SIR,

Englacial debris in glaciers

In the June 1970 issue of the *Journal of Glaciology*, Boulton (1970) extends his detailed observations from Svalbard to suggest as a generalization "that many polar and sub-polar glaciers, such as those of Svalbard, Greenland, Baffin Island, etc., carry very considerable amounts of englacial debris derived from the glacier bed . . .".

Over the course of 10 years I have studied, both in the field and on air photographs, glaciers and ice caps throughout the entire region of Baffin Island and I have very little hesitation in concluding that Boulton's generalization is in fact incorrect, as far as the glaciers and ice caps on Baffin Island are concerned. A majority of the glaciers would have to be classified as "clean" and in many cases, away from the terminal area, the till/ice contact is sharp and there is no evidence of incorporation of the basal till into the ice. Obviously, a large number of glaciers do have a surface-ablation till in the region of their snouts and this grades frequently into one or more ice-cored moraines. However, in such cases, as is well known in the literature, the surficial debris is thin (less than 0.5 m), the amount of debris per unit volume of ice is very small and the ice-cored moraines are, by volume, 95% ice. This in itself still might indicate a moderately rapid supply of debris but one has to take into account at this point the velocity of glacial movement and also the chronology. Studies on a number of glaciers throughout eastern Baffin Island indicate that the ice-cored moraines commonly represent successive events throughout the Neoglacial, that is, the outer ones are dated about 4 000 and the inner ones about 300 years B.P. This, combined with general low velocities, suggests that the debris cover, such as it is, has taken a long time to accumulate.

These observations in no way alter Boulton's thesis on the Svalbard situation but they do suggest that his generalization is perhaps not valid.

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J. T. ANDREWS

29 March 1971

REFERENCE

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SIR,

Englacial debris in glaciers: reply to the comments of Dr J. T. Andrews

Andrews' (1971) comments do not invalidate my generalization that there is a considerable "contrast between the englacial debris load of temperate and polar glaciers". Although I admit that Baffin Island glaciers may transport less englacial debris than many glaciers in Spitsbergen (some in Spitsbergen are clearly similar to those in Baffin Island), I believe that their englacial debris content still contrasts markedly with that of temperate glaciers. Goldthwait's (1951) description of a 32 km stretch of the margin of the Barnes Ice Cap bears this out. He described the ice up to 30.5 or 61 m above the glacier toe as "layered with myriads of dirt-filled thin fractures striking roughly parallel to the ice edge . . . the dirt filling . . . is from 1/100 inch to 1 inch [0.25 to 25.4 mm] thick . . . small pebbles and even large boulders are occasionally seen". This description, together with his plates 1B and 2A, and figures 2 and 3, and other descriptions such as those of Ward (1952) and even Andrews' comments, are sufficient to convince me of the difference between the mode of debris transport in Baffin Island and that of temperate glaciers that I have studied in the Alps, Norway and Iceland. These latter generally transport subglacially derived debris in a basal layer rarely more than 5–10 cm thick (exceptionally 1 m thick). Above this there is a virtual absence of subglacially derived debris at levels comparable to those in which such debris appears to be carried in, for instance, the Barnes Ice Cap (apart from relatively rare wedges of basal debris which have been thrust up along undoubted fault planes). Andrews' assessment of 5% englacial debris content for ice-cored moraines in Baffin Island itself serves to accentuate this contrast. I would estimate this is at least one or two orders of magnitude greater than the subglacially derived debris content of temperate ice above the basal zone. The thickness of supraglacial till overlying dead

ice in Baffin Island is estimated on average as 0.5 m by Andrews, and 1 m by Goldthwait and Ward for the south-east part of the Barnes Ice Cap. This till has presumably formed as a result of melting of immediately underlying ice and thus indicates that it contained a substantial englacial load.

Andrews' observation that he has only seen sharp till/ice contacts in Baffin Island, and that there was no incorporation at these contacts, is irrelevant. The source of the englacial debris may be far from the margin, as might be expected from the basal freezing hypothesis. But as far as the Barnes Ice Cap is concerned, basal incorporation must be clearly responsible for its englacial debris load as there are no nunataks to provide a supraglacial source.

It is hoped shortly to present a comprehensive theory to account for the contrasts between the debris loads of different types of glaciers.

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Sir,

Ground-ice wedges interpreted by A. von Bunge (1884) in Siberia

It is a good thing that Dr Colhoun has reminded us that as early as 1905–08 J. R. Kilroe interpreted an ice-wedge pseudomorph observed near Londonderry as having been formed when the sands and gravels that it cuts were frozen (Colhoun, 1970).

Dr Colhoun has noted that Kilroe's interpretation pre-dated "the classic interpretation of ground-ice wedges in Alaska published by Leffingwell (1915, 1919)", which is true. But Leffingwell was by no means the first author to give the proper interpretation. Ice-wedges were first described from East Siberia by Adams (1815) and Middendorff (1867), and correctly interpreted by von Bunge (1884) on the basis of extremely careful field observations. This has been stressed by Troll (1944) and myself (Cailleux and Taylor, 1954).

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9 March 1971

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