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Thin Section of Snow Cut by a Heated Wire.

by

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1. Introduction

For the microscopic texture of ice net work composing deposited snow to be seen, the snow must be cut into a thin section. But it is almost impossible to cut snow with any edged tool such as a knife or a razor because snow is very fragile. However sharp its edge may be, the edged tool will exert a mechanical force upon the snow causing it to break. In order to avoid that trouble the present author took the way of cutting the snow by melting. By nature, melting can be done with application of no or a very little mechanical force.

There have been developed methods to cut snow with edged tools by filling the air spaces in it with solidified liquid.¹⁾²⁾³⁾⁴⁾ Those are very good in that sections as thin as one hundredth of one millimeter can be made. However the procedure requires much time and labour. It is often impossible to carry them out in the field. One millimeter or somewhat less is the minimum thickness of the thin sections which can be made by the present method of cutting by melting. But this method is very simple and takes only a short time. It can easily be practised in the field. As long as there is no requirement of very exact quantitative results, the thin sections made by the present method is sufficiently useful in the study of deposited snow.

2. The apparatus.

The apparatus used for the above mentioned purpose is shown diagrammatically in Fig. 1; the photograph in Fig. 2 illustrates the apparatus. In those figure and photograph, B is a sliding stage and D an aluminium beam supported at X by a pillar. Both the stage and the pillar are placed on wooden board A. The sliding stage carries the snow sample to be cut. To the tip of beam D is attached a U-shaped ebonite frame C, between the two heads of which is stretched a nichrome wire H of diameter 0.1 mm. The wire is heated by a weak electric current (0.3 A) coming from a small dry cell. When placed on the snow sample, the heated wire descends into the snow by melting it.

A rectangular snow sample S cut out of the snow cover in the size of 2.5 cm × 3 cm × 6 cm is placed on sliding stage B. By turning the head of screw P stage B can slowly and smoothly be moved on wooden board A in the direction of the

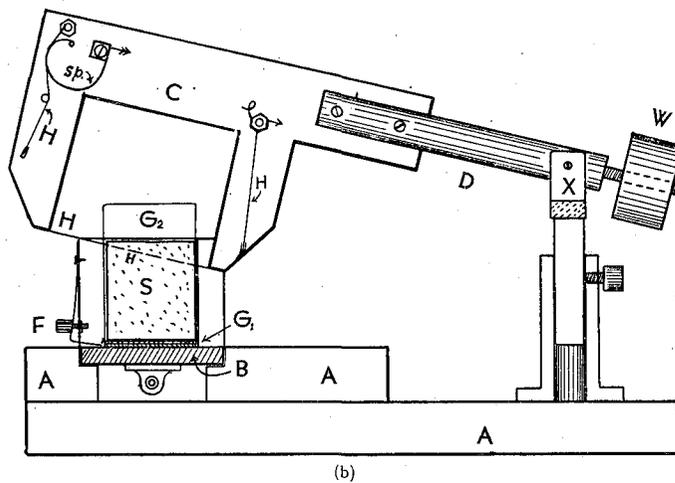
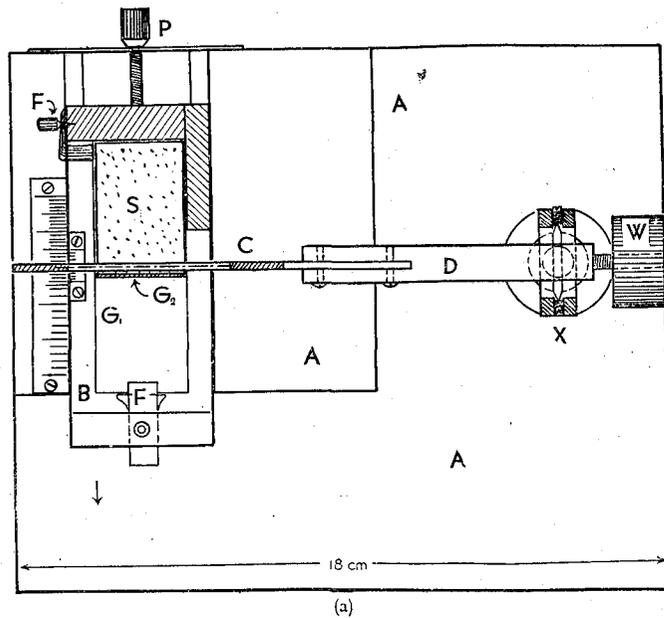


Fig. 1. The apparatus used for cutting thin sections of snow.

(a) Plane diagram (b) Elevation

A: Wooden board. B: Sliding stage. C: Ebonite frame on which a heating wire is stretched. D: Aluminium beam. F: Metal fixer for fixing glass plate G_1 . G_1, G_2 : Glass plates. H: Nichrome wire of diameter 0.1 mm. S: Snow sample from which thin sections are to be cut. sp: Spring for giving tension to heating wire. W: Adjustable counter balance. P: Screw micrometer for moving sliding-stage B.

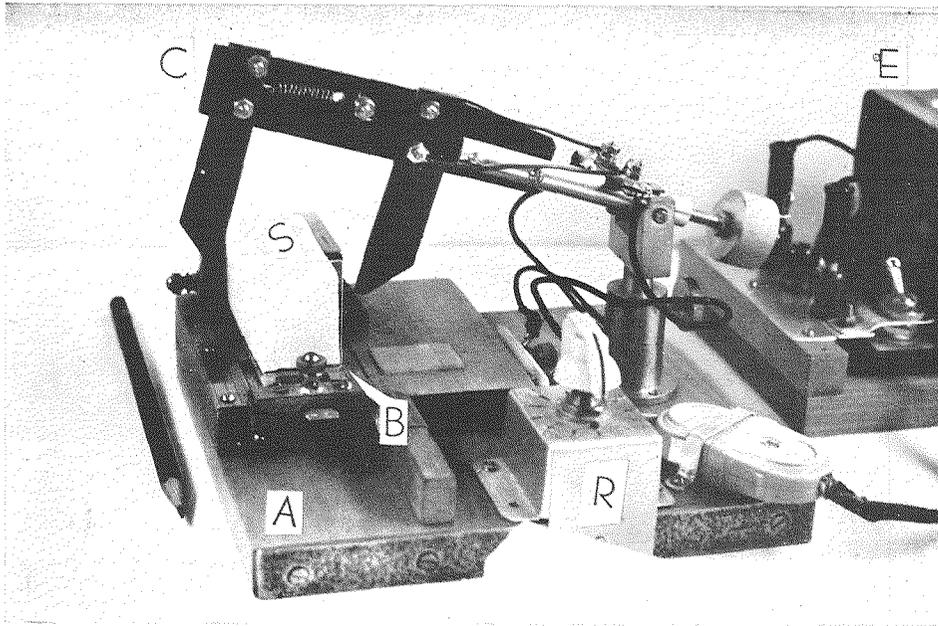


Fig. 2. The apparatus for cutting thin sections of snow as illustrated diagrammatically in Fig. 1.

E: Dry cell of 4.5 V. R: Slide rheostat with 20Ω
S, A, B and C are illustrated in Fig. 1.

arrow shown in Fig. 1 (a). Snow sample S must be so placed on stage B as never to move relative to it. But at the same time the block should easily be removed from the stage for exchange for another. For that purpose thin glass plate G_1 (slide glass for microscope) is frozen to the bottom surface of the snow block and that glass is fixed firmly to stage B by metal fixers F's. The nichrome wire is then placed gently upon the top surface of snow sample S. The wire gets into the snow by melting it. The best cut is made when the descending speed of the wire is about 3 cm/min in the case of moderately compact snow. The descending speed can be adjusted by changing the electric current or by shifting counter balance W attached to the other end of aluminium bar D. As soon as the wire reaches the bottom surface of the sample the cutter should be quickly lifted up by hand. Otherwise the snow will be melted needlessly. The snow on one side of the cut is taken off, and a slide glass G_2 for microscopy is frozen to the cut surface after having been warmed to some extent by the hand. The plate melts the surface slightly and the melted water freezes again fixing the plate to the surface. Then sliding stage B is moved by a distance of 1.1 mm by rotating screw micrometer P. By lowering nichrome wire H a new cut is made in the snow sample at a distance 1.0 mm from glass plate G_2 . In this way a thin section of snow 1.0 mm thick is

obtained already mounted on glass plate G_2 ready for microscopic observation. Several sections may be cut successively from one and the same snow sample by repeating the procedure as described above.

One small dry cell of 4.5 V is sufficient to give the needed electric current. Slide rheostat R shown in the photograph of Fig. 2 has 20Ω as its maximum resistance. It is for adjusting the heating electric current in wire H. To get the best result the current should be changed according to the density of the snow sample. The air temperature should be kept below 0°C throughout the course of the procedure. Any temperature within the range $-3^\circ\text{C}\sim-10^\circ\text{C}$ will most conveniently be used. Lower temperatures are good also.

3. Differences in the microscopic texture of different layers composing snow cover.

The stratified structure of snow cover comes to be clearly visible when the wall of a hole made in the snow cover is sprayed with colored water. Many colored stripes appear on the wall. If the colored wall is blazed with the flame of a blow torch the stripes become much more distinct. Photo. A in Pl. I shows an example of such a sprayed and blazed wall of a hole made in a snow cover one meter and a half thick. The author was interested in why such distinctly colored stripes appeared. There must be some differences in the microscopic texture between the deeply colored portions of stripes and the remaining parts. The stripes must be due to some particular thin layers of which the microscopic texture is so made as to absorb and keep more water than other layers do. Towards the end of winter snow begins to melt on its surface and the melted water permeates down through the snow. There must be something common to that permeation and the movement of the coloured water sprayed on the wall of snow.

Three photographs a, b, c to the right side of Pl. I show thin sections cut out vertically from the snow near the stripe marked (1) in Photo. A of the same Pl. Photo. a is of the deeply colored thin layer of stripe (1). Photo. b shows the fine texture of the snow lying just below stripe (1) in contact with it. The difference in the texture is quite sudden and remarkable. Photo. c shows the texture two centimeters below the bottom of stripe (1). The textures in Photos. b and c are alike.

It should be remarked that the thin sections shown above as well as in the following were not made on the actually colored wall of snow. The wall was colored to the half as shown in Photo. A, Pl. I. The samples of snow for thin sections were taken on the uncolored half at the required positions by the aid of the stripes in the colored half.

Stripe (1) is located in the upper part of the snow cover; the snow layers near that stripe are not old. Photos. b and c in Pl. I show ice networks in which the ice rods are primarily connected in the horizontal direction. The snow crystals which made the snow of those photographs were flat ones of the dendritic type. It has

been noted by de QUERVAIN⁵⁾ that the flat snow crystals tend to take a horizontal position as the snow layer composed of them gradually subsides. The horizontally connected texture of Photos. b and c must be due to that tendency. The photographs in Fig. 3 show another example of snow having the same texture of which both vertical and horizontal thin sections were made. Photo. a is a vertical thin section; it is closely similar to Photos. b and c of Pl. I. The horizontal section shown in Photo. b of Fig. 3 discloses the horizontal connection of flat dendritic crystals. Although the crystals had much changed their original forms, still their individualities can be recognized. As obvious from the photographs, the texture of

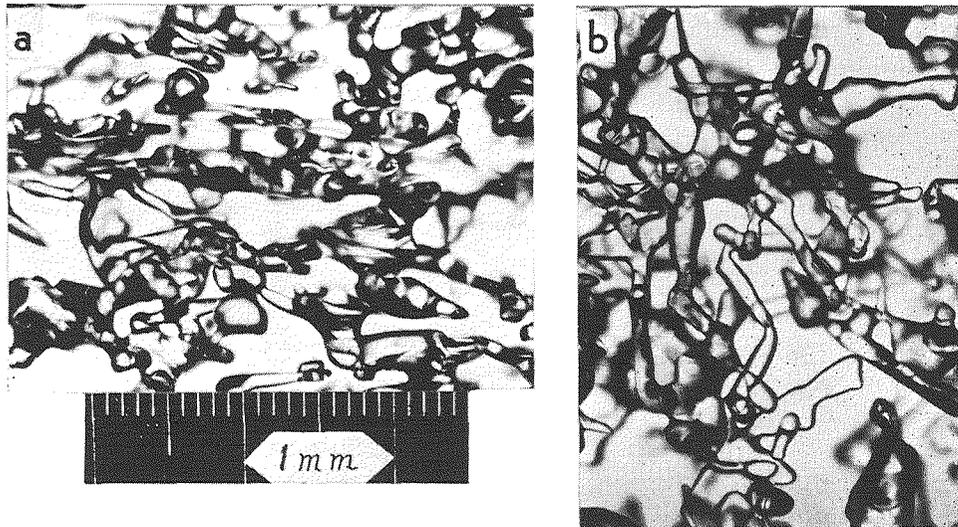


Fig. 3. a Thin section cut vertically from a snow layer composed of dendritic crystals.
b Horizontal thin section of the same layer as illustrated by Photo. a.

stripe (1) (Photo. a, Pl. I) is much more dense than that of the snow layer lying below it (Photos. b and c). Though not shown by photograph, the snow layer which lies above the stripe also has a much coarser texture than the layer of the stripe does. By virtue of surface tension of water, the denser the texture is, the more it can absorb and hold water. When the wall of snow is sprayed, the colored water sprayed onto the snow layer above the stripe is held there only partially because that layer is coarse in texture. The held colored water freezes on its place but the rest flows down the wall to be caught by the layer of a stripe which has a large power to retain water. In this way the snow above the stripe is lightly colored while the layer of a stripe is deeply. The blazing with blow torch flame melts the wall. The melted water also flows down washing out the wall above the stripe. That part of the wall is cleaned while the layer of a stripe becomes

colored more deeply by absorbing the rinsings. The layer of a stripe can take in as much water as flowing down the wall by pulling it inwards into the inside of the wall. The pulled-in water freezes to make a strong colored plate of ice. When a cut is made perpendicular to the wall of snow, the layer of a stripe is found to be colored inward some distance.

Besides stripe (1) many other stripes can be seen in Photo. A, Pl. I. Of those the ones marked (2), (3), (4) and (5) are chosen and their textures, together with those of the snow layers lying next to or near them, are shown in Pl. II and Pl. III. It is the general tendency for the ice network of a snow layer to become thick and dense as it lies deeper within the snow cover. The layer of a stripe also increases in density with the depth the density always keeping greater than that of average snow.

One will notice a sudden change in texture in the level at two-thirds height in Photo. B-a, Pl. II. This is a thin section made vertically across the bottom surface of the layer of stripe (2). The snow layer underlying stripe (2) became a coarse granular snow by being subjected to warm weather while it lay uncovered until the next snowfall.

Such wall of snow as described above in the natural state is not of the same whiteness. Some stripes can be discerned on it even before it is sprayed with colored water. But those natural stripes do not always coincide with the colored ones. Stripe (1) appeared as a natural stripe comparatively brighter on the white background of the snow wall. It was deeply tinted when sprayed; the natural and colored stripes coincided in this case. But, in the case of stripe (2), the layer which could be discerned before spraying was not the layer of the colored stripe itself but the granular snow layer lying just beneath it. That granular layer appeared dark on the white wall of snow.

In the above case the wall of snow was looked at with the light falling on the wall and then reflected by it. If the wall is lighted from behind and is looked at with transmitted light, there may come into appearance some certain feature of the wall which distinguishes the coloured stripe (2). Indeed, as will be described below, a sharp boundary was found also at the top of that coloured stripe by illuminating the wall in such a way. A portion of the wall, as illustrated in Photo. (b), Fig. 4, was made into a vertical plate of 2 cm thickness by removing the snow on the rear side of the wall. When the sun illuminated the plate from behind there appeared many stripes which were larger in number than on the sprayed wall. At the level of coloured stripe (2) a distinct dark band can be seen, both the top and the bottom of it being sharply distinguished. The layer of granular snow lying below it, which was dark in reflected light, is now bright in transmitted light.

Generally, with two snow layers of the same density, the one composed of smaller ice particles is less transparent than that of larger ice particles. And, if

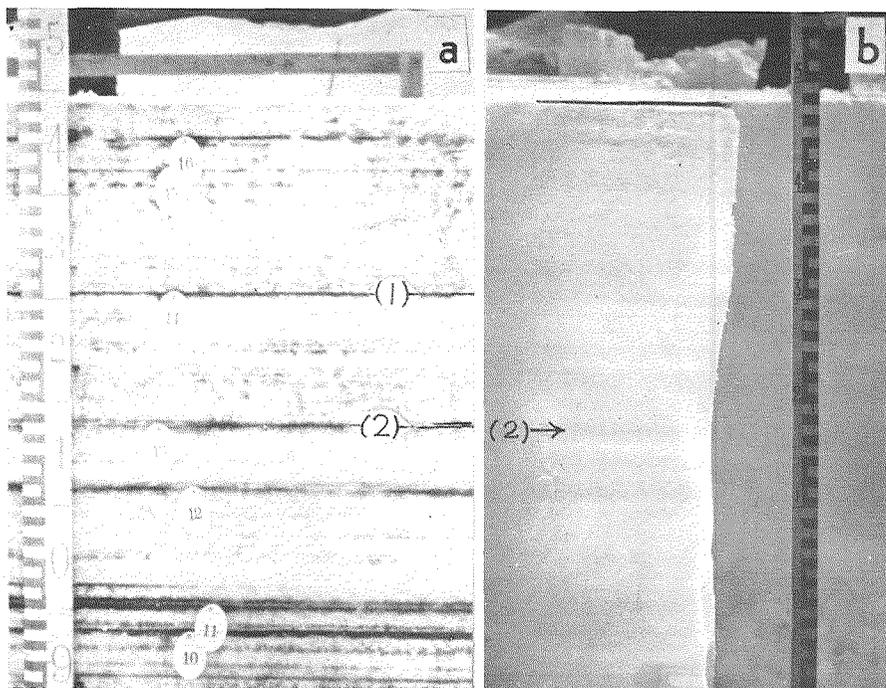


Fig. 4. a The upper part of the same wall of snow as illustrated in Photo. A, Pl. I. The bottom of this picture is 90 cm above the ground.
 b Shade figure of the snow wall in the natural state.

the particle size is the same in two different layers, the one with larger density transmits less light than that of smaller density. If snow reflected light on its very surface, the more transparent it is, the less light it would reflect. But actually the reflection on snow is not a surface reflection but an internal one. The light falling upon the snow surface penetrates into the snow and is reflected back by the ice grains lying in the interior. It is the transparency of snow itself that helps the light in penetrating. Therefore the power of transmitting light does not decrease the power of reflection in the case of snow. This is the reason why the wall of snow does not disclose its layers in the reflected light although actually the layers have different power of transmitting light.

Stripe (3) is an example of such stripes that cannot be seen as a natural stripe. Photo. B-b, Pl. II shows the texture of snow just above that stripe while Photo. B-c shows that of the stripe itself. The density is certainly different between the two. But a difference of such an extent is not large enough to make them distinguishable in the natural state.

Photo. B-a, Pl. III shows the texture of the snow layer just beneath stripe

(4). This photograph is placed here not in connection with that stripe but to show the general textural features of old snow layers located deep in the snow cover. The snow layers between stripes (4) and (5) may be considered to be of the same like texture. Stripe (5) is the thickest and the most distinguishable. Its texture is shown in Photo. B-b, PI. III. The ice network is very compact; the density of this layer of stripe (5) was found to be as large as 0.47 gr/cm^3 . No other stripes had such great density. At the bottom surface of the layer of that stripe, the texture changes suddenly into such as shown in Photo. B-c, PI, III. This is the texture of depth hoars. It consists of large hoar crystals joined with one another by weak ice bonds. The density of this layer of depth hoars was found to be 0.35 gr/cm^3 . This value of density cannot be said to be as small as one possessed by a snow layer. But the fact that the constituent ice elements are large hoar crystals gives that layer a thinly scattered character in the sense that there are rather large spaces between the ice elements. Due to such a situation the layer of hoar crystals can hold much less water than a layer does of the same density but composed of small ice elements.

There are two possible cases in which the colored stripe appears. The one is the case of thin snow layer which is denser than those lying above and below it; stripes (1), (2) and (3) belong to that type. In the other case a thick snow layer of large density lies upon one of thinly scattered character and colored water flowing down from above is stopped at the boundary between the two to make a colored band. The thick roof of a snow cave holds much water; the water is stopped from dropping off the ceiling by being kept hanging as drops. The like occurs at the boundary mentioned above. Stripe (5), which should rather be called a band than a stripe, is made because of such a situation. As it is located in the lower part of the snow cover a great amount of colored water comes down towards it. But the thinly scattered space which the layer of depth hoars possesses makes the colored water accumulate above on the top level of that layer. The large thickness of stripe (5) and the diffused character of its top edge could be understood in this way.

4. Change in texture occurring to one and the same snow layer.

Each of the snow layers composing a snow cover is compressed by those lying upon it. Consequently the texture of each layer is changed. But it is not only the compression that causes change in texture but thermal phenomena such as sublimation and condensation of water vapour also have marked influence upon the texture. Once the present author followed under a microscope an aggregate of snow crystals placed on a net of silk fibre as it changed in texture in the cold room of his Institute.⁶⁾ In that case, however, the aggregate was acted upon only by the thermal phenomena without any compression. If thin sections are made at intervals from one and the same snow layer within a snow cover, the actual change caused by both compression and thermal phenomena can be studied.

Photo. A, PI. IV shows the wall of a hole made in a snow cover on Jan. 11th,

1958 at Sapporo. The thick top layer which had been deposited on the previous day was chosen for observation. Photos. B and C in the same Pl. show respectively the wall of snow 15 days (on Jan. 25th.) and 47 days (on Feb. 26th.) after the day of deposition of the layer in question. That layer is indicated by the arrows in these photographs. It should be remarked that the temperature never rose to 0°C throughout that period. The microphotographs, Photos. a, b and c, are respectively the vertical thin sections made on the snow layer on the same days as Photos. A, B and C were taken. The snow crystals which made the snow layer were graupels. In Photo. a where the snow layer is only one day old the original particles of graupel are still clearly distinguishable. In his experiment in the cold room the author observed just the same change in texture of graupel in their early stage of metamorphosis. Such an accord is quite understandable because the snow layer was not yet overlaid by any other layers; the snow layer was free from any compression as was also the aggregate of graupel in the experiment. In the following two weeks the texture changed from that in Photo. a to that shown in Photo. b. The particles of graupel had entirely lost their individuality and the constituent ice elements of the texture had grown much in size. The author saw such growing of the ice elements in his experiments but the grown elements were not joined with one another as they were in the actual case of Photo. b. During the period from Photo. a to Photo. b, upon the snow layer in question many additional snow layers accumulated and compression which was non-existent in the experiment had come into effect. The passage of a month next brought the texture to the condition shown in Photo. c. The constituent ice elements had become still larger while the joints between them were very much strengthened.

In the experiment where the aggregate of snow crystals underwent changes with no external load laid upon them, the main cause of change in texture seemed to be sublimation of the ice elements and the condensation of water vapour onto them. Indeed the change was stopped completely when the sublimation and condensation were prevented by immersing the aggregate in oil.⁷⁾ Such phenomena as volume diffusion, surface migration of molecules and plastic deformation which are known to have large effect in the case of sintering of metal grains or of ceramic grains must have, if any, worked very weakly in the above experiment. But, in the case of the actual snow layer, some of them, if not all of them, seem to have largely come into effect to give rise to the strong joints between the growing ice elements.

5. Snows of the same density but different in texture.

Density is one of the most important characters of snow which are widely used to specify it. On the other hand it is well known that snows of the same density can still show very different features. This must be due to the fact that their textures are not the same. Differences in the kind of snow crystals deposited as well as the conditions to which the snow is subjected after its deposition give rise

to variations in textures. Microphotographs of thin sections shown in Pl. V give some examples of different textures of snows which have almost the same density of $0.28\sim 0.30$ gr/cm³.

Photo. a, Pl. V is a snow layer of graupels one week after deposition. The snow has settled to such an extent as to reach a density of 0.30 which is twice as large as the initial density. But individual particles of graupel are still clearly distinguishable. This kind of texture, the snow being as composed of small icy balls, can only result from an accumulation of graupels. The textures in Photos. b and c are characterised by ice rods connected mainly in the horizontal directions. The vertical connections are rather weak, especially in the case of Photo. c. The texture of Photo. b was made from needle-like snow crystals while that of Photo. c from large dendritic crystals. As mentioned above in regard to Photo. b, Pl. I, the dendritic crystals tend to lie horizontally while they are undergoing metamorphosis in the settling snow layer. Needle-like crystals also do the same. The horizontally connected textures of Photos. b and c come from such a situation.

The texture exhibited in Photo. d, Pl. V is one in which the constituent ice elements are connected mainly in the vertical direction. This is the structure composed of depth hoars found usually in the lower part of a snow cover. Another example of this kind of texture is shown above in photo. c, Pl. III. Photos. e and f of Plate. V show the most commonly found textures of compact snow. Such textures are composed of differently shaped ice granules joined together to make an irregular three-dimensional ice network. The granules are connected evenly in all directions unlike those of Photos. b, c and d.

6. Discussion on the diameter of the cutting wire.

If those parts of the ice network of snow that are melted by the cutting wire got lost of themselves, a section much thinner than 0.1 mm might be made by the present method. However, the melted water never disappears but permeates a short distance into the interior of the thin section to change the texture in its outer layer. Then, if the section is made very thin, the texture will be changed throughout the entire thickness. At least the inner parts of the section must remain free from any change if one wishes to see the true texture of the snow. Such a change in texture might be minimized if the amount of the melted water were reduced by the use of a very thin wire. But too thin a wire gives rise to another trouble: after the wire has got through the sample the cut surfaces of the snow stick together not to be separated. Therefore, if the wire should be very thin, it should not be so thin as to allow the cut surfaces to unite again. A consideration follows on the smallest diameter which the cutting wire could have.

For the sake of simplicity let it be assumed that the ice network of snow is made of ice rods of radius a . In Fig. 5, A, B, C, D shows one of the ice rods which is to be melted by the cutting wire W of radius b moving from left to right. The ice rod will be melted in that part indicated by E, F, G, H which is as long as the

diameter of the wire. During the process of melting some part of the melted water may spread on the wire to evaporate while the remainder may make thin films covering the side surfaces of unmelted portions of the ice rod. Those films freeze afterwards onto the ice rod to thicken it. It is difficult to say exactly what will happen to the melted water,

but, after the cutting wire has passed through, there must remain spherical caps of water E, K, F and G, L, H on the cut ends of the ice rod as shown in Fgi. 5. Each of the spherical caps has a radius r_s , which, is equal to the diameter of the ice rod, that is, $r_s=2a$. The spherical cap of water with this very radius is the one which can stably rest on the cut end of the ice rod. The stability can be understood in the following way. Water can also rest on the side surface of the ice rod in the form of a thin cylindrical film. If the surface tension of water is denoted by σ , and the thickness of the film is neglected as compared to the radius of the ice rod, the water in this film is subjected to a pressure p_0 which exceeds the atmospheric pressure P by σ/a , that is, $p_0=P+(\sigma/a)$. Suppose that there rests on the cut end a cap of water

with radius r . Then the water in it is acted upon by a pressure $p=P+(2\sigma/r)$; the excess of pressure due to surface tension is $2\sigma/r$ in this case. If $p=p_0$, both the cap and the film can remain as they are with no exchange of water between them. For p to be the same as p_0 , $(2\sigma/r)$ must be equal to σ/a ; therefore $r=2a$. This value of r was denoted above by r_s . Let the height of the cap, the height of its tip above its base, be denoted by h . In the above case of $r=r_s=2a$, h is equal to $h_s=a(2-\sqrt{3})=0.268 a$. It is obvious that the larger h is, the more water the cap contains and the smaller its radius r becomes. The smaller radius means the larger value of pressure p in the cap. Therefore, if h is larger than h_s , p exceeds p_0 and the excess $(p-p_0)$ of pressure causes water to move from inside the cap onto the side surface of the ice rod to extend the water film upon it. With the movement of

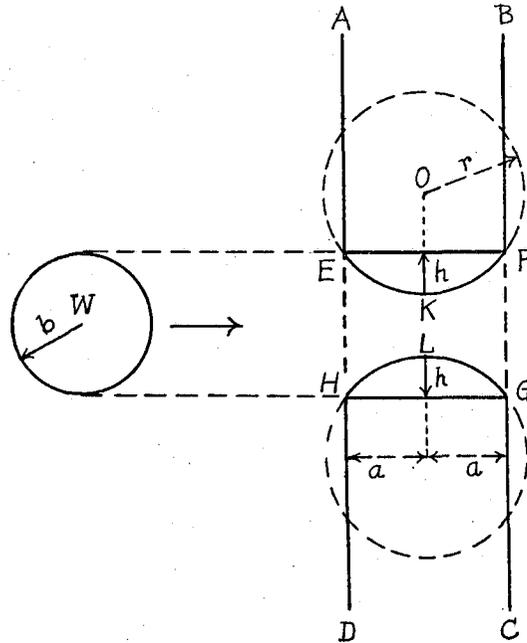


Fig. 5. A, B, C, D is a long cylindrical ice rod of radius a to be cut by heating wire W of radius b . The wire melts the portion E, F, G, H and leaves dome-like drops of water E, K, F and H, L, G on the cut surfaces E, F and H, G. The height of the domes is denoted by h .

water h decreases while r increases, accompanied by reduction of p . The movement of water stops when the radius r reaches r_s , because then the excess of pressure vanishes. On the contrary, when h is less than h_s , r is larger than r_s with the result that p is less than p_0 . Then the water is forced to move from the film into the cap. If the film is sufficiently extended to supply as much water as is needed, the cap will attract more of the water until it attains the height h_s . There the movement of water stops. In this way a cap of any height h tends to attain the height h_s in virtue of the surface tension of water; the cap of water with that height is stable.

The cutting wire melts the ice rod at the portion E, F, G, H indicated in Fig. 5. That portion, being melted, gives water of volume $v_w = 2\pi k a^2 b = 5.77 a^2 b$, where k stands for the ratio of the density of ice to that of water. At 0°C k is equal to 0.917. The stable cap h_s high resting on the circular cut end of the ice rod of radius a contains water of the volume $\pi a^3 \left(\frac{16}{3} - 3\sqrt{3} \right) = 0.430 a^3$. Let v_0 denote twice this volume; $v_0 = 0.860 a^3$.

Out of the melted water of volume v_w , only a portion having volume v_0 can stay on the cut ends of the ice rods. The excess $(v_w - v_0)$ of water mostly goes onto the side surfaces of the ice rods to give them some changes in form. Such changes should be kept down to a minimum by reducing the excess water. That can obviously be done by the use of a thin cutting wire. But its radius b must always be kept larger than h_s . Otherwise the two caps on the cut ends of the ice rods will touch or interpenetrate each other to bridge over the cut. The bridge of water thus made freezes after the cutting wire has passed by with the result that the sides of the cut are connected again by an ice bridge. This means that the snow sample cannot be separated even though a cut has actually been made through it. In this way the minimum radius allowable to the cutting wire is found to be $h_s = 0.269 a$, with the least excess water of which the volume is calculated as $0.685 a^3$. Water of half this volume, that is, of $0.343 a^3$, spreads on the side surface of either of the cut ice rods to thicken them by freezing. Let it be assumed that the excess water makes a film on the side surface extending a distance equal to a from the cut end of the ice rod. The above value $0.343 a^3$, the volume of the excess water, divided by the area $2\pi a^2$ of the film yields as its thickness the value $0.055 a$: the ice rod is thickened by the excess water only by 5.5% of its own radius near its cut end.

The height h_s of the stable cap of water is nearly equal to a quarter of the radius a of the ice rod. Therefore a cutting wire one fourth the diameter of the ice rod is the best in that it leaves the least excess water with no subsequent bridging over of the cut.

Actually the ice rods composing the ice network of snow are never of the same thickness. In compact snow some of the ice rods can be thick as 0.7 mm while

their mean diameter is 0.3~0.4 mm. The thickest ice rods in the soft snow shown in Photos. B(a) and B(b), Pl. 1 are 0.4 mm in diameter; their mean diameter seems to be about 0.2 mm. Judging from such circumstances, 0.1 mm may most conveniently be chosen as the diameter of the cutting wire. This wire will be too thin for some ice rods and they will be joined again after they have been cut. But so long as those rejoined ice rods are small in number, the sample of snow can easily be separated at the cut. As stated above in Section 1 the present author uses a cutting wire of 0.1 mm in diameter with good results. The cut ends of the ice rods can be seen under a microscope when it is focused on the top surface of the thin section of snow made as described in Section 1. Some of the ends look to have been sharply cut while others are rounded, clearly indicating that the excess of melted water has frozen around them. A little shift of the focus into the interior of the thin section reveals the true texture of snow which has not been subjected to any effect of the cutting. All the photographs shown in the Pls. were taken with this internal focusing. It should be noticed that a cutting wire thicker than 0.1 mm should be used for such a large-grained snow as shown in Photo. B(c), Pl. III. Otherwise the snow sample will stick together after the cut is made. Indeed the author failed often with snows of this sort if he did not replace the cutting wire with a thicker one.

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PLATE 1

- A. Vertical wall of a hole dug in a snow cover. The wall was sprayed with colored water and blazed with the flame of a blow torch.
- B. Microphotographs of vertical thin sections.
 - a) of the snow at the position of colored stripe (1)
 - d) of the snow just below stripe (1)
 - c) of the snow lying 2 cm below stripe (1)

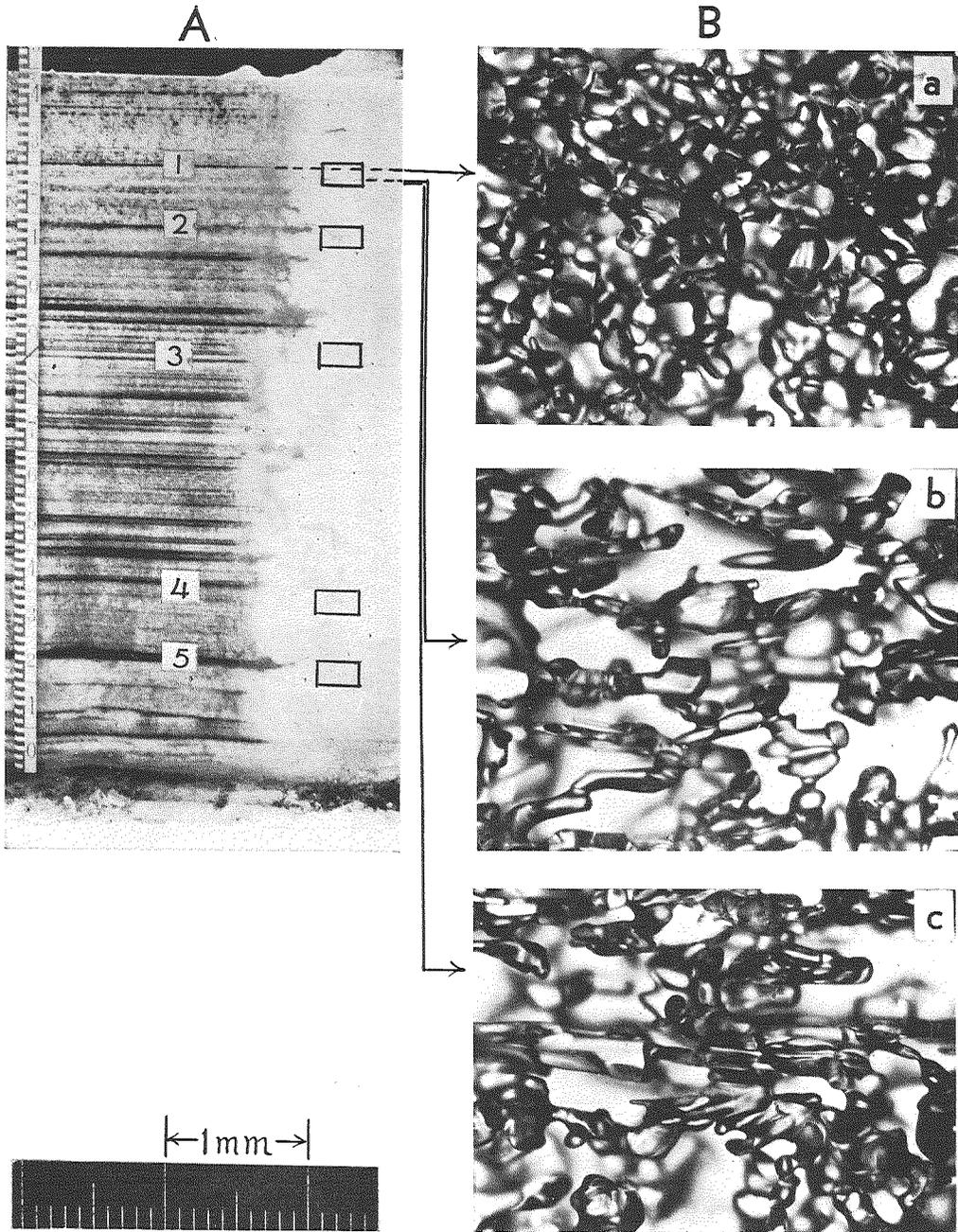


PLATE II

- A. Colored wall of the hole dug in a snow cover.
- B. Vertical thin sections.
 - a) across the bottom boundary XY of stripe (2); stripe (2) lies just above a layer of coarse granular snow.
 - b) of the uncolored snow just above stripe (3)
 - c) of the snow within stripe (3)

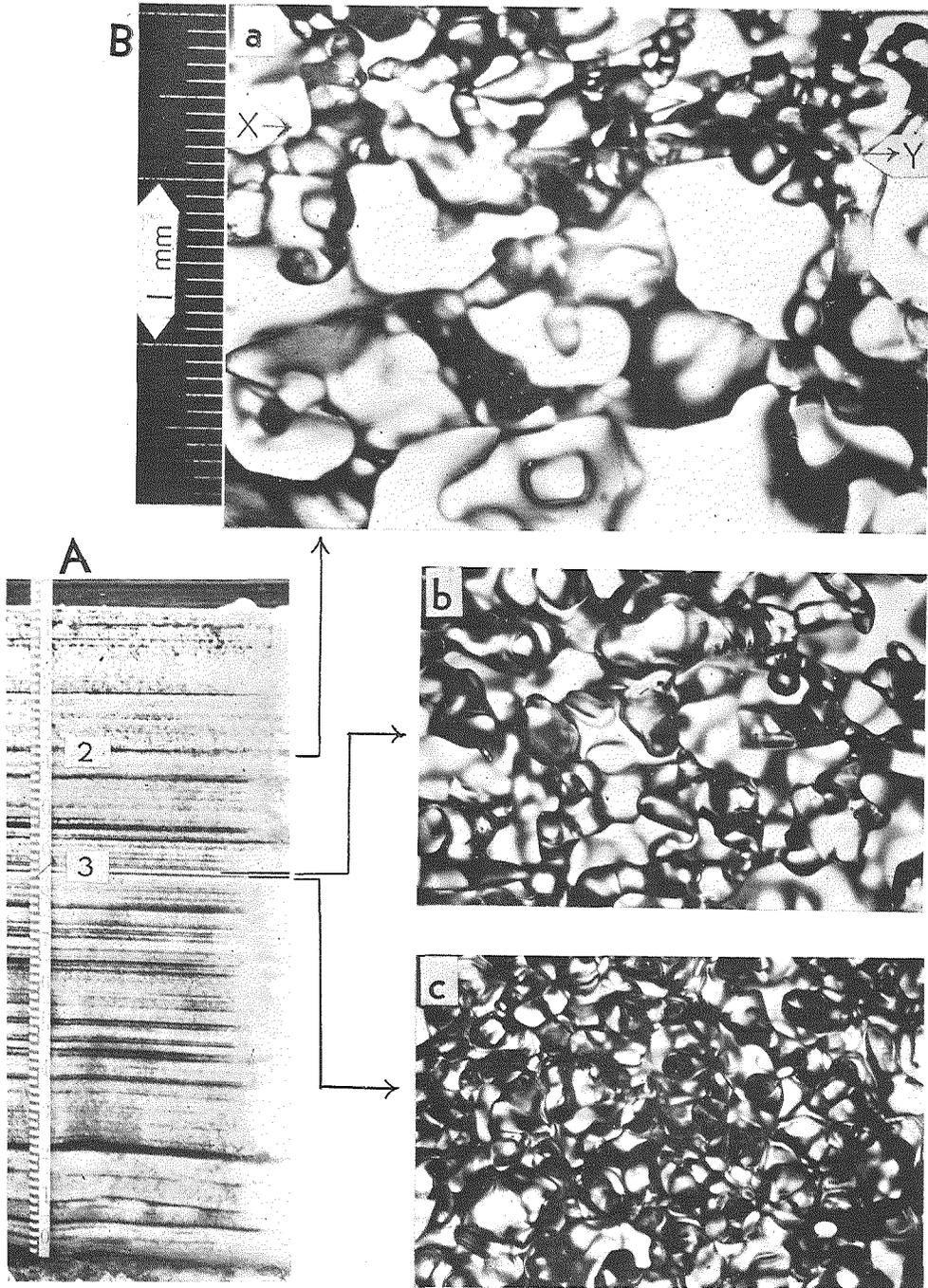


PLATE III

- A. Colored wall of the hole dug in a snow cover.
- B. Vertical thin sections.
 - a) of the snow lying below stripe (4)
 - b) of the snow within stripe (5)
 - c) of the depth hoar layer lying just below stripe (5)

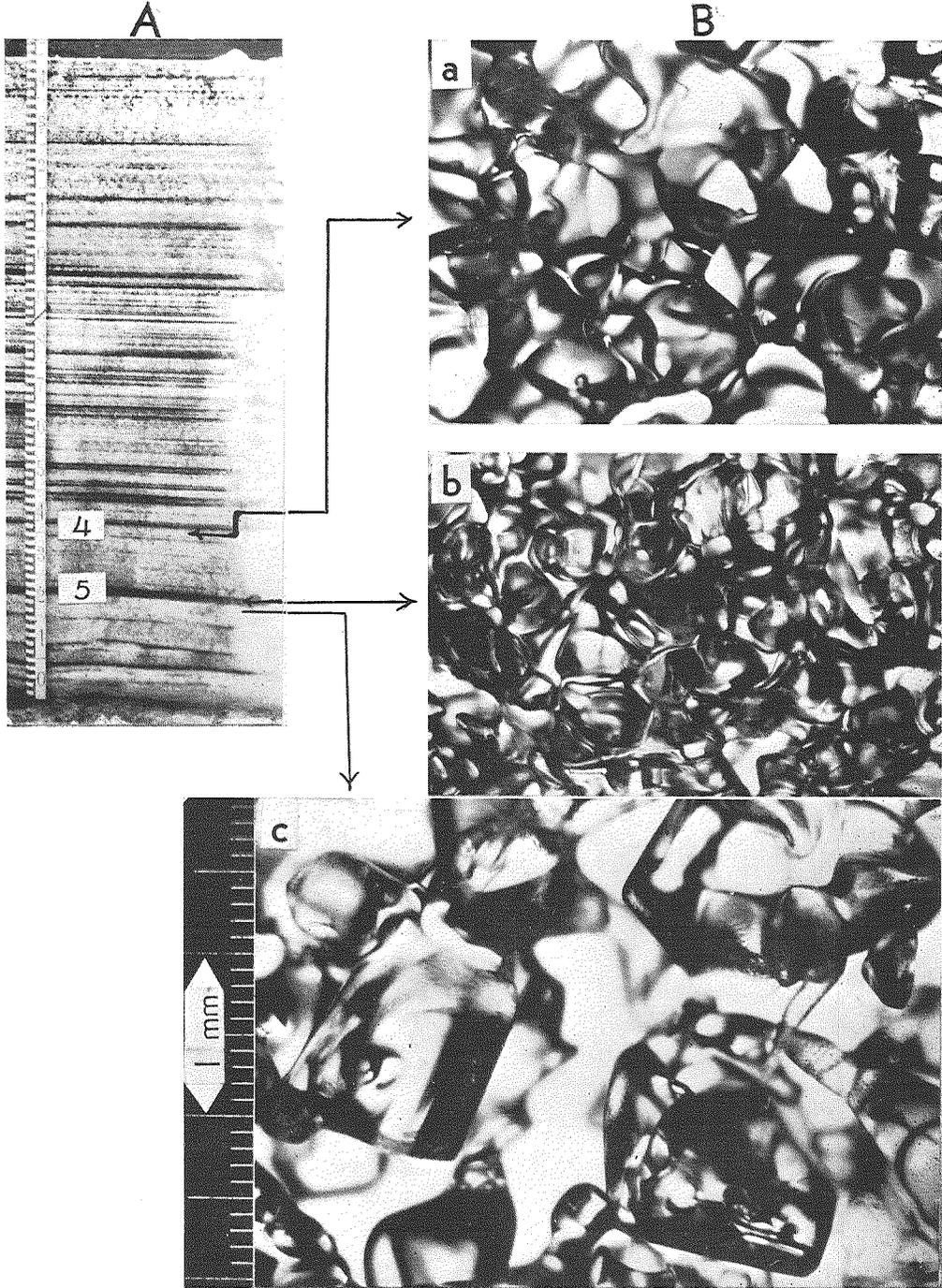


PLATE IV

Wall of holes made in the same snow cover at Sapporo on different days in 1958.

A) Jan. 11th **B)** Jan. 25th **C)** Feb. 26th.

Vertical thin sections cut on the three different days from one and the same snow layer (J-10 layer) which is indicated in Photos. **A**, **B** and **C**.

a) Jan. 11th (the next day after the deposition of J-10 layer)
b) Jan. 25th **c)** Feb. 26th

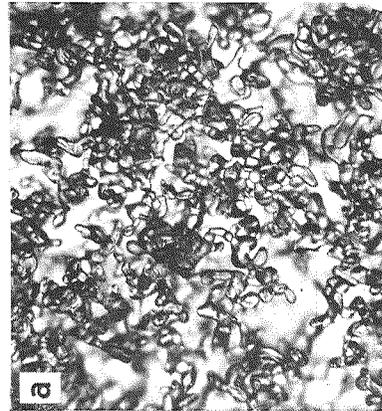
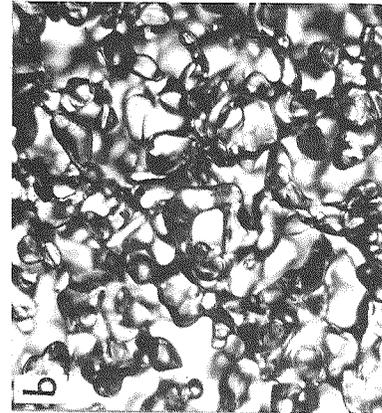
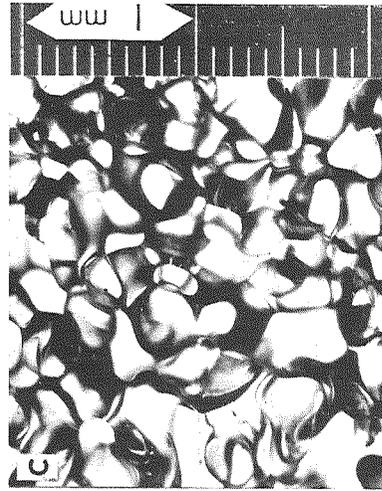
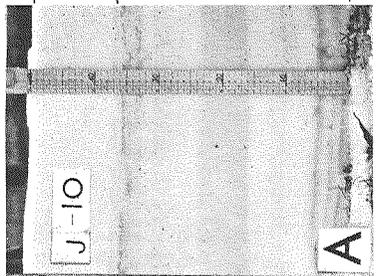
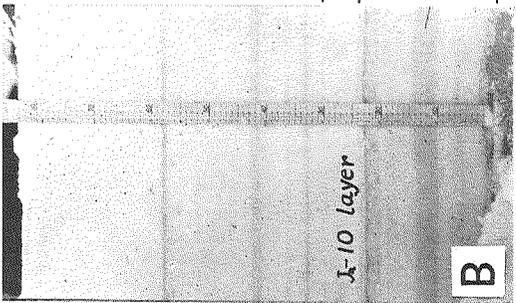
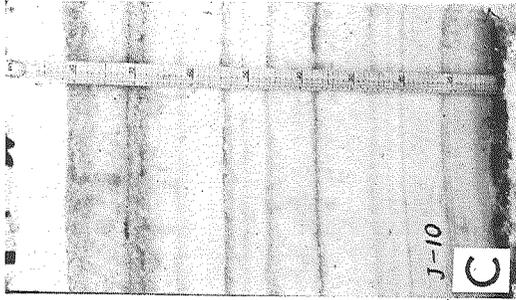


PLATE V

Vertical thin sections cut from different snow layers which have the same density.

- a) Snow composed of accumulation of graupels
- b) Snow layer made by deposition of needle-like crystals
- c) Snow layer composed of dendritic crystals
- d) Depth hoar layer
- e, f) Ordinary compact snow

