STRUCTURE OF 413.5-M DEEP ICE CORE OBTAINED AT MIZUHO STATION, ANTARCTICA

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Abstract: Ice cores down to a depth of 413.5 m were obtained at Mizuho Station (70°41.9′S, 44°19.9′E), East Antarctica, in April to July, 1983. Grain features (size, periphery length and shape factor) and air bubble morphology were examined from thin section photographs taken within a month after the recovery of the ice cores. They showed discernible differences from those of the similar examinations previously done of ice cores of the same place recovered in 1972. The differences are attributed to the fact that the latter examinations were based on the photographs taken much later after the recovery. Fabric patterns were also examined at selected depths also within one month after the recovery.

1. Introduction

The glaciological party of the 24th Japanese Antarctic Research Expedition (JARE-24) worked at Mizuho Station (70°41.9′S, 44°19.9′E) from April to July, 1983 to recover a 13-cm diameter ice core down to a depth of 413.5 m with a thermal drill. The recovery rate was 99.9% (NARITA *et al.*, 1985). The core will be henceforce called the JARE-24 core.

Cores brought to the surface are subjected to stress relaxation which significantly changes their physical properties. For instance, the chemical composition of cores may not depend on the stress relaxation, but the density depends directly on the relaxation. GOW (1980) proposed an order of time-priority in various examinations of ice cores, in which the density measurement was given the first priority. Of the JARE-24 cores, the density was measured immediately after their recovery (NAKAWO and NARITA, 1985).

This paper presents the results of investigations of grain features, fabric patterns, and air-bubble morphology, which were given the next priority in GOW's proposal. The investigations were done with thin sections prepared within a month after the recovery of the cores. Similar investigations were already done for 147.5-m deep JARE-13 cores which were obtained at the same place in 1972, although the thin sections were prepared more than one year after the recovery (NARITA *et al.*, 1978). The comparison of the present and the previous investigations will show the effect of the relaxation.

2. Results

2.1. Core quality

Core quality was good down to a depth of 80 m. Between 80 to 120 m, cracks were found running diagonally at intervals of 0.15 to 0.5 m. Many horizontal cracks concentrated in a band of 0.1 m thick were found at a depth about 120 m; below 120 m the horizontal cracks were found at intervals of 5 mm or less. Crack features were quite similar to the case of the JARE-13 cores (NARITA *et al.*, 1978).

2.2. Thin section preparation

The thin section preparation was done at an ambient temperature of about −30°C in a snow cave. Two vertical sections, orthogonal to each other, and one horizontal section, each about 5 cm × 4 cm × 1 cm, were cut with a band saw at designated depths about 20 m apart. The three sections were made because we intended to examine three-dimensional shape of grains and air bubbles. After one side of the section was planed carefully with a microtome, the section was put on a glass plate thinly coated with aniline. Then the plate and the section were warmed to −10°C so that the aniline would melt and fill the space between the section and the glass plate. Again the temperature was lowered to fix the section on the plate. The surface of the section was planed with the microtome to the thickness of about 1.5 mm for photography or less than 1 mm for fabrics examination with a Rigsby stage.

When observing or photographing the thin section, it was placed in a warm bath at −10°C so as to melt aniline and make it transparent. Aniline is superior to the water for bonding, because the aniline is used around −10°C and no cracking occurs during thin section preparation.

2.3. Grain size and shape

Figure 1 shows photographs of vertical sections at 9 depths which indicate a rapid increase in grain size with depth down to 100 m. Many horizontal lines found in photographs below 158.4 m were the cracks in poor-quality core. The grain area (S) and periphery length (L) were measured from enlarged prints of these photographs, and the shape factor (ϕ), that is, the ratio of the circumference (L_c) of a circle which has the same area of a grain to the periphery length (L) of the grain, was computed. The vertical profiles of these quantities are shown in Figs. 2a, 2b and 2c; open circles show the mean values of dispersion bars, and black dots and dotted bars are those for the JARE-13 cores. The mean grain area increased greatly from 2.8×10^{-6} m^2 at 70 m to 5.1×10^{-6} m^2 at 158.4 m and then slightly to 7.8×10^{-6} m^2 at 262.9 m. The periphery length profile showed a similar tendency, which reflects almost a constant shape factor.

2.4. Fabric patterns

Fabric patterns, or the distribution of optical axis direction of grains, were examined from horizontal thin sections with the aid of the Rigsby stage. Those at the depths of 100.1, 201.9 and 401.9 m are shown in Figs. 3a, 3b and 3c, respectively. It is seen that the deeper the depth, the more concentration takes place around the

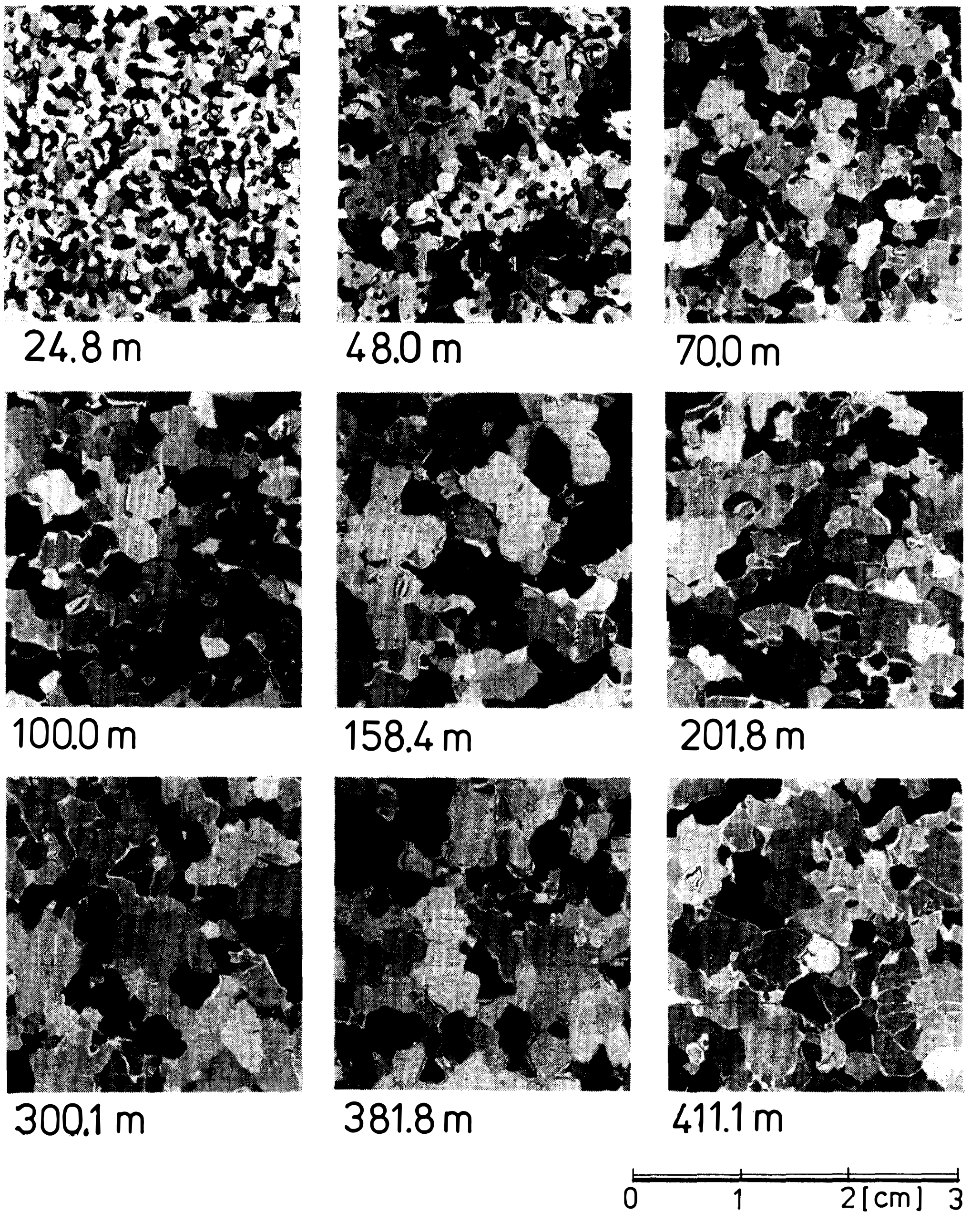

Fig. 1. Microphotographs of vertical thin sections of fresh JARE-24 core, taken under crossed polarized light.

vertical plane shown by a dotted line. Figure 3d is the fabric pattern of the JARE-13 core at a depth of 88.7 m, which will be discussed later.

2.5. *Air bubbles*

Figure 4 shows 6 photographs of 1.6-mm thick sections; it is seen that cylindrical bubbles almost disappeared at 100 m. Concentration and diameter of air bubbles were measured from these photographs and the results are shown in Figs. 5a and 5b. The increase in concentration from 100 to 140 m and from 250 to 350 m means the occurrence of splitting of bubbles at these depths.

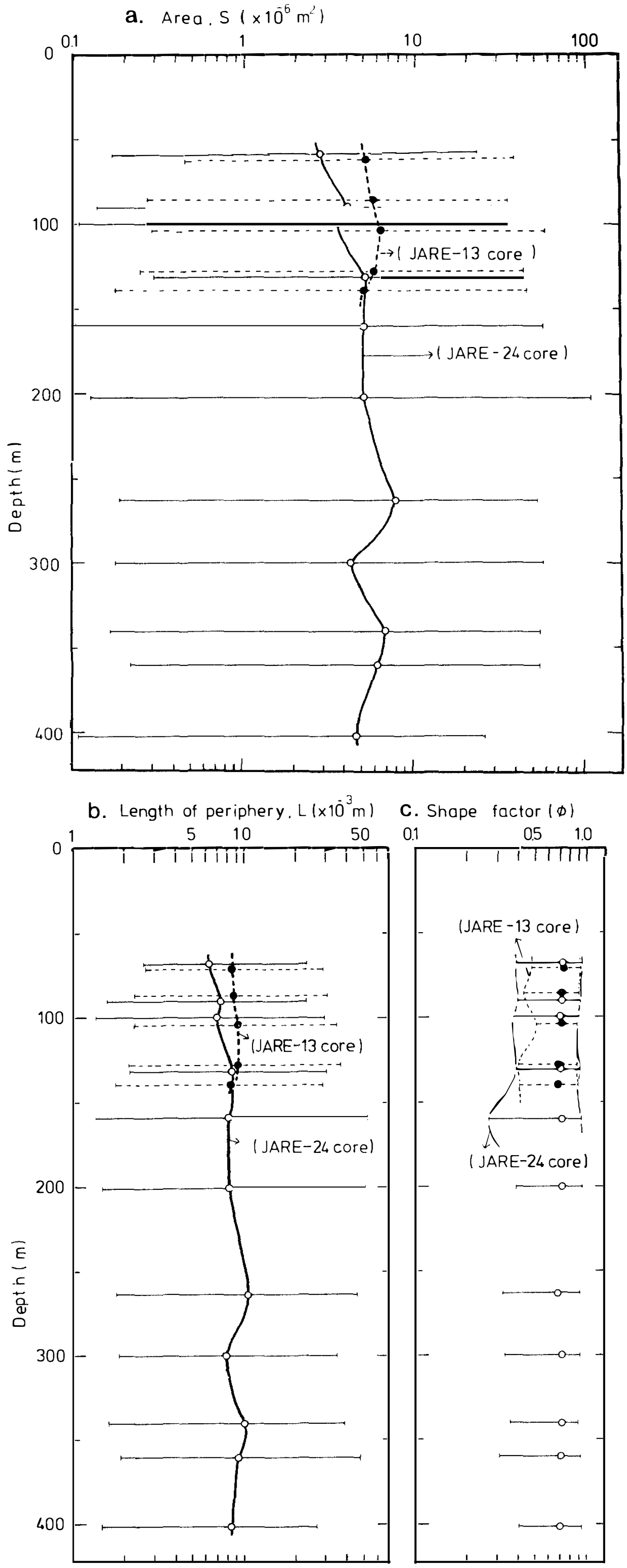

Fig. 2. Vertical profiles of size (S) (a), length of periphery (L) (b), and shape factor (ϕ) (c) of crystal grains. Open circle and closed circle show the arithmetic mean values of the JARE-24 core and the JARE-13 core, respectively. The full and dotted lines mean the range of measured values for the respective cores.

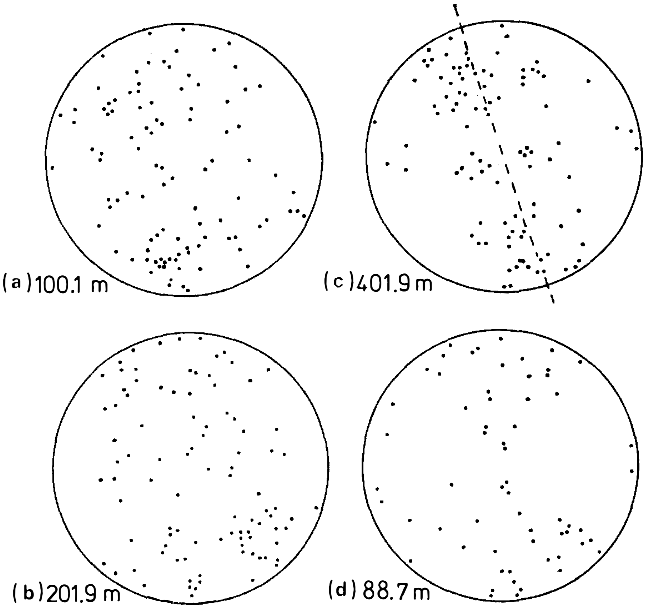

Fig. 3. C-axis orientations of the JARE-24 core at depths of 100.1 m, 201.9 m and 401.9 m, and of the JARE-13 core at 88.7 m.

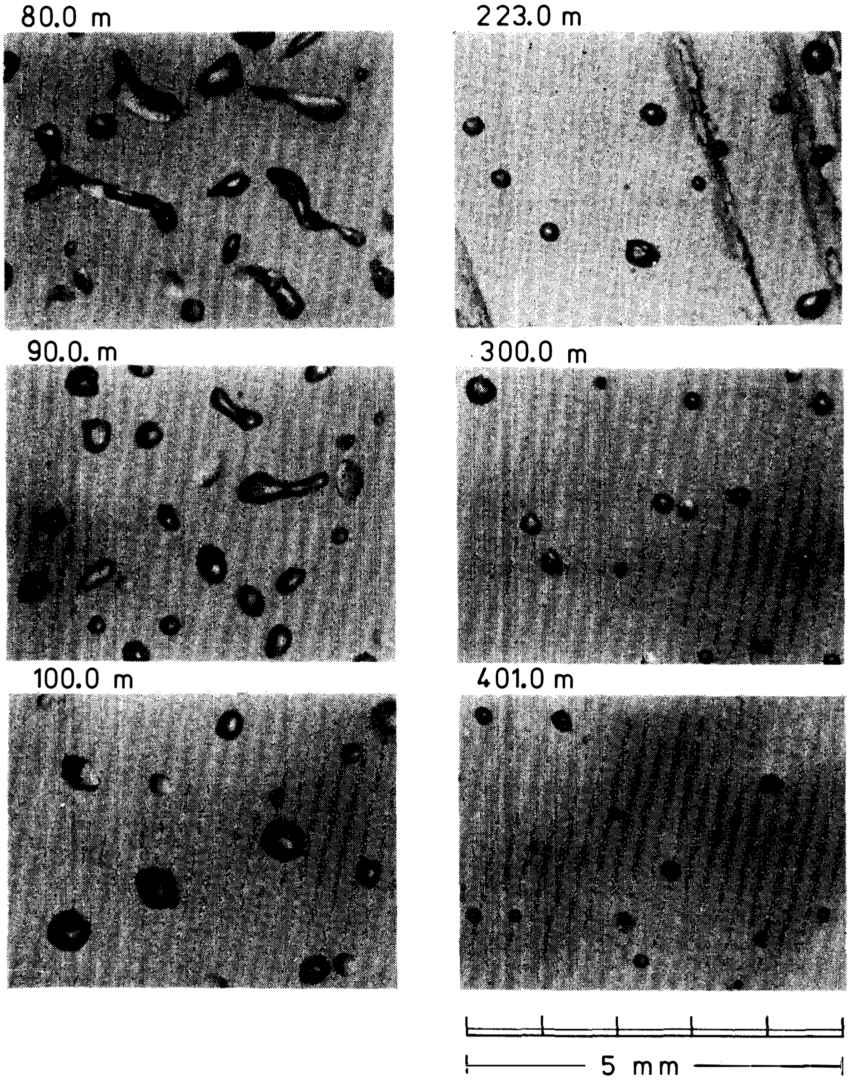

Fig. 4. Microphotographs showing shapes of air bubbles at six different depths.

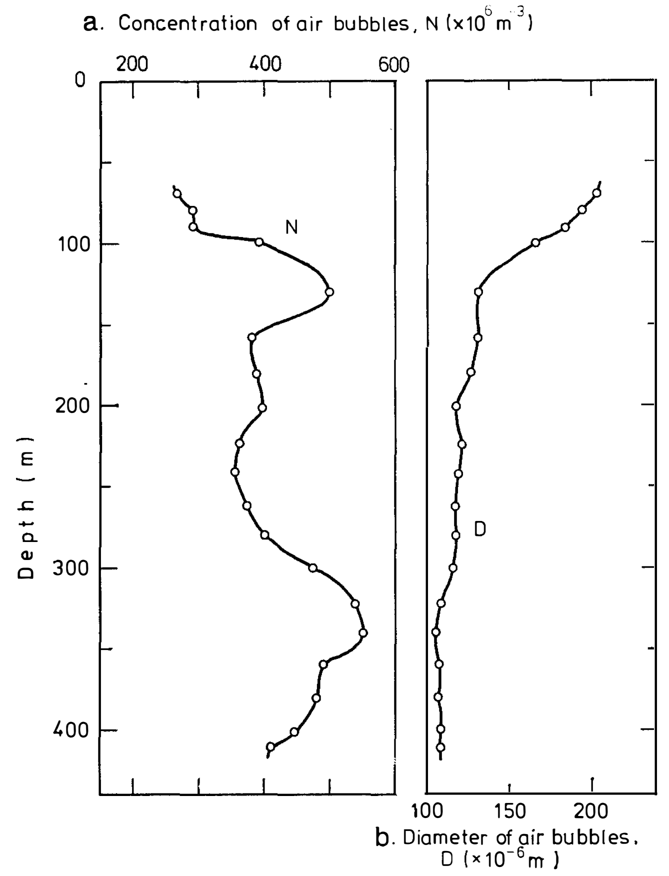

Fig. 5. Concentration (a) and arithmetic mean diameter (b) of air bubbles plotted against depth.

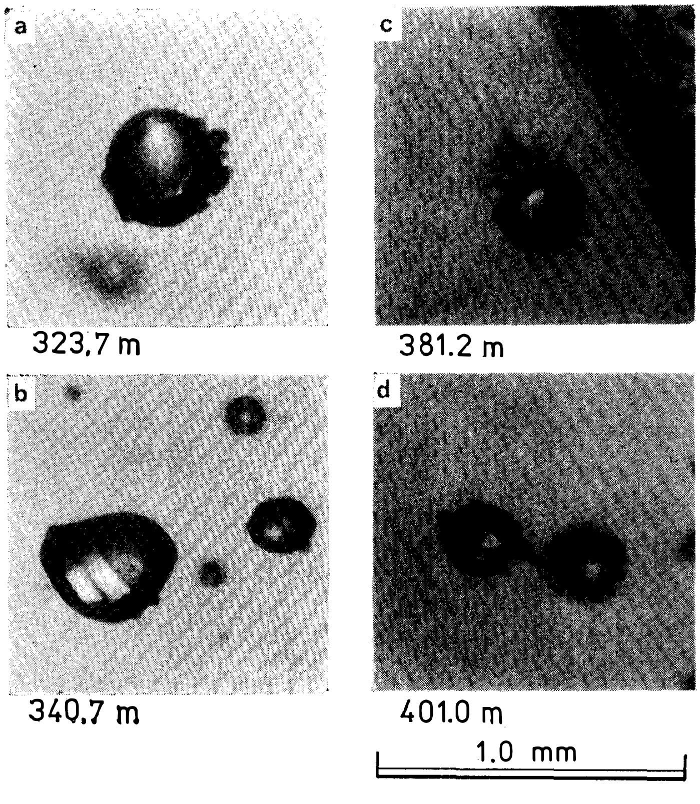

Fig. 6. Microphotographs showing pressure-cracked bubbles (323.7 m, 340.7 m and 401.0 m in depth) and many small bubbles like a cavity cluster around air bubbles (381.2 m in depth).

The shape of each air bubble was examined in detail with high magnification microphotographs. Below 180 m, several percent of bubbles had "brims" as seen in Figs. 6a, 6b and 6d. The brims may be caused by thermal shock and pressure release. At 381.2 m, an air bubble accompanied by many small ones was found as shown in Fig. 6c; it is similar in appearance to the cavity cluster found by GOW and WILLIAMSON (1975).

3. Concluding Remarks

Since the ice is plastic, ice cores kept at atmospheric pressure will show phenomena due to stress relaxation, among which, besides simple expansion (decrease in density), recrystallization may be most important. Now, as seen in Fig. 2a, the JARE-13 cores which were examined more than one year after recovery have a larger mean grain area than that of the JARE-24 cores at corresponding depths above 120 m. Also, the minimum values of the shape factor of the JARE-13 cores are larger than those of the JARE-24 cores, as shown in Fig. 2c, that means that the grains of more complex shape predominate in the JARE-24 cores than in the JARE-13 cores. We consider that the recrystallization process occurred over one year in the JARE-13 cores. As shown in Fig. 2a, the mean grain area of the JARE-13 and JARE-24 cores is the same at the 130-m depth where cracks are developed in the cores. The occurrence of cracks will assist the stress release, so the stress relaxation pehnomena, especially recrystallization, are hard to detect.

The recrystallization probably results in the change in fabric pattern. The fabric pattern of the JARE-13 core at 88.7 m (Fig. 3d) seems to be more concentrated than that of the JARE-24 core at 100.1 m. This may be explained by the recrystallization. Effect of stress relaxation on recovered deep cores has been pointed out by many authors (*e.g.* GOW, 1971; GOW and WILLIAMSON, 1975). The present paper showed that the effect was quite large even on shallow cores from a depth of less than 100 m.

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