

CORRESPONDENCE

The Editor,

Journal of Glaciology

SIR,

Englacial debris in glaciers

One or two comments are necessary in view of Boulton's (1971) letter in reply to my original commentary.

The first point is that my observations on the sharp contact between ice and the underlying till is not irrelevant because I am talking about continuous ice-cliff sections cut by lateral melt-water channels that are 1–3 km in length. These sections indicate that the englacial debris planes for these glaciers are derived from within the first 400 m of the margin. In one or two instances, I have noticed *isolated* debris bands further up-glacier that probably do reflect the incorporation of debris by a freeze-thaw mechanism. The second point is that my reason for commenting on Boulton's paper was to point out that in terms of glaciers on Baffin Island, the *absolute* amount of englacial debris is not large. In fact, I have recently calculated on the basis of the volume and age of moraine debris that the average rate of glacial erosion in the area is only 50 mm/1 000 years. If we take a glacier 1 km² and allowed 100 years occupancy time, and further say that all englacial debris is restricted to the ablation zone, then on the basis of these figures there is *only* 5 000 m³ of debris entrained in the glacier at any one time. This means that the average concentration of the debris is approximately 0.05% by volume in the ablation zone.

I realize that Boulton's statement about the very considerable difference between sub-polar and temperate glaciers is partially couched in relative terms, but I am concerned that this *relative* expression should not be construed to indicate large *absolute* amounts in the case of Baffin Island glaciers. The third point is something of a query, but I think it does have relevance. On a qualitative basis, as a result of looking at late-glacial end and lateral moraines in the Rocky Mountains National Park, Colorado, Arctic Canada, Norway, Italy and the United Kingdom, there appears to be a direct proportional relationship between the size of these moraines and the present activity index. In other words, moraines that I have examined in temperate areas are considerably larger than those in arctic glaciers (that is, for late-glacial moraines that have no ice core). If these end- and lateral-moraine complexes are formed from englacial debris, as I think they must be, then this relationship appears to be opposite from that suggested by Boulton.

In case there is any doubt, I should add that I think Boulton's paper is extremely important and any questions that I am raising should be construed as being made in a constructive manner.

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JOHN T. ANDREWS

REFERENCE

Boulton, G. S. 1971. Englacial debris in glaciers: reply to the comments of Dr J. T. Andrews. *Journal of Glaciology*, Vol. 10, No. 60, p. 410–111. [Letter.]

SIR,

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

Allow me to make three points which I hope will clarify my position for Dr Andrews:

1. As a matter of observation I have suggested that cold glaciers and temperate glaciers transport subglacially derived debris in rather different positions. In the former, it is disseminated through a relatively large thickness of basal ice (100–200 ft (30.5–61 m) on the Barnes Ice Cap), and in that ice has bulk concentrations which in most cases average about 5% by volume, although individual debris bands may contain much higher concentrations. In temperate glaciers, the debris tends to be restricted to a thin basal layer rarely more than 1 m thick. I have not attempted to contrast the debris discharge of these glaciers, but the position in which debris is carried. Dr Andrews' calculation of a 0.01% debris content in the whole of the ice of the ablation area is interesting but not pertinent to my suggestion.