

ablation data from Greenland (Braithwaite and Olesen, 1985, in press). However, we have recently tested a simple energy-balance model using turbulent-flux equations from Ambach (1986) and long-wave radiation equations from Ohmura (1981). Ablation calculations by the model are surprisingly accurate and will be described in a future paper.

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SIR,

*The influence of J.G. Goodchild*

John Shaw (1988) is correct in assuming that, unlike him, I do not regard J.G. Goodchild as one of the "grandfathers" of glacial geology, but I certainly do not deny importance to the study of land forms and sediments in inferring past processes.

Goodchild's (1875) descriptions of the glacial sediments of the Vale of Eden are excellent for his time, and are even now a useful guide which helps us in interpreting the origin of these sediments. However, I believe that the inferences which he drew from them are largely incorrect, primarily because of his lack of any real knowledge of actual glacial environments and the consequent need to fall back on imagination alone as the explanatory tool. Though Goodchild cannot be blamed for this lack in 1875, there are many who follow his tradition and who have no excuse to ignore the knowledge of actual physical processes, which has built up since then, in constructing their hypotheses. I fear that the confusion between the real and the hypothetical may be illustrated by John Shaw's comment that the quote he gives from Goodchild represents an "accurate description" of the formation of melt-out till. It is *not* a description; it is an imaginative inference, a distinction which is often forgotten by those who do not moderate their inferences from ancient sediments by studies of modern processes. I adhere to the view that, if geological features can be explained equally well by processes which are known to occur and hypothetical processes, the former should be preferred.

I would argue that Goodchild's view of "under-melting", also held by Carruthers (1953) and many modern glacial geologists, including Shaw, as a widespread process giving rise to thick melt-out tills deposited beneath stagnant ice, is seriously flawed. I would argue that it is thermodynamically improbable, that it requires either excessive erosion rates to load the lower parts of a glacier with sufficient debris or an inexplicable late-stage change in regime, and indeed that the observations which have been used to justify the hypothesis can be explained by recourse to known rather than hypothetical processes. When I originally coined the term *melt-out till* (Boulton, 1970), it was observed and inferred to be a much more limited phenomenon and different in its sedimentological associations than Shaw believes it to be.

I take a broader view of sedimentology than John Shaw appears to, when he writes that "direct observation of processes is desirable", as if it is an optional extra. I regard good sedimentology as the integrated study of processes and products on all scales. It is commonly found that the influence of origin from sedimentary product alone is ambiguous, and I would plead with those glacial geologists who do not already do so to take a more holistic view.

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SIR,

*The influence of J.G. Goodchild*

Geoffrey Boulton answers my letter on the contributions of J.G. Goodchild to glacial sedimentology by two thrusts. First, he avers that Goodchild's under-melt interpretation is largely incorrect. Secondly, he alleges that some glacial geologists ignore actual physical processes. I find his first argument to be unsubstantiated and his second unwarrantable.

If Boulton is to demonstrate that Goodchild's hypothesis is wrong, he is obliged to show, by means of evidence, that it is contradicted by either observation or sound theoretical principles. Alternatively, he could show that another hypothesis better explains the original and any subsequent observations on the glacial deposits of the Vale of Eden. He does neither in his reply and we are asked to discard an important hypothesis on the basis of an unsupported belief. In a similar vein, Boulton's dismissal of the under-melt hypothesis, first proposed by Goodchild, is on the basis of opinion not evidence. Let him expound his theoretical reasons for discarding this hypothesis and explain by other means the observations used to support it. There is a world of difference between alleging that something can be done and actually doing it.

I cannot imagine any glacial geologist knowingly ignoring actual physical processes. The actualistic works of Boulton, Lawson, Powell, and others are widely cited in the glacial sedimentology literature. But, when the evidence speaks against known processes, land-form and sediment interpretation requires imaginative inference. Even then,

Goodchild did not "fall back on imagination alone". His interpretation of sand and gravel as a product of water washing was founded on experience. His method was both experiential and inferential, involving the interpretation of well-documented observation. I find it odd that this method could be dismissed as leading to a dead end.

Boulton employs the technique of interpreting my meaning to make it appear absurd. Such cleverness may win debating points, but it does nothing to promote understanding. Evidence from the direct observation of process is desirable not because, as Boulton implies I suggest, it is an optional extra, but because it is a luxury not always available to geologists. As examples, the theory of continental drift, the flood hypothesis for the Channeled Scabland, and much of our knowledge of the behaviour of deep-sea turbidity currents all originated without the luxury of direct-process observations.

I am under no illusion that reconstructions of the past are real; we are concerned here with validity not truth. This humbling thought applies to any explanation of ancient sediment and land forms, whether we appeal to known or deduced processes. But, since Boulton sees fit to question my sense of reality, I feel free to examine his. He claims that, whereas his concept of subglacial melt-out till (Boulton, 1970) is based on observation, others base theirs on inference alone. Despite this assertion, I find no direct observations in Boulton (1970) on the process he defined as subglacial melt out. On the other hand, he described 2.4 m of till he believed to have been deposited subglacially by the melting of stagnant ice beneath Nordenskiöldbreen. This till is clearly of melt-out origin according to the definition used by those whose thinking he finds flawed:

*Melt-out till* — till formed by the melting of debris-rich ice that is neither sliding nor deforming internally in the zone of formation (Shaw, 1982, p. 1549).

Boulton (1971) caused confusion by referring to this subglacial till as a type of lodgement till. It appears to me more logical to classify it as subglacial melt-out till, with the consequence that Boulton's argument against the

under-melt principle is also an argument against his own observations. I believe he is wrong on both counts. I find no fault with the conclusions he drew using Goodchild's tradition of inferring process from sedimentary characteristics. The thermal and dynamic regime of Nordenskiöldbreen over the 200 years or so of till deposition cannot possibly be *described* from a synoptic view of the ice/bed material interface near the present glacier margin. Thus, Boulton's claim to objective reality is spurious; like Goodchild's, his conclusions depend on inference.

I find J.G. Goodchild's influence to be of lasting significance and his under-melt hypothesis remains unchallenged. No *evidence* has been presented to the contrary. Despite his claim to a broad view of sedimentology, I believe that Geoffrey Boulton's observations are so restricted in time, geographical extent, and environmental context it is hardly surprising that he recognizes rather limited sedimentological associations for melt-out till.

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#### ERRATUM

Vol. 34, No. 116, p. 137, col. 1

1. 51 *should read* "D.A. Hodgson, Jean-Serge Vincent, Lou King, Gordon"
1. 58 *should read* "Vladimir Kotlyakov and Mikhail Grosswald of the Institute of"