laws governing sliding and/or strong deformation within the boundary layer. I agree with Hutter *et al.*[6] who wrote "as long as experts debate the proper form of sliding law, it is illusory to estimate longitudinal strain effects of basal stress". Until this problem is solved our modelling of ice sheets will be inadequate.

In these circumstances, the obvious need is to improve our knowledge of factors governing the flow of existing ice sheets and glaciers carrying large ice fluxes. Over much of Antarctica and Greenland, most surface motion appears to be caused by internal deformation rather than basal sliding[7,8]. Only in fast-moving peripheral ice streams and trunk glaciers is sliding dominant[9,10].

In contrast to the soft till beneath the Antarctic Ice Stream B[1,2], the section of Variegated Glacier where surging started moves over water-saturated basal moraine almost impenetrable to drilling (W.D. Harrison, University of Alaska). The basal shear stresses were around 200 kPa before surging and only half that during surging (C.F. Raymond, University of Washington). But this should be related to a stress of only 20 kPa on Ice Stream B[2]. The effective pressure Δp borne by the basal till itself, that is, overburden pressure minus basal water pressure, was put at 50 ± 40 kPa for Ice Stream B[2] while for Variegated Glacier it varied from 0 to 400 kPa during surging and 0 to 1, 600 kPa at other times. Rapid changes of glacier motion were closely correlated with changes of borehole water levels and water discharge at the terminus[11].

Both Ice Stream B and Variegated Glacier gave evidence of very active erosion. During June 1983 the water-borne sediments discharged from beneath Variegated Glacier during the surge were estimated to be equivalent to 10 mm of rock over the whole glacier bed, and 0.5 m of rock during the entire surge cycle of 20 years (25 mm per year) (Humphrey, University of Washington). Assumption of steady-state sediment flow beneath Ice Stream B gave a corresponding figure[2] of 5 mm per year. Similar figures have been reported from large fast glaciers in Central Asia[12].

Basal moraine characteristics and driving stresses of tidewater glaciers appear close to that of Variegated Glacier than Ice Stream B. The correlation of short-term changes of ice movement with tidal heights near their terminii shows that changes of Δp of the order of 30 kPa has a considerable effect on the movement of tidewater glaciers. Although Jacobshavn Glacier moved faster when tidal levels were higher as expected, the opposite was true of Columbia Glacier. M.F. Meier and collaborators (US Geological Survey, Tacoma) put this down to changes of longitudinal stress/strain rate against the terminal moraine — as indicated also by increasing mean velocities of the terminal zone over the past decade as the zone has thinned because of ablation. Some adjustments to theory are needed. The case for the soft-bed glaciology of Ice Stream B received most support from field studies of deformation of soft till beneath the slowly moving Breidermerkur Glacier, Iceland (G.S. Boulton, University of East Anglia) and from the build up of soft till beneath the lower end of the small surging Trapridge Glacier, Yukon (G.K.C. Clarke, University of British Columbia).

Out of some 50 papers, only one presented quantitative data of past fast flow using a wealth of evidence on Vashon Glacier, a lobe of an ice sheet discharging into the Puget Lowlands of western Washington around 14,000 years ago (Hallett, University of Washington). Velocities near the 'equilibrium line' (given from dates of advance and retreat) were around 600 m per year, the driving stress was around 40 kPa and Δp was low with water separating till from ice in some as shown by sorted deposits.

Although some outer lobes of former ice sheets have characteristics similar to Ice Stream B, the case[3] for using such a low basal stress model over wide areas of ice sheets is not obvious. It is more difficult to explain observed sea-level lowering during the last ice age with such a model. Alternatively, channelled water flow beneath ice sheets away from the margins would prevent water pressures building up to the level where basal till would deform readily, as suggested by Shoemaker[13].

All cases of the fast ice flow for which field evidence was presented at the meeting probably involve rapid shear of basal till associated with high basal water pressures (low Δp). The resultant basal shear stresses still vary widely, being low when the till is mainly composed of soft mud but ranging widely around more usual values when the basal till consisted of morainic boulders. An adequate explanation is still needed for how large quantities of glacial mud are produced, transported, then deposited to produce low friction elsewhere; and we still need a better understanding of sub-glacial hydrology, especially beneath large ice sheets. □

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100 years ago

PROFESSOR J. C. Adams, whose portrait we this day present to our readers, entered St. John's College, Cambridge, in 1839. He soon gave promise of those great mathematical powers that have brought such renown to his University. By what seems to have been an inspiration of genius, he was guided after taking his degree to concentrate his talents on the solution of an astronomical problem of excessive interest but of corresponding difficulty. The planet Uranus had shown irregularities in its motion. The orbit differed from the elliptic path which an undisturbed planet would pursue, and the deviations could not be fully accounted for by the influences of the other known planets. The only explanation of the discrepancy which astronomers could be expected to favour lay in the supposition that there was some other still more remote planet yet unknown.

It was the search for this unknown planet which attracted Professor Adams. We can imagine the delight with which a well-equipped mathematician would throw himself into the solution of such a problems. On it he was to concentrate the powers that had been cultivated during his University career. The discovery of Neptune was a brilliant inauguration of the astronomical career of Adams. We find that he has worked at and written upon the theory of the motions of Biela's comet; he made important corrections to the theory of Saturn; he made an elaborate investigation of the mass of Uranus, to which he was naturally attracted

from its importance in the theory of Neptune; he has improved the methods of computing the orbits of double stars; but next to the discovery of Neptune the fame of Adams mainly rests on his researches on the moon and on the theory of the November meteors.

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