Journal of Glaciology, Vol. 13, No. 69, 1974

CORRESPONDENCE

The Editor,

Journal of Glaciology

SIR,

Depth of water-filled crevasses that are closely spaced

In discussing "Can a water-filled crevasse reach the bottom surface of a glacier?", Weertman (1973) states that, for the field of closely spaced crevasses shown in his figure 1, they would not reach the bottom, but the depth of crevassing would be virtually unchanged whether the crevasses were filled with water or not. He considers that the criterion that a crevasse will penetrate the glacier to a depth L at which the overburden pressure equals the tensile stress T would still give $L = T/\rho_i g$ whether the crevasse is filled with water or not (ρ_i is the density of ice, g the acceleration due to gravity).

However, Weertman's criterion is not consistent with the argument attributed to F. C. Frank in the reference (Nye, 1955) quoted by Weertman, or indeed with his own later discussion when dealing with an isolated water-filled crevasse. In the Nye and Frank discussion, it is considered that a crack will propagate downwards until its tip reaches a depth where the longitudinal pressure in the ice just balances the internal pressure in the crack. In the case of an air-filled crevasse, atmospheric pressure acts both on the surface of the glacier and within the crack, with the result explained by Nye (1955) that the depth of penetration is independent of atmospheric pressure. However, within a water-filled crevasse, the pressure will be $(p_0 + \rho_w g y)$ where p_0 is atmospheric pressure, ρ_w the density of water, and y the depth below the surface. The overburden pressure within the ice will be $(p_0 + \rho_i g y)$, which will fall short of the pressure in the water-filled crevasse by an amount $(\rho_w - \rho_i) g y$. Since this increases with increasing y, the crevasse will propagate down to bedrock as long as it is kept full of water.

In order to develop a detailed analysis of the stress field around a crevasse, Weertman uses a model of a single crevasse in an otherwise continuous mass of ice. Clearly his equations will not hold for the case of a field of closely spaced crevasses, owing to the interaction of the effect of neighbouring crevasses. However, even in the case of a uniform field of multiple crevasses, the stress field around the tip of each crevasse that causes the crack to propagate, will be concentrated in a distance small compared to the spacing between crevasses. Hence the argument in our second paragraph will be appropriate rather than a more general theory for a single crevasse.

To some extent the argument is academic, since in practice one will not have a perfectly uniform field of crevasses. The presence of deeper crevasses filled with water will tend to relieve stresses on shallower crevasses. Also the outermost crevasses will be subject to larger stresses on one wall as described in Weertman's paper.

We can also see that since $(\rho_w - \rho_i) g y$ increases with depth, a crack could propagate into regions where longitudinal stresses were no longer tensile (Weertman also makes brief mention of this). At a depth of about 220 m, this stress difference could reach a value around 0.2 MN m^{-2} (2 bars), and overcome a typical value of a compressive longitudinal stress. Such conditions with a longitudinal tensile stress at the surface and compressive stress near the base of a glacier would occur if conditions in a glacier were best described by the theory of beam bending.

Scott Polar Research Institute,
Cambridge CB2 1ER, England

G. DE Q. ROBIN

8 January 1974

REFERENCES

Nye, J. F. 1955. Comments on Dr. Loewe's letter and notes on crevasses. *Journal of Glaciology*, Vol. 2, No. 17, p. 512–14.

Weertman, J. 1973. Can a water-filled crevasse reach the bottom surface of a glacier? *Union Géodésique et Géophysique Internationale. Association Internationale d'Hydrologie Scientifique. Commission de Neiges et Glaces. Symposium on the Hydrology of Glaciers, Cambridge, 7–13 September 1969*, p. 139–45.