nuclei are observed. A sketch of this crystal is shown in Fig. 2, in which A and B show the appendant nuclei. At A the branch was separated artificially before taking the photograph, in order to show clearly the matter of things. It must be noticed that the twigs C and D which occur at the points to which the nuclei attached, are markedly longer than the other twigs. This phenomenon is worth further investigation.

Fig. 2.



markedly longer than the other twigs. This phenomenon is worth further investigation.

ii) *Crystals of bilateral symmetry.*

Among the irregular crystals treated in this paper, some show nearly the nature of bilateral symmetry. Many photographs were taken of the crystals of this kind, among which two are reproduced in Photos. 13 and 14, Plate III. Photos. 74 and 89 of the previous report, No. 2, also belong to this kind. These crystals seem to have been developed from two or more nuclei lying side by side.

iii) *Malformed hexagonal plates with dendritic extensions at corners.*

This sort of malformed crystal was frequently observed at Mt. Tokati last winter. Four photographs are reproduced in Photos. 15-18, Plate III, of which Photo. 15 is an example showing a slight deviation from a regular form and Photo. 18 exemplifies a case of marked malformation. One of the characteristic features of this type of crystal is a narrow cut in the plate, which may appear in a middle portion of the side, Photo. 16, or at a corner of the plate, Photo. 17. The physical nature of this cut is not yet clear.

iv) *Dendritic crystals with branches grown unsymmetrically.*

The extraordinarily symmetrical nature of six branches of some snow crystals has been long a question. A typical example is shown with some discussions in the previous report, No. 2. Crystals with unsymmetrical branches, however, are not less often observed. Considering the frequency

of occurrence, these unsymmetrical crystals may be more common than the symmetrical ones. Of course the question of symmetry is a matter of degree. Such crystals as shown in Photos. 1-4 of report No. 2 are at present considered as symmetrical, although a close examination of the photographs reveals that the mode of distribution of twigs differs slightly for different branches. The degree of unsymmetry is more marked in the case of the crystal reproduced in Photo. 19, Plate IV. This one will be taken to belong to the group of unsymmetrical crystals, though the criterion is rather arbitrary. Photo. 20 is an example which shows a further branching of a twig, the mode of this secondary branching being unsymmetrical for two sides of one main branch. Most of the complicated crystals of this sort show some deviation from a symmetrical form and a perfectly symmetrical crystal is very rarely observed.

Another characteristic type of unsymmetry is a marked elongation of one branch or a few branches over the other ones. Three examples are shown in Photos. 21-23, in which Photo. 21 represents a typical case when two branches are more elongated than the others. In case of Photo. 23, the branches in the lower part of the right hand side of the photograph are more complicated in their structures than the other parts. It appears that the supply of water vapour from the surrounding atmosphere to the crystal has been greater to this direction during the course of the crystal growth. A remarkable photograph was obtained of a crystal which is the best example of this kind, Photo. 24. In this case there is little doubt but that the water vapour was chiefly supplied to the crystal from a direction that appears downwards in the photograph. From these photographs the authors were lead to consider that the supply of water vapour from a partial direction rather frequently happens in the course of the formation of crystals.

*v) Crystals representing a high grade of irregularity.*

Various crystals of extremely irregular forms are brought together in this group. Four examples are shown in Photos. 25-28, Plate V. The features of the most of these crystals are explained as advanced states of those already described under *i)-iv)*; for example, the crystal of Photo. 25 is a complicated form of the malformed hexagonal plate described in *iii)*, and that of Photo. 26 shows a trigonal nature and is made up of two or more plates, one overlapping with the other. Those of Photos. 27 and 28 also show the appearance of having developed from many nuclei, the whole structure only being very complicated.

#### 4. Needles and Peculiar Forms of Columnar Crystals

##### i) *Needles.*

The snow crystal of needle form is one of the types observed least frequently. It was observed three times at Sapporo in the winter of 1933-34, again three times at Sapporo and twice at Mt. Tokati last winter. Four photographs of this kind of snow were reproduced in report No. 2, and another three are added in this paper. The authors had the chance to observe a snowfall on the 15th Feb. 1935 at Mt. Tokati, when only needles fell in a fairly heavy snowfall which continued about one hour. One of the photographs obtained in this case is reproduced in Photo. 29, Plate V.

As described in previous report No. 6, the authors consider that there are two kinds of needles; the one is an elongated prism and the other is a bundle of thin pillars. In our climate the latter is chiefly observed, and the meteorological condition for the occurrence of this sort of needle agrees with the condition observed in the case of the formation of a frost crystal, the form of which is similar to this type of snow. In this paper the latter type of needle is chiefly dealt with. Sometimes a component pillar is observed to fall as a single crystal, which takes a form as shown in Photo. 30. When forming a bundle, the component pillars usually grow in parallel with each other, but occasionally some of them attach obliquely to the side of the others. One example of such a case is shown in Photo. 31. The meteorological conditions favourable for the occurrence of needle crystals will be described in the following paper, No. 8.

##### ii) *Peculiar form of columnar crystals.*

A snowfall made up chiefly of a peculiar type of columnar crystals was observed in the evening of the 16th Jan. 1935 at Sapporo. The crystal showed an appearance of an irregular assemblage of columns and plates, three examples of which obtained on that occasion are reproduced in Photos. 32-34, Plate VI. They are quite different both in their appearance and structure from any of the crystals which have been hitherto observed by authors in Japan or reported by many observers in various places of the world. At first no way of explanation was found for the mechanism of their formation, but the laboratory experiment on the artificial production of frost crystals<sup>1)</sup> suggested that the plane parts observable in the structure may be extensions of the side planes of the columns which form the skeleton of this crystal. A columnar crystal with an extended side plane was

---

1) U. NAKAYA and I. SATO, This Journal, Investigations on Snow, No. 6.

actually produced in the laboratory experiment. This type of crystal will be provisionally called a columnar crystal with extended side planes. Similar crystals were also found at Mt. Tokati twice last winter, although the number was very small. One of them is reproduced in Photo. 35. The snowfall in which this crystal is found, consisted of an assemblage of columnar crystals associated with small planes as shown in Photo. 37. Whether these crystals are also to be considered as the columns with extended side planes is not clear. One crystal of extraordinary structure was photographed, which seems to be an extremely complicated form of this type. It is shown in Photo. 36, but discussion will be reserved till more data are collected.

### 5. Spatial Dendritic Crystals

As described in previous report No. 2, there are two kinds of spatial dendritic crystals; the one has dendritic branches extending in space from a stellar base crystal and the other has dendritic branches radiating in space from the centre. These two types were previously classified only morphologically, but the result of the later observations indicates that they probably belong to different classes also from the standpoint of the mechanism of formation. The former is produced by the attachment of dendritic branches extending in space to a stellar base crystal. The mechanism of getting this form may be explained by the appendant nuclei attached to the various points on the branches of the base crystal, as described in the foregoing section 3, *i*). In the latter case, it was found that the crystal has, so to say, a stone at the centre. This stone may sometimes be so small that its presence is overlooked, one example being shown in Photo. 38, Plate VII. Such crystals, however, are rather rarely observed and most of this kind represent an appearance as shown in Photo. 39, in which case the stone is very clearly observable. This stone was found to be made up of several short columns gathered together.

It is sometimes observed that such an assemblage of short columns falls to the earth surface without bearing any dendritic branches, one example of which is shown in Photo. 40. At present the authors consider that a spatial dendritic crystal of radiating form is formed having the stone as nucleus, which is made of an assemblage of columns, while the other type with a stellar base crystal lacks such a stone. Then the condition of the upper layer of the atmosphere for producing one kind of the spatial dendritic crystal may be quite different from that producing the other type.

It is often observed that an assemblage of columns with short extensions of plane form falls to the ground. One example of this type of crystal is shown in Photo. 41. In this case the snow particle is very small and the whole aspect of the heap of snow quite resembles that of powder. The term "powder snow" used in daily life comprises many kinds of snow crystals. This type is one of the representative components of powder snow.

### 6. The Graupel (Snow Pellet) and the Graupel-like Snow

It is now generally accepted that the graupel is formed in a lower atmospheric layer where the supercooled water droplets are abundantly extant, but the mechanism of its formation is not clearly known. The authors had many chances at Sapporo and at Mt. Tokati to observe snow crystals which look to be in the intermediate states of snow and graupel. There are three types of the form of graupel as already noticed by many observers; the lump graupel, the cone-like one and what shows a trace of six-petalled flower. The authors propose to explain the lump graupel as a modified form of a spatial dendritic crystal of radiating type and the last mentioned type as developed from a spatial dendritic one with a stellar base crystal.

In our climate, the snow crystals with numerous water droplets attached are very frequently observed. As reported in the previous paper,<sup>1)</sup> these droplets are of the order of 0.03 mm. in diameter, which agrees with the known value of the diameter of cloud particles. When so many water droplets attach to a plane dendritic crystal of snow, it turns into a thick plate crystal as described in report No. 2. These droplets are liable to attach also to the spatial dendritic ones and in that case these snow crystals seem to become graupels.

A series of photographs supporting this theory is reproduced in Photos. 42-44, Plate VII. Photo. 42 shows a side view of a spatial dendritic crystal with a stellar base, to which many water droplets (cloud particles) are attached. Photo. 43 is a side view of a similar crystal, the only difference of which from the one in Photo. 42 is that the cloud particles attached are so numerous in this case that the whole crystal presents a semi-solid appearance. It is proposed to call snow crystals in this stage graupel-like snow. When the cloud particles attached increase still further in number, this graupel-like snow becomes more compact in structure and

---

1) U. NAKAYA and T. TERADA, Jr., This Journal, Investigations on snow, No. 4.

turns into the usual graupel. The appearance of the graupel belonging to this series, therefore, shows a trace of a six-petalled form. One example of this type of graupel is shown in Photo. 44. Thus the origin of this special form of graupel is explained.

Another series of photographs showing the course of formation of lump graupel is shown in the photographs in the succeeding report No. 8, in which is reproduced a photograph of a graupel-like snow crystal grown from a spatial dendritic crystal of radiating type as well as one of a lump graupel which seems to have been developed from this kind of graupel-like snow. The origin of the graupel of a cone-like form remains unclarified. The rotation of the graupel which occurs while it is falling may be a cause, as described in CZERMAK's paper,<sup>1)</sup> but at present the authors refrain from touching this question.

Crystals in an intermediate state of snow and graupel were also observed by European observers.<sup>2)</sup> BARKOW<sup>3)</sup> proposed a similar theory to the present authors' on the formation of the graupel. Some parts of his paper must be corrected as pointed out by K. WEGENER,<sup>4)</sup> but the authors consider that this theory which assigns the formation of graupel to the attachment of numerous cloud particles to a snow crystal, is in the main correct. The point of importance is that any sort of snow crystal is observable, the amount of cloud particles attached to which is varied continuously from snow to graupel. There is no reason why a graupel must be considered separately from a snow crystal with many cloud particles attached.

The condition favourable for the production of graupels is the existence near the earth surface of a thick cloud layer of supercooled droplets, the temperature in which is a few degrees below 0°C, and a snow layer over it. Any upward current will be very favourable for the attachment of an innumerable number of cloud particles to the original crystal.

---

1) P. CZERMAK, Sitz. Ber. Wien, II, a (1900) 185.

2) G. GREIM, Met. Zeit., 23 (1906) 320.

3) E. BARKOW, Met. Zeit., 25 (1908) 456.

4) K. WEGENER, Met. Zeit., 26 (1909) 272.

**Explanation of Photographs**

## Plate I. Two, Three or Four-branched Crystals.

1. Tokati, 1935, I 11,  $\times 19.5$ . A three-branched crystal.
2. " , 1934, XII 29,  $\times 15.0$ . An apparently regular crystal was separated artificially into two three-branched crystals.
3. " , 1935, II 13,  $\times 11.3$ . A four-branched crystal.
4. " , 1935, II 13,  $\times 20.3$ . An apparently regular crystal was separated artificially into two and four-branched crystals.
5. " , 1935, I 9,  $\times 44.8$ . A two-nuclei crystal.
6. " , 1934, XII 29,  $\times 21.0$ . A two-nuclei crystal.

## Plate II. Crystals developed from two nuclei.

7. Tokati, 1934, XII 25,  $\times 50.6$ .
8. " , " , XII 25,  $\times 26.5$ .
9. " , " , XII 25,  $\times 53.0$ .
10. " , 1935, I 11,  $\times 45.3$ .
11. " , " , I 9,  $\times 48.0$ .
12. " , " , I 11,  $\times 26.0$ .

## Plate III. Crystals of bilateral symmetry and irregular plates.

13. Tokati, 1935, I 9,  $\times 25.0$ . Crystal of bilateral symmetry.
14. " , 1934, XII 25,  $\times 29.0$ . " " " " .
15. " , " , XII 26,  $\times 27.5$ . Irregular hexagonal plate with dendritic extensions.
16. " , " , XII 25,  $\times 27.8$ . Similar to the above.
17. " , " , XII 25,  $\times 24.7$ . Similar to the above but more complicated.
18. " , " , XII 25,  $\times 27.5$ . Similar to the above.

## Plate IV. Dendritic crystals with unsymmetrical branches.

19. Tokati, 1935, I 11,  $\times 27.0$ . Slight deviation from a symmetrical form is shown.
20. " , 1934, XII 25,  $\times 21.6$ . Unsymmetry of secondary twigs.
21. " , 1935, I 11,  $\times 19.7$ . Two branches are elongated.
22. " , 1934, XII 25,  $\times 22.7$ . Similar to the above.
23. " , 1935, II 13,  $\times 10.7$ .
24. " , " , I 11,  $\times 17.0$ . All branches in one side are remarkably developed.

## Plate V. Irregular plane crystals and needles.

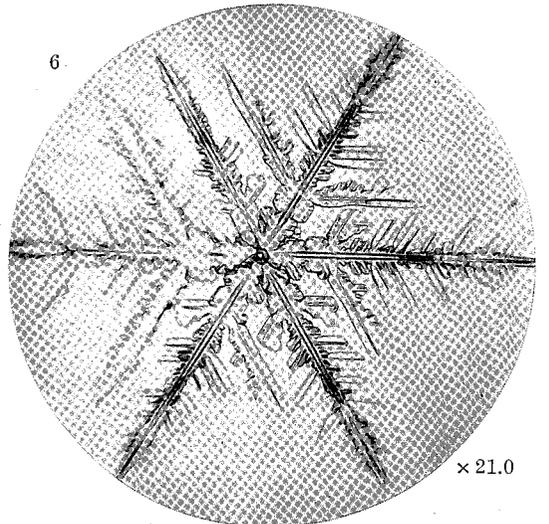
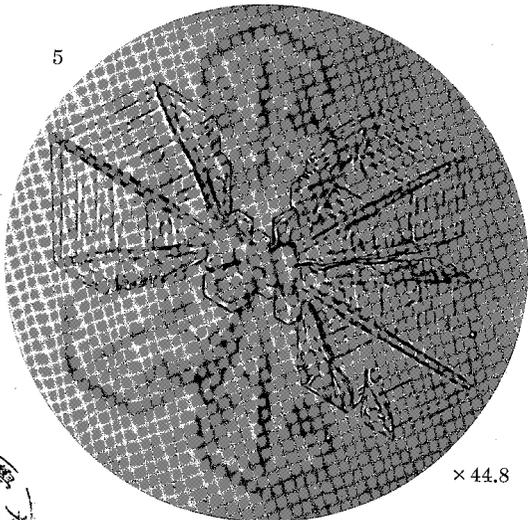
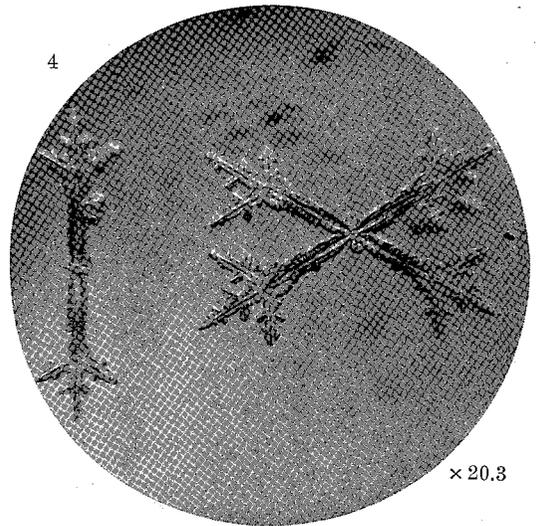
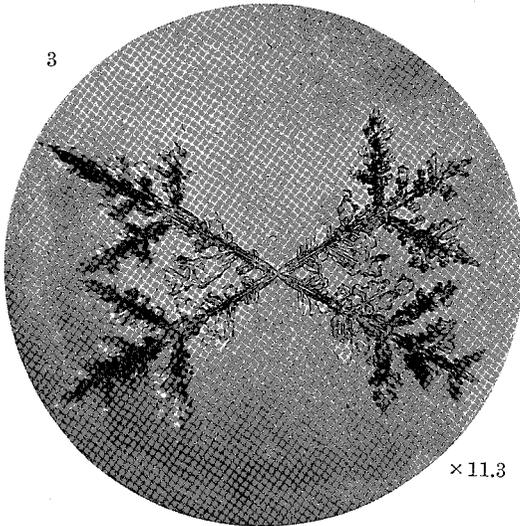
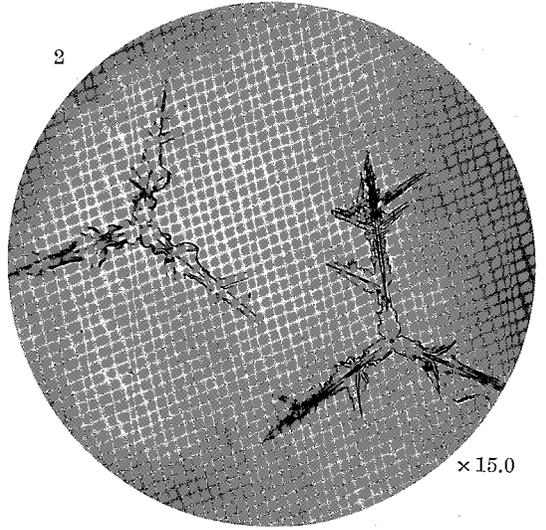
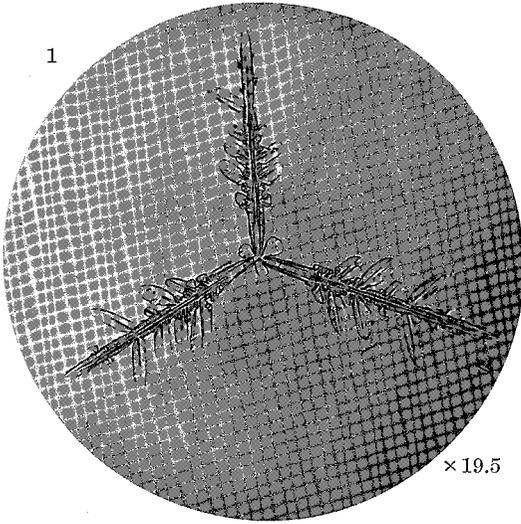
25. Tokati, 1934, XII 26,  $\times 27.1$ . Malformed plate with extensions.
26. " , " , XII 26,  $\times 27.0$ . Very irregular crystal.
27. " , " , XII 25,  $\times 21.3$ . " " " " .
28. " , " , XII 25,  $\times 22.7$ . " " " " .
29. " , 1935, II 15,  $\times 18.9$ . An assemblage of needles.
30. " , " , II 15,  $\times 53.0$ . A component pillar of a needle.
31. " , " , II 15,  $\times 22.1$ . Some of the pillars attach obliquely to the side of the others.

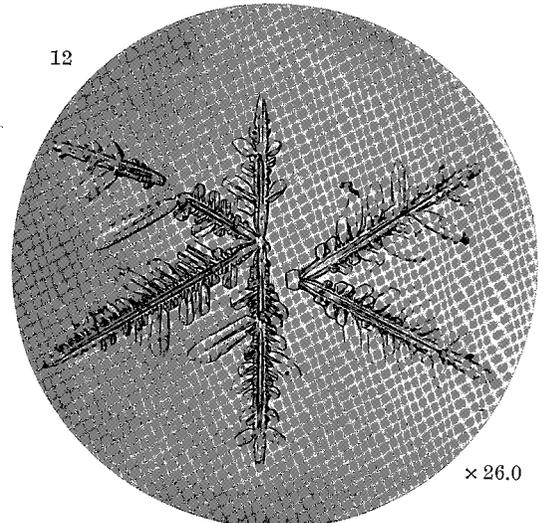
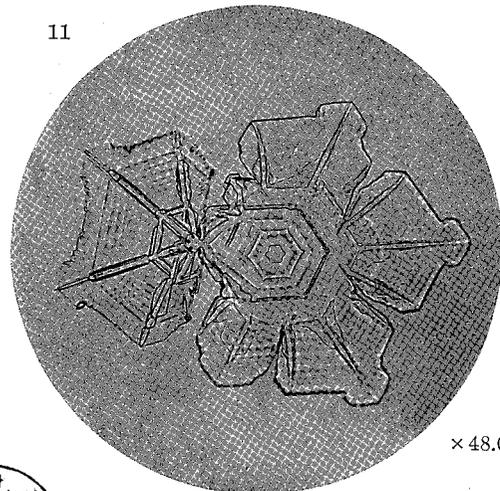
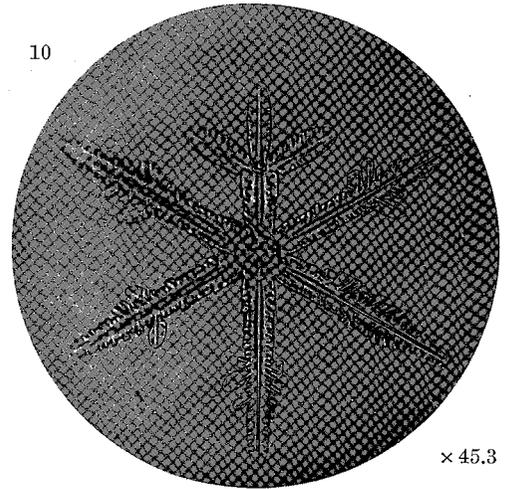
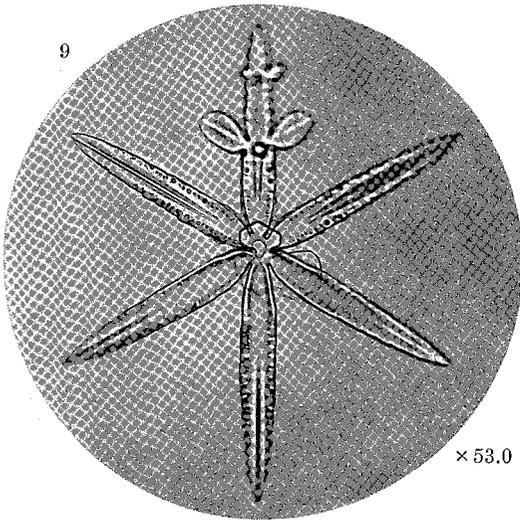
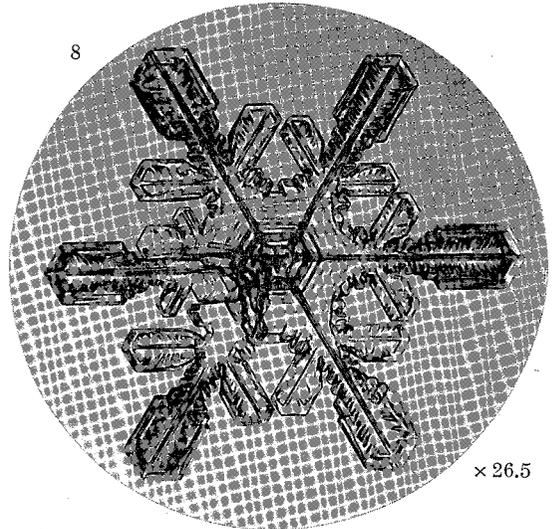
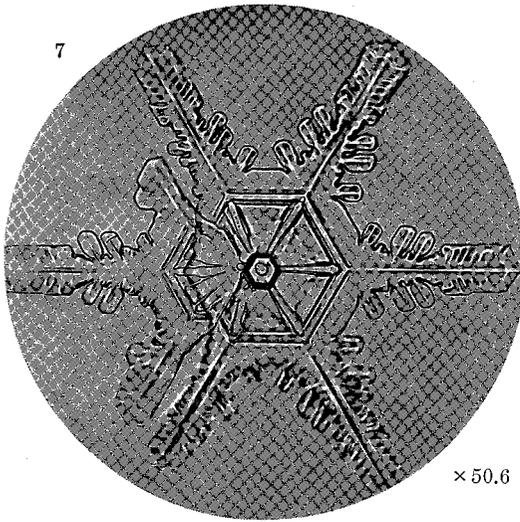
## Plate VI. Peculiar form of columnar crystals.

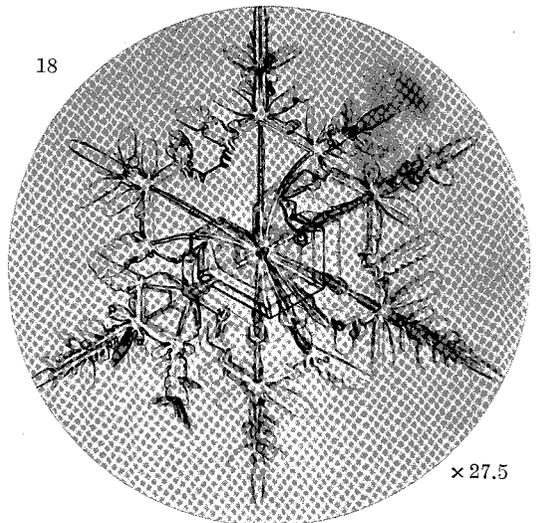
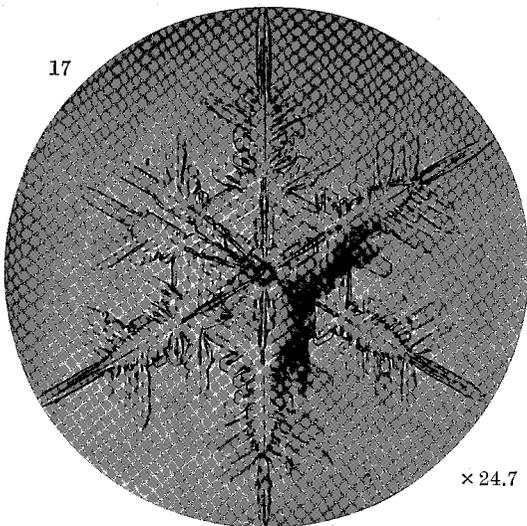
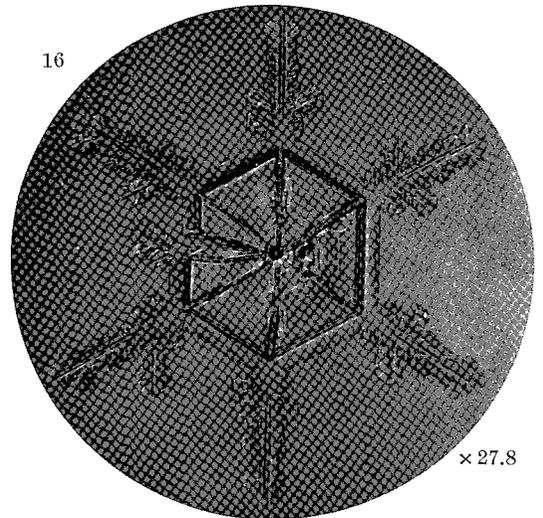
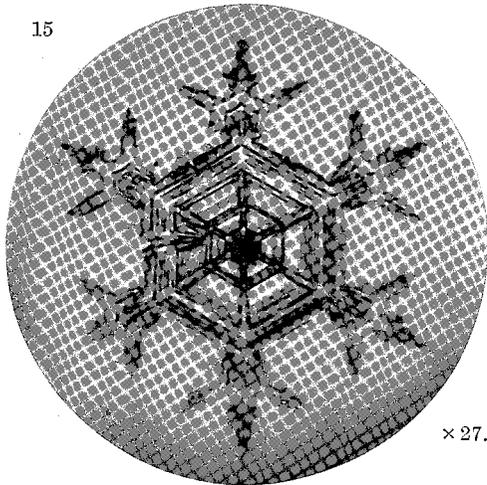
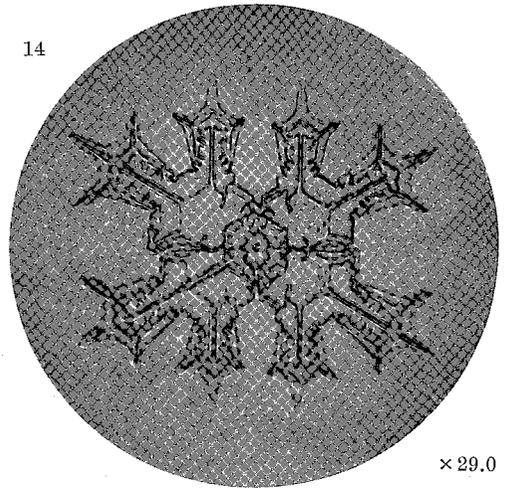
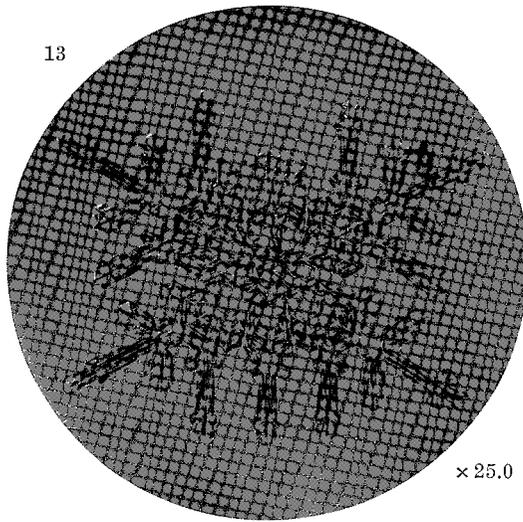
32. Sapporo, 1935, I 16,  $\times 38.8$ .  
 33. " , " , I 16,  $\times 38.8$ .  
 34. " , " , I 16,  $\times 38.8$ .  
 35. Tokati, " , II 11,  $\times 46.0$ .  
 36. " , " , II 13,  $\times 6.5$ . Extraordinarily complicated form of this type of crystal.  
 37. " , " , II 11,  $\times 20.3$ . An assemblage of columns with small planes.

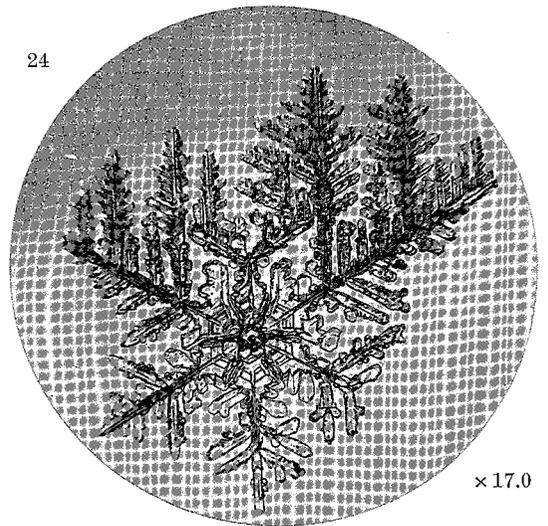
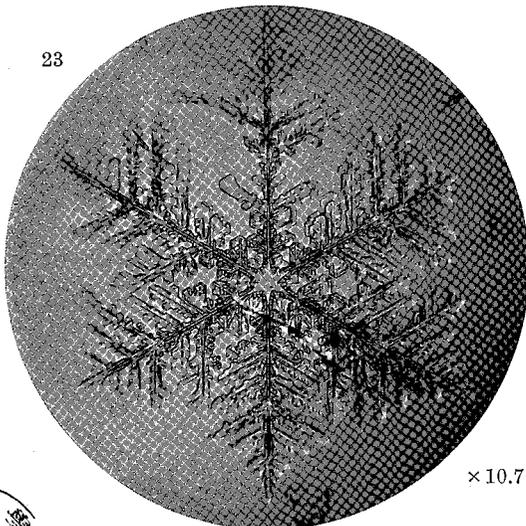
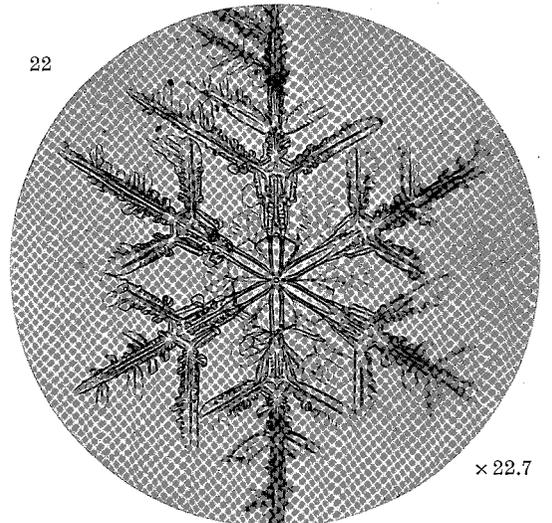
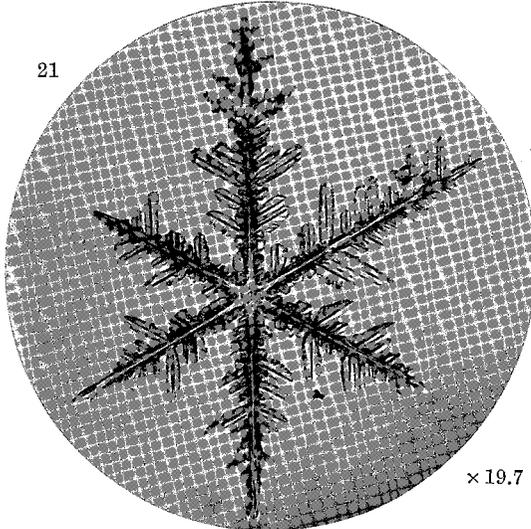
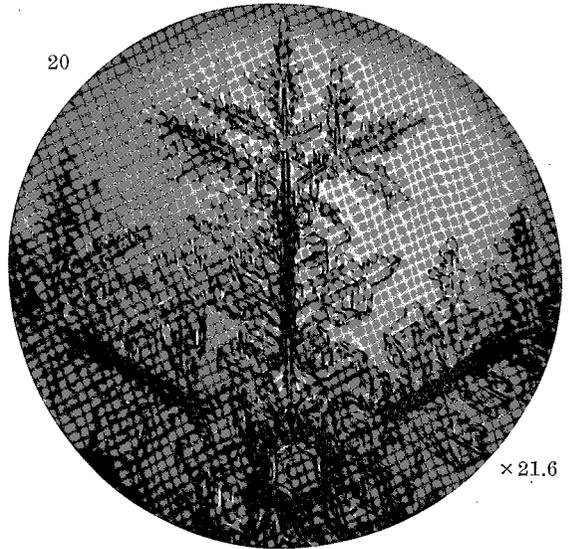
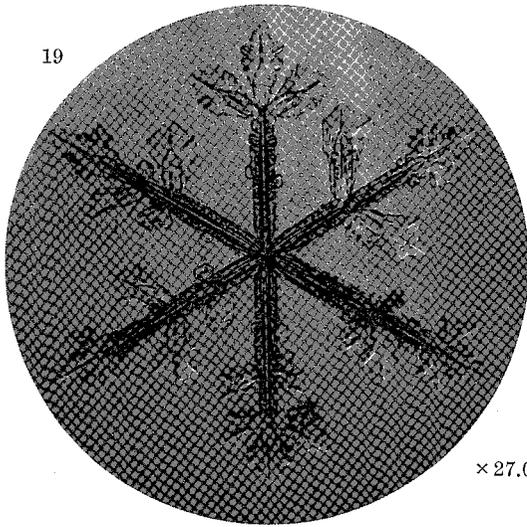
## Plate VII. Spatial dendritic crystals and graupels.

38. Tokati, 1934, XII 25,  $\times 21.3$ . A spatial dendritic crystal of radiating type.  
 39. " , 1935, II 13,  $\times 29.0$ . A large central stone is visible.  
 40. " , 1933, XII 22,  $\times 46.0$ . Assemblage of columns which seems to be the same as the stone in the above example.  
 41. Sapporo, 1935, I 31,  $\times 17.3$ . A sort of the component crystals of powder snow.  
 42. Tokati, 1935, II 13,  $\times 13.0$ . Initial stage of a six-petalled graupel.  
 43. " , " , II 13,  $\times 13.0$ . Intermediate state of snow and graupel, the graupel-like snow.  
 44. Sapporo, " , III 11,  $\times 11.0$ . A six-petalled graupel.

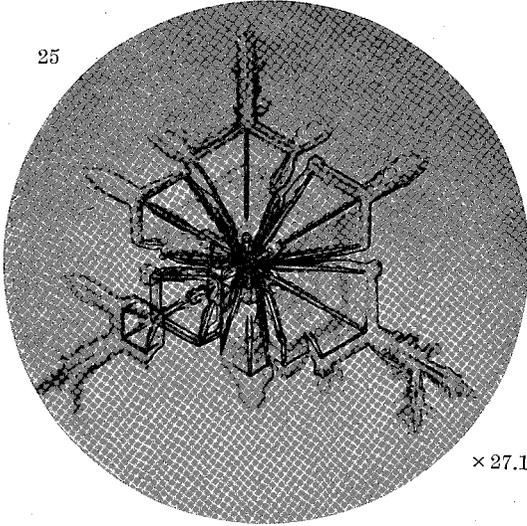






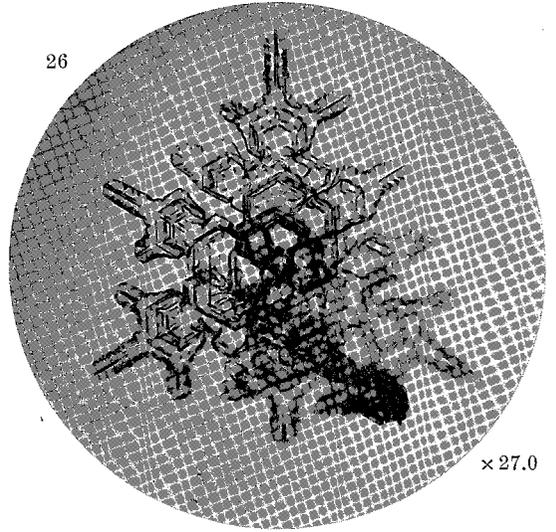


25



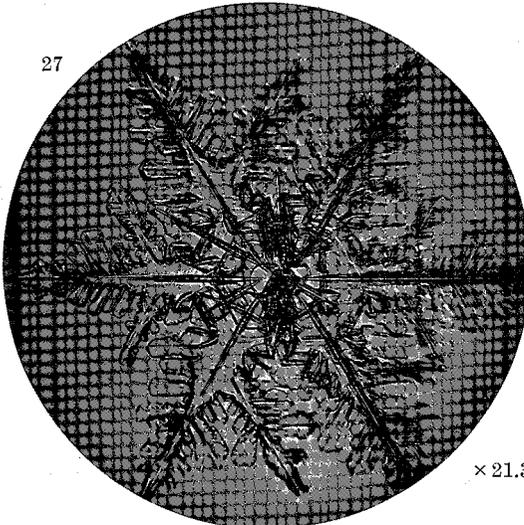
× 27.1

26



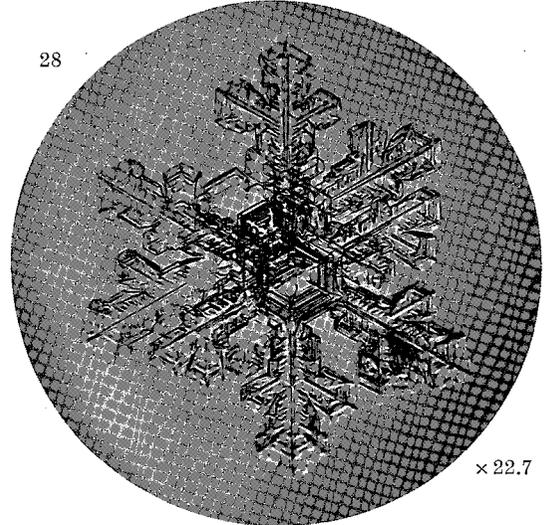
× 27.0

27



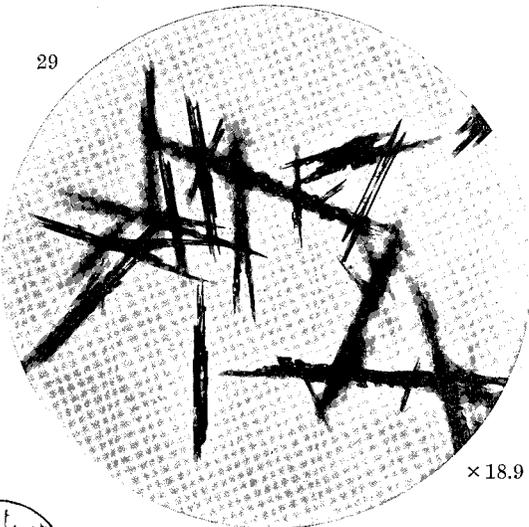
× 21.3

28



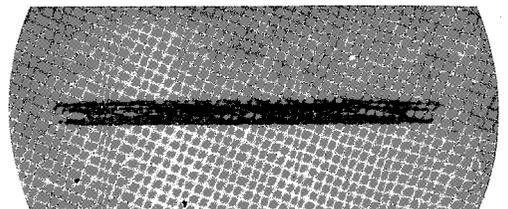
× 22.7

29



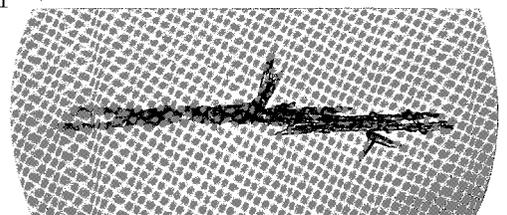
× 18.9

30



× 53.0

31



× 22.1



