*Journal of Glaciology*, Vol. 12, No. 66, 1973

# CORRESPONDENCE

The Editor,
*Journal of Glaciology*

SIR, *A technique for producing strain-free flat surfaces on single crystals of ice: comments on Dr H. Bader's letter and Dr K. Itagaki's letter*

A recent attempt has been made to compare the surfaces of single crystals of ice prepared by the freeze-tap method (Tobin and Itagaki, 1970) with those prepared by Bader's method (Bader, 1972) using the interference microscope.

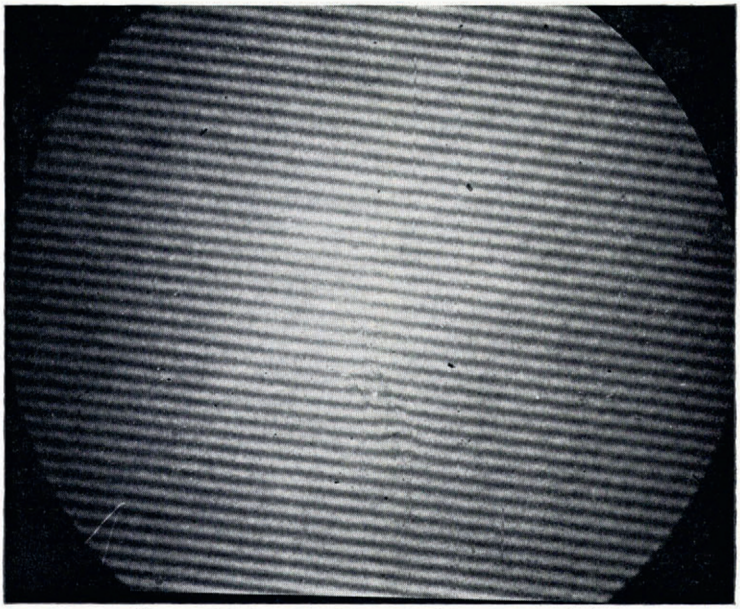

*Fig. 1. Interferogram of ice surface (freeze-tap method).*

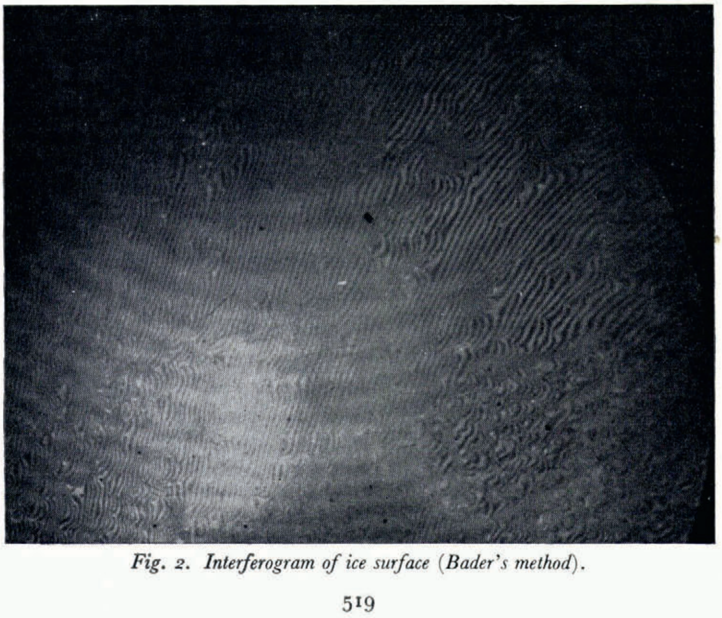

*Fig. 2. Interferogram of ice surface (Bader's method).*

Figure 1 and Figure 2 show typical interference photomicrographs of the two methods approximately five minutes after their preparation at −10°C. Remembering that even, straight, and parallel interference bands indicate a flat, smooth surface, it can be seen that Figure 1 represents a surface which appears to be flatter and smoother than that of the surface in Figure 2. As previously observed (Itagaki, 1972), Bader's surfaces were always slightly curved, which can be readily seen from the slight curvature of the interference fringes in Figure 2.

*U.S. Army Cold Regions Research and Engineering Laboratory,*
*Hanover, New Hampshire 03755, U.S.A.*
*5 December 1972*

T. M. Tobin*

## REFERENCES

Bader, H. 1972. A technique for producing strain-free flat surfaces on single crystals of ice. *Journal of Glaciology*, Vol. 11, No. 61, p. 158. [Letter.]

Itagaki, K. 1972. A technique for producing strain-free flat surfaces on single crystals of ice: comments on Dr H. Bader's letter. *Journal of Glaciology*, Vol. 11, No. 61, p. 158. [Letter.]

Tobin, T. M., *and* Itagaki, K. 1970. Instruments and methods. A technique for producing strain-free flat surfaces on single crystals of ice. *Journal of Glaciology*, Vol. 9, No. 57, p. 385–90.

Sir,

*Origin of rock glaciers*

In a recent letter regarding the origin of ice-cored rock glaciers, Carrara (1973) suggested that the debris at their surfaces may represent a succession of shear moraines formed during glacier retreat. Referring to a photograph of the ice core of the Arapaho rock glacier, Colorado Front Range (Outcalt and Benedict, 1965), he concluded that debris bands in the ice "may well be shear planes", and that shearing "would be one mechanism for obtaining a surficial mantle on the ice body".

Field studies of the Arapaho rock glacier support part, but by no means all, of Carrara's hypothesis. Figure 1 is a photograph of the surface of a debris layer (ablation surface) from the ice exposure in question. Mineral and organic inclusions are arranged in parallel streaks, orientated in a down-glacier direction, and indicating that Carrara is probably correct when he suggests that differential movement has occurred.

There is *no* evidence, however, that shearing has contributed a significant amount of coarse debris to the surface of the rock glacier. During the summer of 1966, erosion by a melt-water stream exposed a discontinuous 220 m long vertical section of buried ice, extending along the axis of the rock glacier from the shallow depression at its rear to a position about 400 m behind its front. The thickness of the exposed ice varied from 1.0 to 9.8 m. Examination of the ice core revealed only a few stones that were larger than 2 cm, and none that was larger than 6 cm. The ice is much too clean and contains stones that are at least an order of magnitude too small to be the source of the thick accumulation of boulders on the surface of the rock glacier. The latter have an average diameter of approximately 1 m (White, 1971) with occasional boulders 15–20 m in maximum dimension.

Along the walls of the melt-water channel, the thickness of the debris mantle ranged from 0.2 to 2.4 m, increasing down-valley. The debris was composed of two units: (1) a poorly sorted basal sand layer containing gravel and a few cobbles; and (2) a surface layer of large open-work boulders. Each layer appears to have originated by a different mechanism.

Boulders in the surface layer are rough and angular. Unlike the smooth, predominantly sub-rounded boulders found on historic moraines a few meters to the north, they show no evidence of modification by glacial transport. I attribute the upper layer of coarse angular debris to rockfall on to the glacier surface, but I am uncertain whether the boulders accumulated gradually through a succession of small rockfall events, or abruptly, as the result of a single catastrophic rockfall avalanche (Mudge, 1965).

* Present address: USA OCNA and SOC, Aberdeen, Maryland, U.S.A.