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WATER-PRESSURE DEPENDENCE OF THE VELOCITY OF ICE STREAM B, ANTARCTICA

(Abstract)

by

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The basal velocity of a glacier with basal shear stress τ is determined by the nature of the bed and by N, the difference between the overburden pressure and the water pressure. If N is large, owing to efficient drainage of the bed through subglacial aquifers or channels, then the ice will maintain intimate contact with the bed and both sliding (slip between ice and bed) and bed deformation (slip within bed) will be slow or zero. If the water supply exceeds the capacity of the basal drainage system, N will decrease until some combination of water flow through a thickened Weertman film and water advection in a deforming bed balances the supply; both mechanisms increase the basal velocity of the glacier.

Weertman sliding theory shows that slow sliding causes variations in normal pressure on the bed, and that water will accumulate and cause ice–bed separation at any spot where this normal pressure falls below the water pressure. If the water pressure is sufficiently high, these areas of ice–bed separation will merge into a modified Weertman film with average thickness d and water pressure N less than average overburden pressure. We estimate that $N \approx \beta\tau/f$, where β is a dimensionless roughness coefficient of 0(1) that measures the ratio of vertical to horizontal stress on a roughness element, and where f is the fraction of the bed flooded by the thickened film. The value of f can be calculated from the bed geometry and the average water-film thickness, d. Weertman theory then shows how sliding velocity increases with d and thus with $1/N$, and how water flux through the film increases with d and limits further decreases in N.

Boulton and Hindmarsh (1987) have shown that the shear deformation rate, $\dot{\varepsilon}$, of till beneath Breiðamerkurjökull is described well by $\dot{\varepsilon} = k\tau^a/N^b$ where $a \approx 1.3$ and $b \approx 1.8$ are empirically determined constants. We estimate standard errors of ±0.2–0.3 on a and b.

We have used the water-pressure theory sketched above, Weertman sliding theory, the Boulton and Hindmarsh bed-deformation relation, and data from Ice Stream B, West Antarctica, to model the ice stream. The robust results are that N decreases and till softens down-stream, and that sliding between ice and till contributes a small fraction (probably <10%) of the total basal velocity. Differences between the model and measured data are minimized for $\dot{\varepsilon} = k\tau/N^2$, which falls within likely error limits for the Boulton and Hindmarsh data.

Three papers reporting much of this work have been submitted to the *Journal of Glaciology*.

REFERENCE

Boulton, G.S. and R.C.A. Hindmarsh. 1987. Sediment deformation beneath glaciers: rheology and geological consequences. *J. Geophys. Res.*, **92**(B9), 9059-9082.