GLACIAL EROSION OF A HIGH ARCTIC VALLEY

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ABSTRACT. A large valley, ideally suited for "selective linear erosion" by ice, extends from the Kreiger Mountains to Tanquary Fiord, north-central Ellesmere Island. During the last glaciation, the outlet glacier at the head of the valley advanced 18 km and was at least 250 m thick where it contacted the sea in the lower valley. Erosion of bedrock inside the last ice limit is recorded by an abraded diabase dyke, and by crag-and-tail features developed in limestone. Linear erosion "by ice, extends from the Kreiger Mountains valley advanced 18 km and was at least 250 m thick where it contacted the sea in the lower valley. Erosion of bedrock inside the last ice limit is recorded by an abraded diabase dyke, and by crag-and-tail features developed in limestone. During deglaciation (7800 B.P.), melt-water streams along the ice margin incised a large alluvial fan that pre-dates the last glaciation. The fan shows little alteration by the over-riding ice and its final erosion by the melt-water streams incised, but did not remove, its original ice-wedge polygons.

The preservation of the fan indicates that the glacier was locally non-erosive and that it probably advanced across the fan by over-riding a protective frontal ice apron. Although it is commonly assumed that such alluvial fans occupying glacialized valleys are of post-glacial age, this need not be the case in permafrost terrain. In fact, at this site, there has been a net increment of alluvium versus glacial erosion or deposition spanning the last glacial cycle. The paper discusses the processes of erosion associated with sub-polar glaciers and questions whether erosion by them or more pervasive ice is responsible for such High Arctic valleys and fiords.

RESUME. Erosion glaciaire d'une vallee du Haut Arctique. Une grande vallee, idealement disposee pour une "erosion lineaire selective" par la glace, s'etend depuis les monts Kreiger jusqu'au Fjord Tanquary, au centre nord de I'ile Ellesmere. Au cours de la derniere glaciation, le glacier qui en sortait avançait de 18 km et son epaisseur depassait 250 m au contact de la mer. L'erosion du lit rocheux en depe de la derniere extension glaciaire est gravée dans un dyke erode, et dans le calcaire qui montre des fissures et des moufures. Au cours de la deglaciation (7800 B.P.), les ruisseaux d'eau de fonte le long des bords du glacier ont incise de grands cônes alluviaux antérieurs à la derniere glaciation. Ces cônes alluviaux ne montrent que peu d'alteration par la glace qui s'ecoulait dessus, et l'erosion finale par les courants d'eau de fonte decoupa, sans les emporter, les polygones originaux à coins de glace. La conservation des cônes de déjection indique que le glacier, localement n'a pas érodé, et qu'il s'est vraisemblablement avancé sur les cônes en chevauchant un culot de glace protecteur. Bien qu'on suppose habituellement que de tels cônes de déjection occupant les valées glaciaires soient postérieurs à l'époque glaciaire cela ne semble pas être le cas sur le permafrost. En fait à cet endroit, il y a eu alluvionnement plutôt qu'erosion ou dépôt glaciaire pendant la dernière glaciation. Cet article discute les processus d'erosion associés aux glaciers subpolaire et pose la question de savoir si leur erosion ou celle d'une masse de glace plus importante est responsable de telles valées ou fjords du Haut Arctique.

INTRODUCTION

The efficacy of erosion by High Arctic glaciers remains poorly understood. Little erosion is predicted by a theoretical, maximum ice cover over the Queen Elizabeth Islands, Arctic Canada (Fig. 1), because much of the ice was cold-based (Sugden, 1978). Nevertheless, the channelling of ice streams down pre-glacial fluvial valleys presumably caused "selective linear erosion" (Sugden, 1978) that overdeepened these valleys, producing fiords (cf. Peltier, 1966; Blake, 1970). At present, neither the occurrence nor the effects of such a maximum ice cover are documented for the Queen Elizabeth Islands, although erratics and melt-water channels at high elevations have been reported for many areas (Sim, 1961; Hattersley-Smith, 1969; England, 1976, 1978; Blake, 1977; England and others, 1981; Hodgson, 1985). On the other hand, during the last glaciation of northern Ellesmere Island, most glaciers advanced only 20-40 km beyond their present margins due to the constraints imposed by extreme aridity and the calving of glaciers within fiords (England, 1983, in press; Bednarzki, in press). Therefore, the extent to which glaciers are responsible for the major valleys and fiords of the Queen Elizabeth Islands is unknown (England, 1985).

FIELD WORK

During the summer of 1984, I investigated the Quaternary deposits of a glaciated valley that extends from the ice-covered Kreiger Mountains to the mouth of...
In this vicinity, up to 6 m of till are exposed along the present river, blanketing the bedrock. The till, in turn, is overlain by marine silts which contain in-situ shells at 76 m a.s.l. dated 7805 ± 125 B.P. (S-2649).

Localized glacial erosion is manifested, c. 3 km from the coastline where a diabase dike has been plucked, grooved, and striated by a southerly ice flow toward Flora Island, Tanquary Fiord (Figs 2 and 3). This flow diverges somewhat from the axis of the valley (north-west to south-east), because the ice which deposited the moraines...
was being deflected by a large gypsum hill along the lower east side of the valley while spreading out into Tanquary Fiord. Immediately up-valley from the abraded diabase dike are abundant crag-and-tail features comprised of low ridges of limestone extending from the lee sides of more resistant chert nodules (Fig. 4). The crag-and-tail is aligned with the sculptured diabase dike and therefore they were eroded along a similar flow line. The limestone ridges are commonly <5 cm high and often >25 cm long.

During deglaciation of the lower valley (7800 B.P.), ice-contact deltas were deposited into the sea, marking the local marine limit at 116 m a.s.l. (site A, Fig. 2). By the time the ice front reached site B (Fig. 2), 2 km farther up-valley, relative sea-level had fallen from 116 to 108 m a.s.l., indicating that 8 m of restrained rebound (Andrews, 1970) occurred beneath the retreating ice across this distance. This amount of emergence (8 m) could have been accomplished in 200-300 years of ice retreat given a rate of initial emergence of ~3 m/100 year (England, 1983). Therefore, the average rate of retreat between sites A and B (Fig. 2) was ~10 m year⁻¹.

Between sites A and B, two former melt-water streams have incised a large alluvial fan, producing two sloping escarpments c. 75 cm high and >100 m long. These former channels are nested in the lower valley at the base of the fan and their gradients represent successive positions of the retreating ice margin (Fig. 5a). Because these escarpments were cut during deglaciation, the alluvial fan must pre-date the last glaciation. The degree of alteration of the fan caused by the over-riding ice is minimal and the final glaciofluvial incision along the ice margin is estimated to be similar to the present depth of the active layer in this area (~75 cm). Moreover, tundra polygons on the original surface of the fan cross the escarpments indicating that the melt water incised, but did not remove, their underlying ice wedges (Fig. 5b). Conversely, since deglaciation, these escarpments have not been muted or buried by subsequent mass wastage (solifluction) or alluviation.

**DISCUSSION**

Abraded bedrock and the subsequent deposition of up to 6 m of till indicate that some erosion of the valley occurred during the last glaciation. Although such abraded bedrock cannot be dated directly, it is assumed to be the product of the last glaciation because: (1) it occurs inside the last ice limit; (2) the lateral moraines marking this limit are bordered down-valley by a gypsum hill that would align the flow of ice with the observed striations and crag-and-tail features; and (3) the abrasion is freshly inscribed and laterally capped by till, in turn, overlain by deglacial marine silts dated c. 7800 B.P. The extent of the abraded bedrock indicates that during the last glaciation the ice remained grounded at least to within 3 km of the present coastline (Fig. 2). Although the areas of abraded bedrock within the valley are generally small (<2500 m²), they nonetheless represent a minimum estimate for such abrasion because much of the bedrock is buried beneath till, colluvium, or marine sediments. However, compared to the abraded bedrock, a larger area of the valley (1 km²) is occupied by an alluvial fan that pre-dates the last glaciation. Although the fan occurs immediately up-stream from the abraded bedrock, it has been little altered by the over-riding ice. It is apparent, therefore, that in this valley, different erosional regimes have characterized the glacier bed and, as is the case today, such sub-polar glaciers probably varied from cold-based to warm-based conditions on a local scale (Müller, 1976; Hambrey and Müller, 1978). Today, in the Canadian High Arctic, the most effective erosional processes associated with sub-polar glaciers include: (1) pro-glacial thrusting of permafrost blocks commonly composed of glaciofluvial or glacimarine sediments that are subsequently over-ridden and entrained by the advancing ice (cf. Klöhn, 1971; Klassen, 1982; Stewart and England, 1983); and (2) pro-glacial melt water that incises both unconsolidated sediment and bedrock, producing channels nested in the direction of ice retreat (cf. Blake, 1981; Dyke, 1983). Little is known about subglacial abrasion, although it is recognized that cold-based ice can erode bedrock providing it has sufficient basal debris (cf. Sugden, 1978).
Boulton (1979) has also observed frozen eolian sands that were deformed and plucked beneath over-riding cold-based ice in Wright Valley, Antarctica. Nevertheless, moraines and till blankets (>1 m thick) are rare over large areas of the Canadian High Arctic, suggesting that erosion and re-deposition by these glaciers was slight.

Modern High Arctic glaciers that are advancing often do so by over-riding ice-rich debris aprons that accumulate by dry calving along oversteepened ice fronts (Shaw, 1977). Consequently, new basal ice is passively incorporated such that little active erosion can occur at the glacier bed. This is illustrated eloquently on east-central Ellesmere Island, where a retreating glacier is exposing dead, intact plant communities previously over-run by ice at least 400 years ago (Bergsma and others, 1984). In the same area, the retreat of a glacier, following the most recent Neoglacial advance has exposed an alluvial fan covered by "cortex boudnery ablation till" (Blake, 1978, fig. 10; Boulton, 1974, fig. 21). Finally, on north-central Baffin Island, Falconer (1966) also reported preserved vegetation dated c. 330 B.P. that was exposed by the retreat of thin ice caps during the first half of the present century.

The observations presented here indicate that, although a glacier at least 250 m thick advanced down a valley ideally located for selective erosion, this did not remove or significantly alter a large alluvial fan that lay in its path. The fan occurs adjacent to abraded bedrock that covers less area than the valley. It is apparent that the glacier advanced passively over the fan, presumably ridging a frontal ice apron that covered the undeformed (non-thrust) fan. Subsequently, the strength provided by permafrost within the over-ridden fan exceeded the forces of entrainment or deformation exerted by the ice. If the fan had not been incised by lateral melt-water streams during deglaciation, one would normally assume that the fan was of post-glacial age. However, because the fan pre-dates the last glaciation, it is apparent that there has been a net increment of alluvium versus glacial erosion or deposition at this site. Similar observations have been made on Somerset Island, central Arctic Canada, where selective linear erosion by solifluction features and patterned ground cover thousands of square kilometers. Although these landforms have been reactivated during the post-glacial, they are developed nonetheless on old colluvium and residual terrain that pre-date at least the late Wisconsinan glaciation (personal communication from A.S. Dyke, 1985). Therefore, in permafrost terrain, one must reject the assumption that all sediments mantling deglaciated valleys are of post-glacial age.

The question that follows is whether the erosive capacity of High Arctic glaciers is responsible for the profiles of such valleys, let alone the much larger fiords commonly occupied by water depths of 300-900 m (Hattersley-Smith, 1969). The concept of selective linear erosion has been widely used to explain the development of glacial landscapes. Despite this widespread acceptance of selective linear erosion, one must not lose sight of the fact that in Arctic Canada it is based solely on a theoretical model which assumes a pervasive ice cover whose very presence and dynamics remain to be demonstrated. Moreover, it has not been demonstrated that this concept takes precedence over alternative causes for such valleys; for example, faulting (Bird, 1967; England, 1985). Therefore, further consideration of the erosive capacity of glaciers is warranted, particularly as it pertains to the erosion of the fiords and inter-island channels of Arctic Canada which have been explained routinely by glacial overdeepening. This, in turn, has created a circular view of high-latitude ice sheets that may not be valid.

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REFERENCES


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