the time of freeze-up plot at the very top of Figure 1. Clasts of cobble size do occur in turbid ice but representative samples of the very coarse components are not available. This floating seasonal ice canopy, although having never physically contacted the sea floor as massive ice, may carry over 1000 $m^3/km^2$ of sediment, or 16 times more than the annual sediment supply by rivers feeding the same area (Reimnitz and Kempema, 1987). In some winters, the turbid ice canopy extends as a contiguous band from shore to the 20 or 30 m isobath, and in patches across the entire shelf (Barnes and others, 1982; Reimnitz and Kempema, 1987; Kempema and others, unpublished).

The texture of mud carried by turbid sea ice today is indistinguishable from the mud texture of deep Arctic Ocean cores attributed to glacial conditions (Fig. 1). The patchy coarse components entrained into sea ice by anchor ice become homogenized in the common settling process after release from drifting floes into deep water. Therefore, not even a sandy texture and drop stones can be used as sole criteria for glacial conditions. Also, drifting sea ice imparts striations on rocks in the coastal zone (Dionne, 1985), on boulders embedded in firm mud at 10 m water depth (Reimnitz and others, unpublished), may shatter them (Josenhans and others, 1985), and possibly produce fracture faces on quartz grains (Hodel and others, 1988). Most damaging to the theory that certain surface features and shapes of drop stones are unique to glacial conditions is the fact that pebbles lifted by anchor ice today, and then are rafted by sea ice, include Flaxman lithologies (Hopkins and Herman, 1981) with "glacial striations". Lastly, icebergs impacting the bottom produce gouges but are highly unlikely to entrain shallow-water organisms (Kempema and others, unpublished). However, frazil ice scavenging suspended matter from supercooled water is an effective mechanism to enrich sea ice with planktonic foraminifers and diatoms, as found in the Antarctic (Garrison and others, 1983; Dieckmann and others, 1986; Spindler and Dieckmann, 1986; Sullivan and others, 1986), and confirmed by our unpublished laboratory experiments. Similar mechanisms lift shallow shelf micro-organisms off the bottom and incorporate them into the sea ice (Briggs, 1983, unpublished; Reimnitz and others, 1987; Kempema and others, unpublished). The occurrence of such micro-fossils, along with plant debris and mollusks, in cores to over 1000 m water depths on the continental slope off northern Alaska (personal communication from E. Brouwers, 1983) suggest modern sea-ice transport of shelf sediments to the deep ocean. Ice-rafted components, such as drop stones, sand, and shallow-water benthic organisms in sediment cores of the Arctic Basin therefore are not necessarily an indication of glaciation on the surrounding continents. They are incorporated, moved, and released more effectively by short-lived and more quickly recycled sea ice.

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SIR,

*Chernobyl fall-out on glaciers in the Austrian Alps*

We have investigated the Chernobyl fall-out in 55 vertical snow profiles (359 samples) on Hintereisferner, Kesselwandferner (Oetztal Alps), Schaufelferner (Stubai Alps), and Gefrorene Wand Kees (Zillertal Alps). The results have been compared with those given by Pourchet and others (1988). The maximum measured gross β-activity of the Chernobyl layer in Austrian glaciers is 339 Bq/kg ($^{40}$K equivalents; measurement: November 1986). However, great regional differences have been observed (Ambach and others, 1987). The contamination of the Chernobyl layer is greater by a factor of about 10 on the Austrian glaciers investigated in comparison with the glaciers of the Western Alps (Pourchet and others, 1988). From gamma spectral analysis, a part of 60% of the total gamma activity is due to $^{137}$Cs. It can be expected that the high gross β-activity in the Chernobyl layer will be detectable over many decades and therefore can be used as a further reference level for dating snow.

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SIR,

## *The influence of J.G. Goodchild*

Geoffrey Boulton's recent review of progress in glacial geology over the past 50 years is a very readable but highly personal account. In the light of Professor Boulton's own writing, it has an expected actualistic bias and, although he recognizes work on sediments of past glaciers, he evidently does not consider it to have had much impact on modern glacial sedimentology. If anything, he presents it as having retarded progress. I welcome this opportunity to make an equally personal comment on how I see this perception leading to an injustice.

Boulton (1987, p. 28) writes: "Roughly contemporary attempts to infer processes only from their ancient products, such as those of Goodchild (1875) and Carruthers (1947–48), led others into scientific *cul de sacs* ... ." While I agree that subsequent sedimentological research has shown Carruthers to have been largely mistaken, the work of Goodchild is a benchmark in glacial geology that remains highly relevant (Haldorsen and Shaw, 1982). Goodchild first established that parts of the great ice sheets stagnated and down-wasted, and went on to deduce the nature of subglacial deposition beneath such ice bodies. The vivid picture he painted is as current now as in 1875.

> "When the great ice-sheet began to melt, the stones that were nearest the bottom of the ice, ... began to be deposited on the floor of the glaciated rock, or on patches of the true *moraine profonde* where these existed. The water resulting from the melting of the bottom ice would find its way here and there towards the sea along channels in the slowly thickening deposit of till ... . As the currents shifted they must have allowed till to accumulate in parts where nothing but sand and gravel had been laid down; while on the other hand, they must frequently have cut into banks of till and afterwards filled the denuded hollows with waterworn materials as their course slowly changed." (Goodchild, 1875, p. 95.)

This beautiful and accurate description of the formation of melt-out till and its associated glaciofluvial sediment explains many glacigenic sequences and applies exactly to depositional processes observed beneath modern stagnant glaciers. As Garwood and Gregory (1898) noted, Goodchild had predicted deposition by melt-out and it was only later that they observed this process at modern glaciers.

Goodchild's conclusions on the stagnation of ice sheets and deposition by melt-out have been re-stated many times over the past 100 years (see the discussion on the history of the melt-out till concept in Haldorsen and Shaw (1982)). A very recent work following in the Goodchild tradition of interpreting sediments in detail is Möller's (1987) excellent monograph on glacial land forms and sediments in southern Sweden.

Clearly, it is my view that J.G. Goodchild is a grandfather figure in glacial geology. I am sorry to see his research method diminished and dismissed as a dead end. It is particularly distressing when Boulton in his review only acknowledges melt-out till, which was so elegantly described in 1875 by Goodchild, after its description from modern glaciers in 1972. In my view of the development of glacial sedimentology, this undue emphasis on actualistic evidence distorts our history and is contrary to the proper practice of sedimentology. There are parallels between the study of tills and turbidites; much has been learned about the genesis of both by the study of the sediments themselves. Of course, direct observation of processes is desirable, but it is not a be all and end all. Both modern process studies and evidence from the products of past glaciers are useful in our quest to understand glacial land forms and sediment. Denial of the importance of studies of land forms and sediments themselves tarnishes the memory of such outstanding geologists as J.G. Goodchild.

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## ERRATUM

Vol. 34, No. 116, p. 89-91, Figs 5, 6, and 7

The illustrations and captions for Figures 5, 6, and 7 have been transposed. The illustration above the caption for Figure 5 is in fact Figure 7; the illustration above the caption for Figure 6 is in fact Figure 5; the illustration above the caption for Figure 7 is in fact Figure 6.