The stratigraphic descriptions for Illinois define members that cover areas of the order of 50 km by 100 km (10^3–10^4 km^2). Perhaps each member is to be associated with a single glacial advance or perhaps each bed represents an advance (a bed is a subdivision of a member). It would be very interesting to determine if the compositional variations within each member can be related to a similar pattern in the bedrock and other pre-existing deposits.

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PLOUGH MARKS IN THE WEDDELL SEA

By Olav Orheim

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Abstract. The 1976/77 Norwegian Antarctic Research Expedition carried out studies of the sea bed by side-scan sonar. The equipment was operated from the expedition vessel down to about 350 m depth by personnel from the Continental Shelf Institute, Trondheim. Various types of plough marks mostly ranging from 10 to 100 m in width were observed. These included several generations of crossing plough marks as well as plough marks with abrupt changes in trend reflecting changing iceberg motion. The investigations will be expanded during the 1978/79 expedition to include towing at greater depths, and mapping of sea-bed morphology by mosaic towing patterns.

DISCUSSION

D. E. Thompson: What is the size of your side-scan swath before resolution is lost?

O. Orheim: Typically we were scanning from 50–100 m above the sea bed giving good resolution imagery of the bed over a 300 m wide swath to each side.

ICE-SHEET EROSION—A RESULT OF MAXIMUM CONDITIONS?

By D. E. Sugden

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Abstract. Understanding the relationship between the morphology of former ice-sheet beds and glaciological processes is handicapped by the difficulty of establishing which stage of a cycle of ice-sheet growth and decay is responsible for most erosion. Discussions at this conference and in the literature display a variety of opinions, some favouring periods of ice-sheet build up, others periods of fluctuations, and still others steady-state maximum conditions. Here it is suggested that there is geomorphological evidence which points to the dominance of maximum conditions.

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Along the eastern margins of the Laurentide and Greenland ice sheets there is a sharp discontinuity between Alpine relief which stood above the ice-sheet surface at the maximum and plateau scenery which was covered by the ice sheet. Often the two types of relief are adjacent and yet separated by an altitudinal difference of only 100–200 m. The existence of an abrupt rather than gradual transition from one relief type to the other suggests that most glacial sculpture must have taken place while the ice sheet was at its maximum extent. In other geomorphological situations where high mountains were submerged by ice sheets, the major erosional landforms are frequently found to relate to ice sheets rather than to local mountain glaciers, again suggesting the dominance of erosion during full ice-sheet conditions. Finally, the identification of patterns of glacial erosion on an ice-sheet scale in North America and Greenland points to erosion when the ice sheets were fully expanded, rather than to the variable flow conditions associated with growth or decay.

If ice-sheet erosion is accepted as being a result of maximum conditions, then it places certain constraints on glacial theory, for example the need to develop theories of glacial erosion which apply beneath ice thicknesses of several thousand metres. It also suggests that the use of steady-state models of ice sheets is likely to be a profitable way of relating glaciological processes to the morphology of former ice-sheet beds.

DISCUSSION

W. H. Mathews: You should not attribute the plateaux of the eastern Canadian Arctic to glacial erosion; in western Canada the summits overridden by the ice sheet there have been worn down to rounded domes and ridges. Do you not believe the eastern plateaux were developed before glaciation?

D. E. Sugden: I agree. I did not mean to imply that the plateau areas of eastern Canada were *created* by glacial erosion but that the relief type of selective linear erosion with deep troughs and intervening uplands is characteristic of ice-sheet erosion in some uplands. Probably the uplands were overlain by protective cold-based ice while the troughs contained warm-based ice which was able to accomplish erosion.

J. A. Elson: You have implied that all of the lakes on the Canadian shield are the result of glacial erosion. However a substantial proportion of them may be the result of glacial deposition, possibly more than half.

Sugden: The map I showed was taken from the National Atlas of Canada and showed the distribution of lake surface area. This map does not distinguish between erosional and depositional lakes and was intended to show only that there was a broad concentric distribution of lakes arranged around the former centre of the Laurentide ice sheet. Whether such a pattern is due to deposition or erosion, it appears to reflect processes operating when the ice sheet was well established. In another paper (Sugden, 1978), I plotted the distribution of lake basins of a scale appropriate to glacial erosion. This pattern is essentially similar to the one of lake area.

A. Dreimanis: While your general model agrees well with the facts, particularly from the highland areas, the situation in the lowlands with lobal flows was probably more complicated. For instance, in the Great Lakes Region, judging from the stratigraphy and the age of tills in contact with bedrock, it appears that major erosion, at least in some areas, was at the beginning of the last ice age and during some of the late Wisconsin re-advances.

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SUGDEN: I agree that the situation is likely to be more complex in lowland peripheral areas of the ice sheet, especially because in areas of soft beds the underlying till may deform along with the glacier.

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CHARACTERIZING THE GLACIER BED USING A RADIO-ECHO TECHNIQUE

By C. S. M. DOAKE

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ABSTRACT. If glacier ice is assumed to be a uniaxial birefringent material then two parameters are needed for describing the orientation behaviour of the polarization ellipse of a radio signal returned from the glacier bed. These are δ, the relative phase between the ordinary and extraordinary wave, and r, the ratio of their attenuation coefficients (Woodruff and Doake, 1979). If it is assumed that the attenuation in ice is isotropic, then a value of r other than unity will be due to anisotropic reflection coefficients at the glacier bed. A simple way of measuring r separately from δ could then be used to characterize the reflecting surface.

Defining a rectangular coordinate system in which the wave propagates in the z direction, the effective optic axis lies in the zy plane, a linear transmitted wave of strength E_0 is at an angle α to the x axis then the powers received in linear aerials aligned along the $x'y'$ axes of a rectangular coordinate system at an angle θ to the xy system are given by

$$P_{x'} = E_0^2 A_x^2 \{\cos^2\alpha\cos^2\theta + r^2\sin^2\alpha\sin^2\theta + 2r\sin\alpha\cos\alpha\sin\theta\cos\theta\cos\delta\},$$
$$P_{y'} = E_0^2 A_x^2 \{\cos^2\alpha\sin^2\theta + r^2\sin^2\alpha\cos^2\theta - 2r\sin\alpha\cos\alpha\sin\theta\cos\theta\cos\delta\},$$

where A_x and A_y are the attenuation coefficients in the x and y directions and $r = A_y/A_x$.

By adding the powers in the two aerials the total received power is

$$P = P_{x'} + P_{y'} = E_0^2 A_x^2 (\cos^2\alpha + r^2\sin^2\alpha),$$

which is independent of θ, the azimuth of the receiving aerials. This is a well-known result in radar theory and practice. However, because of the dependence on α, by rotating the transmitting aerial a value for r can be found from the amplitude of the variation in the total power

$$r^2 = \frac{P_{\max}}{P_{\min}}, \qquad r > 1,$$

$$r^2 = \frac{P_{\min}}{P_{\max}}, \qquad r < 1.$$

The choice of the value for r arises because of a 90° ambiguity in the direction of the optic axis which can only be resolved by the full procedure of rotating both aerials.

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