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A CIRQUE-GLACIER CHRONOLOGY BASED ON EMERGENT LICHENS AND MOSSES

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Abstract. Recession of "Golden Eagle" glacier in the central Brooks Range is exposing undisturbed lichen-covered boulders. Radiocarbon analysis of dead moss surrounding these boulders dates a Neoglacial advance across this site at 1 120 ± 180 years B.P Measurements of the preserved lichens indicate that a minimum ice-free period of 1 500–2 500 years preceded this glacial expansion.

Résumé. *Une chronologie des glaciers de cirques basée sur l'apparition des lichens et des mousses.* Le recul du glacier de "Golden Eagle" dans la partie centrale de Brooks Range a découvert des blocs en place couverts de lichens. Des analyses au radiocarbone de la mousse morte entourant ces blocs permet de dater une avance Neoglaciaire dans ce site vers 1 120 ± 180 ans avant le présent. Les mesures des lichens préservés indiquent qu'une période libre de glaces d'au moins 1 500 à 2 500 ans a précédé cette avancée glaciaire.

Zusammenfassung. *Chronologie eines Kar-Gletschers auf Grund des Auftauchens von Flechten und Moosen.* Durch den Rückgang des "Golden Eagle" Gletscher in der zentralen Brooks Range werden ungestört lagernde, flechtenbedeckte Felsblöcke freigelegt. Die Radiokarbondatierung toter Moose aus der Umgebung dieser Blöcke erweist einen neueiszeitlichen Vorstoss über diese Stelle 1 120 ± 180 Jahre vor der Gegenwart. Messungen an den erhaltenen Flechten weisen auf eine eisfreie Periode von mindestens 1 500–2 500 Jahren vor dieser Vorstossphase hin.

On the north slope of the Brooks Range, Alaska, at least 70 cirque glaciers of <2 km² occur within a 1 500 km² area centered about the Atigun River drainage basin (Fig. 1). All are now below the regional snow-line and wasting away rapidly with mass balances on the order of -1 m per year (Ellis and Calkin, 1979). The Neoglacial deposits associated with 40 of these glaciers have been lichenometrically mapped and all but those of "Golden Eagle" glacier (unofficial name) display bouldery surfaces nearly barren of vegetation at the receding margins. At the gently sloping toe of "Golden Eagle" glacier (Fig. 2), retreat has exposed an area of about 800 m² bearing undisturbed, non-sorted patterned ground, and *in-situ* patches of unidentified dead mosses partially enveloping hundreds of lichen-covered cobbles and boulders ranging to 1.5 m across. The lichen population is dominated by the long-living, green crustose *Rhizocarpon geographicum s.l.* In addition, some *R. inarense/eupetraeoides*, *Lecidea*, and unidentified gray crustose lichens were recorded. However, the black fruticose and foliose taxa such as *Alectoria* and *Umbilicaria*, common in the normal regional lichen cover, are conspicuously absent. The arrangement of the crustose lichens suggests that the hosting stones are largely undisturbed by the glacier that overrode them; however, there is a scattering (*c.* 20%) of boulders or cobbles set down from supraglacial or englacial positions. These latter are distinguished by their more angular and predominantly lichen-free character (Fig. 3).

Near the ice margin, the relict lichens are brightly colored, morphologically undamaged, and visually indistinguishable from those of the same species found elsewhere in the region. However, with increasing distance from the ice margin, the thalli deteriorate and colors become progressively bleached. Beyond 40 m of the glacier toe the lichens disappear. The emergence of patterned ground (Smith, 1961; Swinzow, 1962; Falconer, 1966; Black, [c1973]) and of vegetation (Arnold, 1965; Lowden and Blake, 1970; Collins, 1976) from beneath glaciers is well documented in polar areas. Furthermore, on Baffin Island, emergent mosses have been dated at 350 ± 75 years B.P. (I-1204) (Falconer, 1966). Emergent sites with lichens indistinguishable from living forms are less common (see Koerner, 1980), but include those reported from the Canadian Arctic islands (Beschel, 1961; Falconer, 1966; Harrison, 1966). Lichens have also been exposed in a subglacial tunnel in Greenland (Hilty, 1959; Goldthwait, 1960, 1961).

At the "Golden Eagle" glacier site, we have obtained a radiocarbon age of 1 120 ± 180 years B.P. (BGS-614) for the dead mosses surrounding the undisturbed lichen-covered boulders. The sample was obtained within 1 m of the July 1979 ice margin (Fig. 1c). This dates a Neoglacial advance across the presently deglaciated site. The length of the preceding ice-free episode is inferred from lichenometric measurements on the emergent boulders. Crustose lichen cover reached 60% on some boulders, and included a wide range of thallus diameters. The largest *Rhizocarpon geographicum s.l.* had well-defined

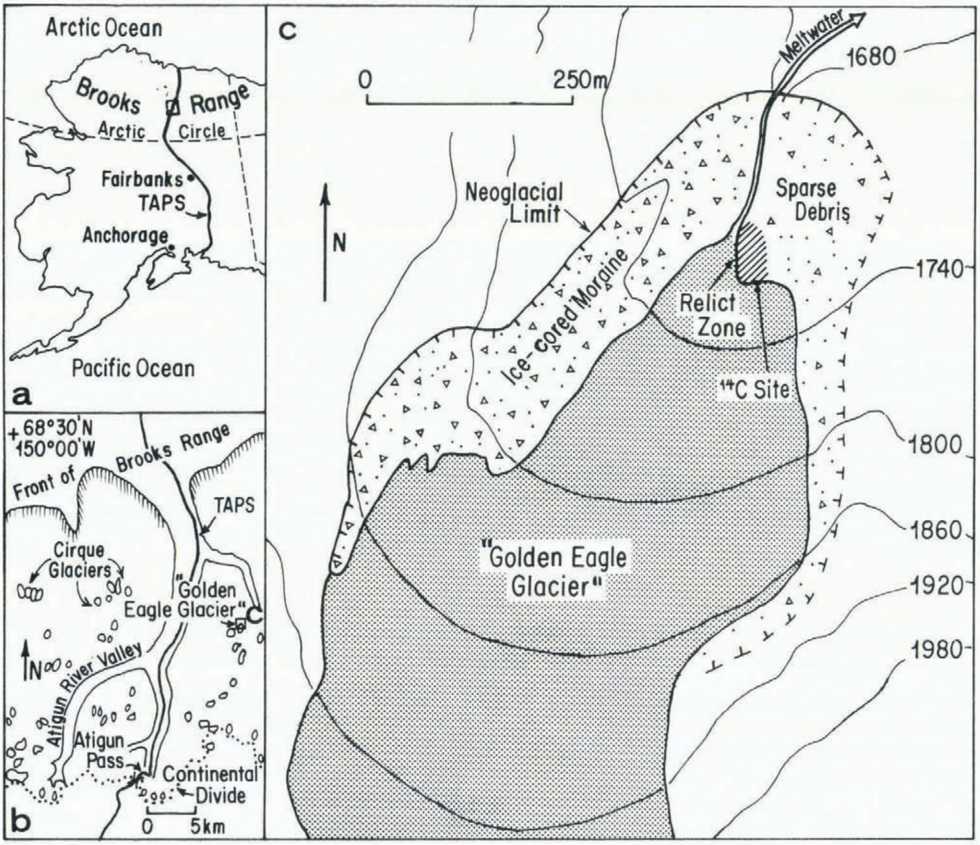

Fig. 1. (a) and (b): location maps of "Golden Eagle" glacier (unofficial name); and (c): the site of relict patterned ground, mosses, and lichen-covered boulders in the east-central Brooks Range, Alaska. TAPS indicates the Trans-Alaska Pipeline System.

thalli with maximum diameters ranging from 62 to 72 mm. A growth curve developed for the central Brooks Range (Calkin and Ellis, 1980) allows this diameter range to be converted to a lichenometric age of 2 000 ± 500 years, suggesting a minimum duration for an ice-free interval prior to the 1 120 years B.P. advance. This advance overran and preserved the patterned ground and vegetation under apparently cold-based conditions.

More recent cirque-glacier expansions have been recorded elsewhere in the Atigun drainage basin, but at "Golden Eagle" glacier only the last major advance dated at ~320 years B.P. (Calkin and Ellis, 1980) is evident, as it formed the terminal Neoglacial deposit (Figs 1c and 2). Based on glacier reconstruction from this terminal deposit, the glacier was *c*. 60 m thick over the site, and had an area of 0.6 km², 33% larger than at present. The equilibrium-line altitude (ELA) was depressed to 1 860 m and the snout extended 250 m farther than present during this A.D. 1500–1600 ± 100 year advance. Retreat from the maximum was not uniform over this interval, as the lichen pattern on the lateral moraine suggests most rapid recession commenced after A.D. 1750. The present ELA is estimated to be between 2 000–2 100 m at "Golden Eagle" glacier.

Fig. 2. Oblique aerial view southward of "Golden Eagle" glacier. The glacier is 1 200 m long. Neoglacial limit is marked by the pronounced lateral moraine on the west side (right) of glacier and by dashed line. Arrow indicates location of emergent relict zone, radiocarbon-dated moss, and position of camera for Figure 3.

Fig. 3. View northward of the preserved patterned ground and boulders from the toe of "Golden Eagle" glacier. Scale is shown by P. E. Calkin at right center. Light-colored, angular boulders were set down on preserved terrain from englacial and supraglacial positions during recent recessional phase of "Golden Eagle" glacier.

Fig. 2.

Fig. 3.

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The relict patterned ground does not appear to be in equilibrium with the present periglacial regime. Stone-fronted terraces about 0.4 m high and 1.5 m broad are being exposed along the receding snout at this site. Although they resemble terraces located beyond the Neoglacial terminal moraine, these deposits are undergoing more active frost heaving.

We are unable to explain the reason(s) why this relict site with patterned ground, mosses, and lichen-bearing boulders was preserved during glacial expansion. However, the glacier may have initially advanced through the mechanism of accumulation rather than by active down-hill movement (which would normally remove evidence of former vegetation or patterned ground). The evidence is available only because the overrun surface on the east side of "Golden Eagle" glacier was not buried under a continuous sheet of drift during the most recent recession (Fig. 2). "Golden Eagle" glacier is the only known glacier within the region where this situation exists.

The explanation for the disappearance of emergent lichens in the down-valley direction across this relict zone is also unknown but may be related to periglacial re-sorting and substrate instability. It is rarely possible to see at a glance whether a crustose lichen is alive or dead (Smith, 1962); however, lichens are known to have a resistance to freezing (Becquerel, 1951; Lange, 1972; Larson, 1978) as well as other environmental extremes found in polar areas (Gannutz, 1970; Kappen and Lange, 1970, 1972; Lange and Kappen, 1972), and to endure long periods of inactivity (semi-dormant) in a frozen state. Therefore, we presume that the preserved lichens may have been killed due to unfavorable conditions for respiration and photosynthesis upon (1) initial submergence, (2) prolonged burial, or (3) emergence (Beschel, 1961; Kappen, 1973). They are now wasting away as duration of exposure increases.

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