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Scientific Note

Section planes of snow specimens visualized with sudan black B

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Abstract: A technique for preparing section planes of snow specimens dyed with sudan black B was introduced. After the pour space of a snow specimen is filled with aniline and frozen solid, a section plane is microtomed and rubbed with sudan black B powder for contrast enhancement. Compared with previous methods, this technique was simple and provided high-contrast images and reduction of noise on a section plane.

1. Introduction

Deposited snow has a network of snow particles. The variety of the network complicates the mechanism of heat and vapor transfer in snow, and also affects the mechanical behavior of snow. Various techniques for preparing thin sections or section planes of snow specimens for photomicrography and image analysis have been developed by researchers (*e.g.* Shimizu, 1958; Kinosita and Wakahama, 1960; Narita, 1969, 1971; Kry, 1975; Perla, 1982; Good, 1987; Brzoska *et al.*, 1998).

A thin section of snow provides a transmitted photomicrograph and information on crystal orientation and grain boundaries using polarizing sheets. A method with aniline developed by Kinosita and Wakahama (1960) seems to be the best method to obtain high contrast photographs and qualitative information on the network. However, the method is time consuming and results of structural parameters depend on the thickness of the thin section (Keeler, 1969; Perla and Ommanney, 1985); for example we overestimate grain size from the image. Besides this, we cannot reconstruct the whole image of the network from thin sections since the method does not lend itself to the preparation of continuous parallel sections through a sample (Perla and Dozier, 1984).

In contrast, the method of section planes is rather simple and can be used to prepare serial sections through a sample to reconstruct the three-dimensional structure of snow. Narita (1969, 1971) adopted the section plane method with water blue powder (water-soluble) in order to determine a specific surface of snow sample from a section plane.

* The deceased.

In this method, a snow specimen filling its pore space with aniline is frozen. After shaving it on a microtome, the section is rubbed by water blue powder which dyes the cross sections of ice particles. However, air bubbles in the specimen which form when the aniline is poured cause noise in the image analysis, because the air bubbles make cavities on a section plane which are also rubbed by water blue powder and cannot be distinguished from ice particles. It is difficult to avoid such mixing of air bubbles when liquid fills the snow specimen. Besides this, small cracks often occur when the filler freezes and shrinks (ex. Fig. 6 of Perla and Ommanney, 1985) and they are colored by water blue powder as well. Perla (1982) summarized techniques for making good images of section planes in snow specimens and introduced an improvement by adding a water-insoluble dye to the filler to enhance photomicrographic contrast, but the noise as described does not seem to be removed by the method.

In this paper, we propose a technique for preparing section planes of snow dyed with sudan black B powder for contrast enhancement. Sudan black B is a kind of oil-soluble stain which only dyes an organic solvent such as aniline.

2. Method

Figure 1 illustrates the procedure. In this method, aniline saturated by water ($NH_2C_6H_5$, melting point is $-11.7°C$) is adopted as a filler. The following steps are similar to those of Perla (1982) and Perla and Dozier (1984), but they previously dyed the filler with water-insoluble stain and did not use sudan black B.

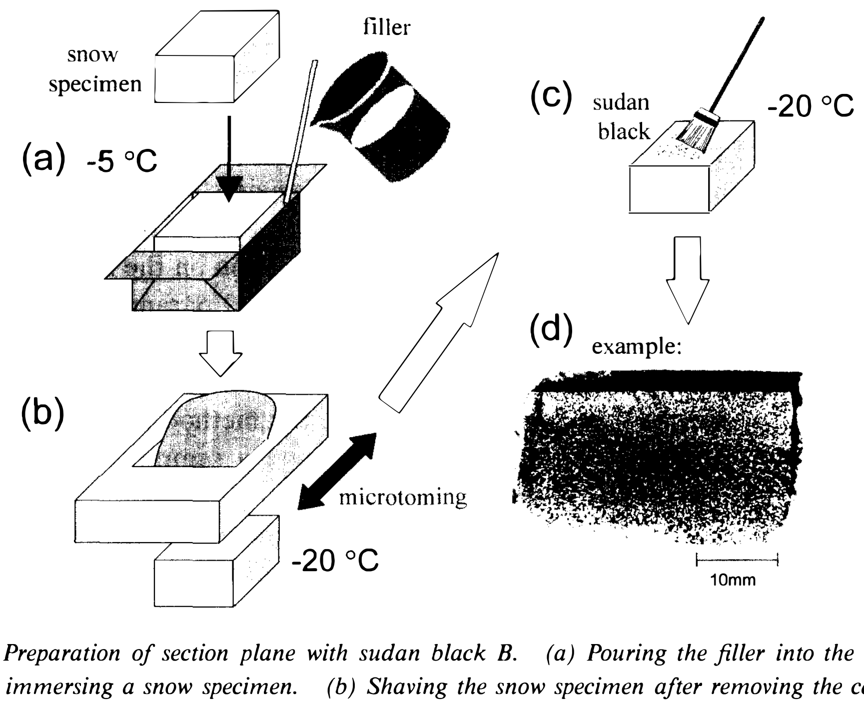

Fig. 1. Preparation of section plane with sudan black B. (a) Pouring the filler into the case and immersing a snow specimen. (b) Shaving the snow specimen after removing the case. (c) Dyeing a section with sudan black B. (d) Example: a section plane visualized with sudan black B. The sample (vertical section) is a layer of partly decomposed precipitation particles sandwiched between layers of rounded grains.

1) A snow specimen is placed in a small case (50 mm by 30 mm by 20 mm in size) made of aluminum foil, and a filler is poured into the case at $-5^{\circ}C$ slowly until the specimen is completely immersed, so as to decrease the possibility of remaining air bubbles in the filler (Fig. 1a).

2) After setting the case at $-20^{\circ}C$ and freezing the filler (it takes several hours), the case is removed and the specimen is clamped in a microtome and shaved to obtain a flat plane (Fig. 1b).

3) A new section is dusted with sudan black B powder and gently rubbed with down or soft brush (Fig. 1c).

4) The filler surface of the section is dyed black gradually. It takes more than five minutes at $-20^{\circ}C$ or one to two minutes at $-15^{\circ}C$ to obtain the highest contrast (Fig. 1d).

5) Finally, surplus powder on the section is brushed and then photographs can be taken.

3. Examples

Granular snow (350 kg m^{-3} in density) was used as a sample. Figure 2a shows a transmitted photomicrograph of a thin section (approximately 1 mm in thickness) made by the aniline method (Kinosita and Wakahama, 1960). Figure 2b shows a section plane, of which the filler was aniline, dyed with sudan black B. A high contrast image was obtained because while only the filler was dyed black the section of ice particles remained. To compare with this method, Fig. 2c shows a section plane dyed with water blue according to the method of Narita (1969, 1971). The section in Fig. 2c was obtained by shaving 0.1 mm from the section in Fig. 2b; accordingly, they had almost the same image. Since water blue dyed both ice particles and small hollows caused by air bubbles in the filler, they cannot be distinguished from each other. We can find such small hollows dyed with water blue in Fig. 2d, which shows a section obtained by shaving 0.05 mm from the section of Fig. 2c. The right black part in Fig. 2c and Fig. 2d was large air bubbles dyed with water blue, such a large hollow does not occur with scrupulous care in pouring the filler. In contrast, in Fig. 2b the powder of sudan black B dyes both the filler and the hollows. Accordingly, we can obtain less noisy photomicrographs with sudan black B.

In this method, there was a tendency for ice particles to become unclear and contrast to decrease as the density of the snow specimen decreased. In such cases the section must be allowed to stand for several hours after rubbing sudan black B powder, the surface temperature of the section must be raised to near the melting point of the filler in order to dye the filler well. Figure 3 shows a high contrast image taken using a slide projector with strong light from 0.5 m away for three minutes as the light source (150 W) at $-20^{\circ}C$. To light the section plane perpendicularly, a half mirror is useful as described in Nishida and Narita (1996).

4. Discussion of pore fillers

Aniline has been often used for filler in preparing thin sections and section planes

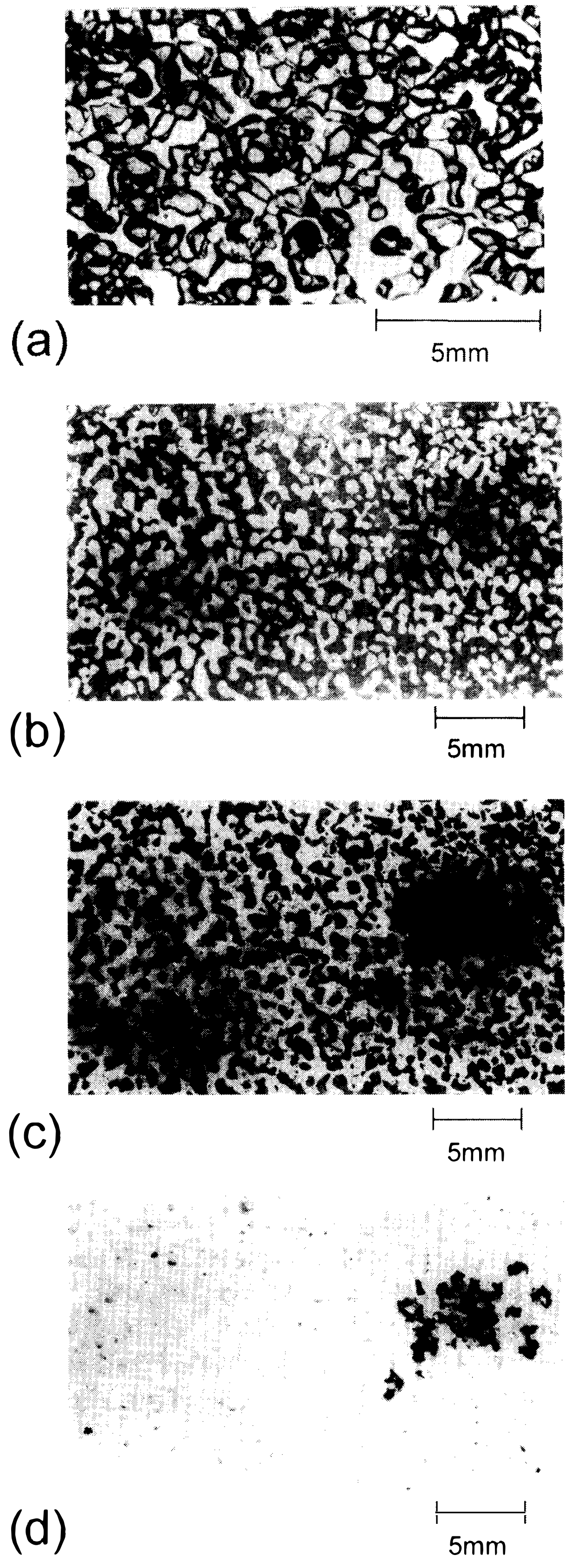

Fig. 2. Thin section and section planes of granular snow (density: 350 kg m^{-3}). Aniline is adopted as a filler. (a) A thin section approx. 0.2 mm in thickness by the aniline method. (b) A section plane dyed with sudan black B. (c) A section plane obtained by shaving the surface shown in Fig. 2b and dyeing with water blue. The contrast of black and white was inverse to Fig. 2b. (d) A section plane obtained by shaving the surface shown in Fig. 2c.

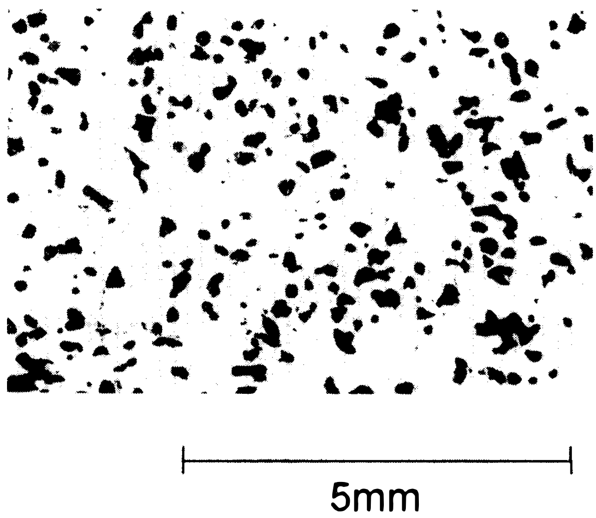

Fig. 3. A section plane of a snow specimen (density is 200 kg m $^{-3}$ *dyed with sudan black B. The contrast of black and white was inverse because the dyed surface slightly melted and reflected the perpendicular lighting to the specimen.*

of snow because it has many advantages as a filler; melting point below 0°C, water insolubility, low viscosity, small shrinkage from liquid to solid, hard enough to shave when it freezes and density close to that of ice (Kinosita and Wakahama, 1960). However, aniline is reported to be toxic and carcinogenic, so the cold room must be well ventilated and the shavings must be disposed of immediately.

On the other hand, there are some alternatives to aniline for filler. Perla (1982) recommended supercooled dimethyl phthalate ($C_6H_4(COOCH_3)_2$, melting point +5.5°C) as a filler for preparation of section planes. Pure dimethyl phthalate can supercool more than 10°C below its melting point and remain in the liquid state when it is poured into a snow specimen at −5°C. Since the melting point is much higher than that of aniline, it is satisfactory if the laboratory temperature is in the range of from −10°C to −5°C during microtoming and surface preparation (Perla, 1982). Although dimethyl phthalate was dyed with sudan black B (Fig. 4), uniformity of the image with aniline (Fig. 2b) seemed to be better than that with dimethyl phthalate. In addition, dodecane ($CH_3(CH_2)_{10}CH_3$) was reported as a filler by Fukuzawa (personal communication, 1994) and has been used for preparation of thin sections, but the solid surface of dodecane could not be dyed with sudan black B. Accordingly, aniline is the best filler for the preparation of a section plane with sudan black B at present.

5. Concluding remarks

A method of preparing section planes of snow specimens was improved with sudan black B as a stain for a filler. The advantage of this method is that we can obtain section planes of high contrast and low noise using sudan black B, which dyes the filler. While it is obvious that the preparation of section planes is still slow and tedious, the procedure will eventually be automated (Schneebeli and Krüsi, 2001). A new method, for example, MRI (Magnetic Resonance Imaging) (Edelstein and Schulson, 1991; Ozeki

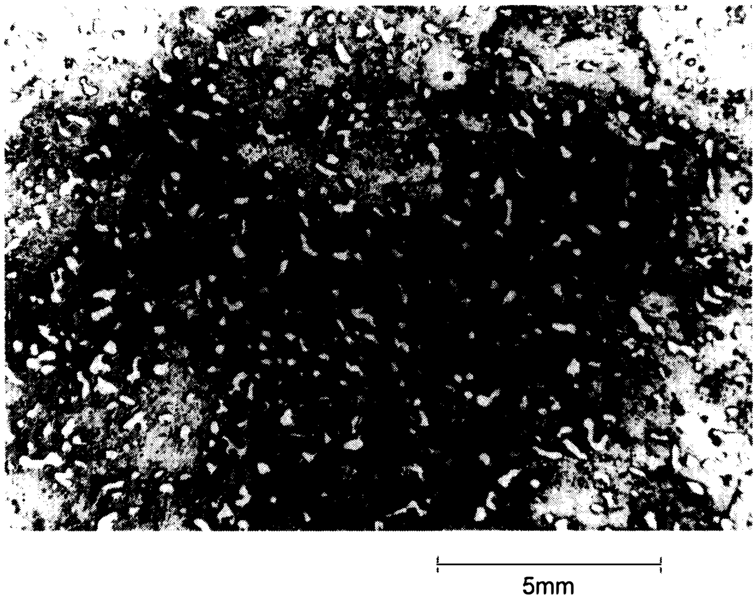

Fig. 4. A section plane of a snow specimen dyed with sudan black B. The filler is dimethyl phthalate.

et al., 2000; Lange *et al.*, 2001) and X-ray computerized tomography (Coléou *et al.*, 2001) is also expected for constructing three-dimensional structure of snow in future studies as well.

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