A NEW METHOD FOR RECORDING THE GRAIN-STRUCTURE OF ICE

By Keiji Higuchi

(Faculty of Science, Hokkaido University)

Abstract. Separated etch pits can be produced by a simple operation using a plastic replica film. Combining this etching technique with Schaefer's replica method, it is possible to record both the size distribution and the orientation of crystal axes of individual grains of ice.

Zusammenfassung. Eizelne Ätzlöcher können durch von Kunstharz-Replik-Filmen auf einfache Weise erzeugt werden. Wenn man diese Ätztechnik mit Schaefers Replikmethode vereint, so ist es möglich sowohl die Korngrössenverteilung als auch die Orientierung der Kristallachsen einzelner Eiskörnchen aufzunehmen.

Introduction

It is necessary for the study of the grain structure of ice to record both the size distribution and the orientation of crystal axes of individual grains. However, no method has been proposed for the simultaneous observation of these two features. Methods for recording the size distribution were devised by Seligman[1], Ahlmann and Droessler[2] and Schaefer[3]. The orientation of the *c*-axis has been determined by the use of crossed polaroids. Recently, Nakaya[4] has developed a simple method which made the determination of *a*-axis possible, by making Tyndall figures* or vapour figures inside single crystals of ice. In recent experiments, the author[5] succeeded in producing the separated etch pits by an operation using the plastic replica film. Combining this etching technique with Schaefer's replica method, it is possible to record the size distribution and the orientation of crystal axes by simple operations.

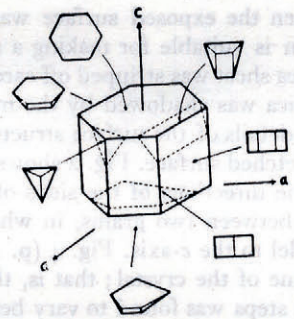

Fig. 1. Diagram to show the kinds of etch pits formed on ice

Determination of Crystal Axes by Etch Pits

Etch pits provide a reliable indication of the orientation of crystal axes of ice, as well as of many other crystals. The geometrical shapes of the etch pits belong to the hexagonal system, as expected from the crystal structure of ice. As shown schematically in Fig. 1 (above) each shape agrees with a section cut from a hexagonal column with a plane. The figure of a regular hexagon was obtained on the surface perpendicular to the *c*-axis, and the sides of the hexagon were found to be

* In this connexion see also Steinemann, S. Results of preliminary experiments on the plasticity of ice crystals. *Journal of Glaciology*, Vol. 2, No. 16, 1954, p. 404 *et seq. Ed.*

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parallel to those of vapour figures, that is, parallel to the *a*-axes [4]. These etch figures can be used as a simple method of determining the orientation of the *a*-axes as well as the *c*-axis. The angles between the ice surface and crystal axes can be calculated from the measurement of the microphotographs of etch pits. Figs. 2 and 3 (p. 122) are microphotographs of the replicas of etch pits, obtained by the following technique.

Procedure for Etching

In the author's experiments, the ice samples were sawed from a large block of commercial ice, which comprised many columnar grains as large as several millimeters in diameter. The polished ice surface was coated with a 1–5% solution of polyvinyl formal dissolved in ethylene dichloride. The coating must be applied immediately after the polishing, because irregular etching starts quickly over the whole surface. After a time, the solvent evaporates and the plastic film covers the surface of the samples, adhering closely to it. If this covered sample is left in a cold chamber, numerous separated etch pits are produced on the surface of the ice. It is desirable to carry out these operations at a temperature of about −20° C. When the temperature of the chamber was −24° C. and the solution was 1%, the etch pits attained a mature stage of development within a few minutes after formation of the plastic film. In the case of the more concentrated solutions, half a day was needed. The etch pits were examined under a microscope and photographed.

Procedure for Making the Replica

The plastic film covering the ice surface was removed after confirming the production of etch pits under a microscope. Then the exposed surface was coated with the replica solution again. In this case, a 3% solution is suitable for making a replica of the etched surface. After evaporation of the solvent, the replica sheet was stripped off carefully, as described by Schaefer [3]. In some cases, the surface of the replica was shadowed by the method used in electron microscope technique, in order to examine the details of the surface structure. Figs. 2 and 3 are microphotographs of shadowed replicas of the etched surface. Fig. 2 shows the etch pits produced on the face perpendicular to the *c*-axis, and the directions of the sides of the hexagons indicate the *a*-axes. Fig. 3 shows the grain boundary between two grains, in which the left is a face perpendicular to the *c*-axis and the right is parallel to the *c*-axis. Fig. 4 (p. 122) shows the replica of a stepped structure observed in the basal plane of the crystal; that is, the base of a hexagonal etch pit. As reported elsewhere [5], the height of steps was found to vary between 3μ and 16μ, the mean having been about 5μ.

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A photograph by C. N. Fenner[7], a member of one of the National Geographic Society expeditions, shows Third Glacier from the west. No early photograph of Fourth Glacier is known. The Knife Creek Glaciers have recently been photographed from the air, by the U.S. Air Force in 1946 (Fig. 3) and by the U.S. Navy in 1951, on mapping quality vertical photography. Comparison of these photographs and the panorama taken in 1953 shows no significant change in the margin of Fourth Glacier within the past few years.

Conclusion

On the basis of the undisturbed condition of pyroclastic debris adjacent to the terminus of Fourth Glacier, the morphology of the glacier, ablation studies at several elevations, and a comparison of the few available photographs it is concluded that:

1. The terminus of Fourth Glacier has been essentially stationary over the past 40 years.
2. Ablation losses from the body of Fourth Glacier have been reduced to a minimum by the thick, insulating mantle of pumice and ash. So effective is this insulation that parts of the pumice mantle are now permanently frozen to within a few feet of the surface.
3. Thinning of the upper reaches of the glacier has resulted from loss of a major part of the accumulation area, slight movement downslope, and perhaps secular climatic amelioration.

This description of the previously unmapped Knife Creek Glaciers and report on the regimen of Fourth Glacier are based on reconnaissance work in the area. It is believed that other glaciers in the vicinity of Katmai Volcano will repay future study and may demonstrate quite dissimilar response to changes brought about by the volcanic eruption of 1912.

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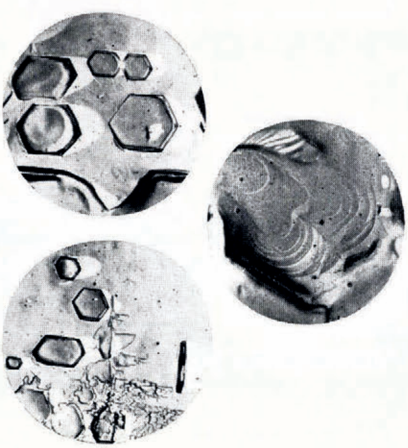

Figs. 2 and 3 (left). Microphotographs of shadowed replicas of etched ice crystals. The crystal in Fig. 2 and the grain on the left of Fig. 3 have faces perpendicular to the c-axis. The right hand grain in Fig. 3 has a face parallel to to the c-axis. Magnification ×13

Fig. 4 (right). Replica of the stepped structure observed at the base of a hexagonal etch pit. Magnification ×35

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