The two equations used take into account all possible changes in a steady ice shelf, considered as a continuum, at a given point. They are:

for mass changes

$$\overset{1}{a_s} + \overset{2}{a_b} + \overset{3}{u}\left[\rho_s \tan\alpha - \overset{4}{\rho_b \tan\beta} - \overset{5}{\int_{z_s}^{z_b} \frac{\partial\rho}{\partial x} dz}\right] - \overset{6}{\left[\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right] \int_{z_s}^{z_b} \rho dz} = 0$$

$$23{\cdot}7 - 57{\cdot}8 + \quad 5{\cdot}5 \quad + 71{\cdot}0 \quad + \quad 3{\cdot}4 \quad - \quad 45{\cdot}8 \quad = 0 \text{ g. cm.}^{-2} \text{ yr.}^{-1}$$

for thickness changes

$$\overset{1}{\frac{a_s}{\rho_s}} + \overset{2}{\frac{a_b}{\rho_b}} + \overset{3}{u}\left[\tan\alpha - \overset{4}{\tan\beta} - \overset{5}{\frac{1}{\rho_b}\int_{z_s}^{z_b} \frac{\partial\rho}{\partial x} dz}\right] - \overset{6}{\frac{1}{\rho_b}\left[\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right] \int_{z_s}^{z_b} \rho dz} - \overset{7}{\frac{\rho_b - \rho_s}{\rho_b} w_s} = 0$$

$$66{\cdot}9 - 63{\cdot}3 + \quad 15{\cdot}6 \quad + 77{\cdot}8 + \quad 3{\cdot}7 \quad - \quad 50{\cdot}2 \quad - \quad 50{\cdot}5 \quad = 0 \text{ cm. yr.}^{-1}$$

Every term of the equation has a number placed above it and also has its value at the particular point on the Ross Ice Shelf given beneath it. Each term in the first equation corresponds to the term with the same number in the second equation, except that there is no term No. 7 in the first equation because this term of the second equation expresses the rate of total ice thickness decrease due to densification of ice without change of mass.

Crary does not consider mass and thickness changes due to movement and density gradient (term No. 5 in both equations) and prefers to determine the rate of thinning due to densification as $\frac{a_s}{\rho_s}\frac{\bar{\rho}-\rho_s}{\bar{\rho}} = 39$ cm. yr.$^{-1}$. But the ice-shelf thinning due to densification is the sum of the thinning of all its individual strata. Our method may be applied to any layer within the ice shelf, or to the sum of layers, whereas Crary's method is not applicable to inner layers because of his use of the factor a_s/ρ_s, and it underestimates vertical density gradient because $\bar{\rho}$ replaces ρ_b.

Soviet Committee on Antarctic Research,
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24 August 1964

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SIR,

Movement of stones under snow cover

Movement of loose stones over bedrock surfaces below a cover of snow, such as described from Mount Twynam (Costin and others, 1964), is characteristic of the area adjacent to the glacier Østerdalsisen, in Norway (lat. 66° 31′ N., long. 14° 06′ E.). Stones are moved down slope on the bare rock which lies

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between the southern margin of the glacier and the moraine which marks the maximum recent extent of the ice (*c.* A.D. 1750). Movement between one summer and another is typical.

The stone shown in Figure 1 measured about 20 cm. × 6 cm. × 4 cm., and the fresh, white abrasion marks up-slope of it were about 25 cm. long on 2 August 1964. The stone had moved approximately down the line of greatest slope (about 24 degrees), oblique to the direction of old striations on the garnet mica schist bedrock. In 1963–64 the maximum snow depth in the area was about 170 cm., which is of the same order as the mean of recent years.

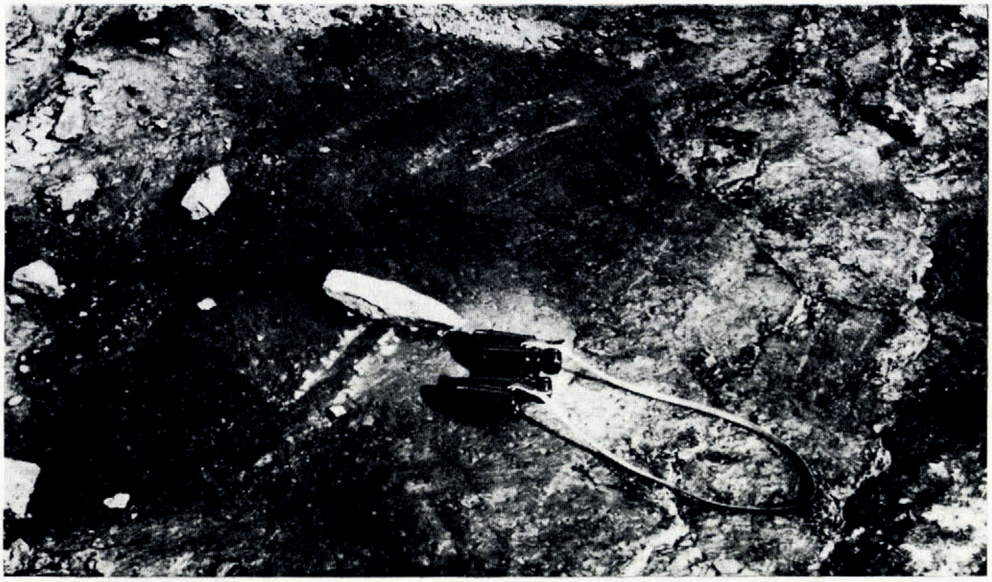

Fig. 1. Down-slope movement of stone. Old striations (top) run slightly across the slope; fresh abrasion marks behind the stone run down the line of greatest slope. Photograph taken 2 August 1964

During the winters, many stones are moved over the bare rock surface bordering Østerdalsisen, though few of them show any definite orientation relative to the slope. There seems no doubt that slow downhill creep of snow may result in abrasion of the underlying rock by loose stones at the bottom of the snow cover.

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20 October 1964

W. H. Theakstone

REFERENCE

Costin, A. B., *and others*. 1964. Snow action on Mount Twynam, Snowy Mountains, Australia, by A. B. Costin, J. N. Jennings, H. P. Black and B. C. Thom. *Journal of Glaciology*, Vol. 5, No. 38, p. 219–28.

Sir, *Comments on Paterson's paper "Variations in velocity of Athabasca Glacier with time"*

The coupling of a glacier to its bed is a most important current problem in glacier-flow studies. Paterson's (1964) paper presents data which contribute to an understanding of this. The magnitudes of velocity fluctuations for periods of a week to a year on Athabasca Glacier are consistent with the velocity-dispersion spectrum obtained from measurements made in 1952–54 on the neighboring Saskatchewan