SIR, *A plea for fixed axes of reference in glacier mechanics*

In his paper on the effect of longitudinal stress on basal shear stress, Nye (1969) sets out at some length the reasons for use of a rectilinear system of axes with one axis aligned along the surface in the direction of flow. The axes therefore vary in direction as the surface slope varies. He derives equations that are substantially simpler than those of a similar paper by Collins (1968) which was complementary to my own paper (Robin, 1967). This presented an approximate solution to the problem and was validated by numerical tests on field results. Since then, Budd (1968) and Beitzel (unpublished) have provided further numerical tests of the same problem, which appear to explain the relationship between surface slopes, calculated longitudinal stress gradients and estimated longitudinal strain-rates (Robin, 1967; Beitzel, unpublished) or measured longitudinal strain-rates (Budd, 1968).

Nye claims two advantages for his analysis: first that it leads to simpler equations and thus makes the phenomena easier to understand, and secondly that there is a practical advantage in having axes referred to the upper, accessible surface of the ice sheet.

The fact that the equations are simpler is granted. This consequence of the use of surface-oriented axes was pointed out by Collins (1968). The essential point is whether this makes the phenomena easier to understand. With Nye's system of axes, the parameters σ_x, σ_z, τ_{xz}, $\mathrm{d}\bar{\sigma}_x/\mathrm{d}x$, and $\dot{\epsilon}$ all change in value each time the reference axes on the surface of the glacier are redefined. It is difficult to comprehend the magnitude of these changes when dealing with rapid changes of surface slope on a polar ice sheet. Collins's equations may be more complex, but the simple fact that his parameters at any point have the same meaning throughout the analysis of a complete profile is of great advantage in understanding the significance of his paper.

As regards the practical advantages of a variable system of axes, it has not been shown how the system is to be applied in practice. While Nye's paper produces equations to define the slope at a point, the main problem has been to understand the reasons for the variations of slope along a line of flow. To do this one must use a series of finite intervals to determine $\dot{\epsilon}$, σ_x, $\Delta\bar{\sigma}_x/\Delta x$ etc. With fixed horizontal and vertical axes one calculates the main parameters once for each interval along the flow line. With a variable system does one calculate the parameters for each interval in relation to the mean surface slope of each interval? This question is asked since surface slopes may vary considerably, even within intervals chosen to be of sufficient length for practical measurements of strain-rates. When calculating $\Delta\bar{\sigma}_x/\Delta x$, since the reference axes will differ between adjacent intervals of measurement, one must set about some transformation of coordinates to determine stress gradients. If and when this problem is tackled, it appears likely that precise equations dealing with finite interval calculations on the basis of Nye's paper may prove to be just as complex as Collins's equations.

By all means let us seek simplified solutions which work. The point of Robin (1967) was to do this, while Collins's (1968) complementary paper presented a precise analysis of the approximations involved in terms of the same fixed axes. While Nye's analysis appears to be precise and simpler than Collins's paper, introduction of variable axis directions means that his equations cannot be applied directly to the field measurements mentioned above, which all use a fixed system of coordinates.

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