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Photographic evidence of the return period of a Svalbard surge-type glacier: a tributary of Pedersenbreen, Kongsfjord

Surge-type glaciers in Svalbard rarely leave dateable evidence that indicates surge periodicity. Documentary evidence for the active phases of surges is thus particularly valuable. Unfortunately, owing to the recent settlement of Svalbard (largely 1900 onwards), such documentary or photographic evidence is limited. However, published accounts of several expeditions during the late 19th century provide largely untapped sources of information regarding glacier frontal positions (but see Van der Meer, 1992). Comparison of expedition photographs with modern vertical and oblique aerial photographs provides a valuable tool in estimating glacier surge return periods (Jiskoot and others, 2001).

Pedersenbreen is a small (5.6 km^2) valley glacier (altitude range 90–650 m) located at the eastern end of Kongsfjord, Svalbard (78°52′ N, 12°18′ E; see Hagen and others, 1993, and Fig. 1). It consists of five tributary cirques that join to feed a single glacier tongue. The thermal regime of Pedersenbreen is unknown but is probably similar to that of nearby midre Lovénbreen, which has temperate ice in the accumulation zone below a cold surface layer and a cold ablation area (Hagen and Sætrang, 1991). Aufeis below the glacier snout (Fig. 2) further suggests that Pedersenbreen may be polythermal (Bennett and others, 1998). Hagen and others (1993) did not report it as a surge-type glacier, but structural glaciological evidence (deformed longitudinal foliation) suggests that in the past its western tributary cirque has pushed into the main flow unit (Bennett and others, 1996). Features commonly indicating surge-type behaviour include looped medial moraines, formed as active glaciers flow past less active or stagnant neighbours, deforming the intervening medial moraines. Similarly, potholes on the glacier surface, formed during the quiescent phase, together with a heavily crevassed surface, indicate a glacier in the active phase (Meier and Post, 1969; Post, 1972).

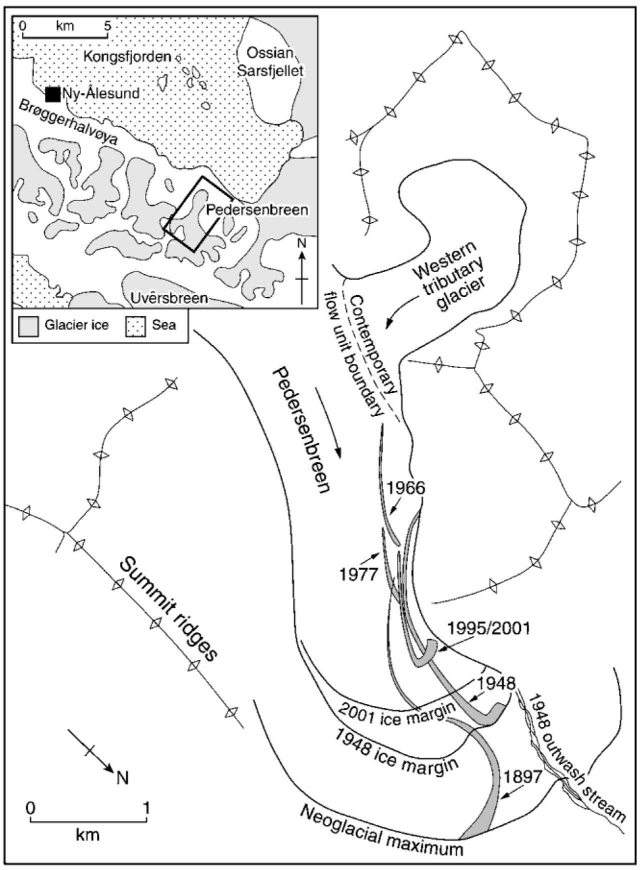

Fig. 1. The positions of looped moraines on the surface of Pedersenbreen in 1897, 1948, 1966, 1977, 1995 and 2001. Inset map indicates location of the Svalbard study area.

A looped moraine was present close to the snout of Pedersenbreen on a photograph taken in 1897 by E. J. Garwood from Storholmen, an island in Kongsfjord (Martin Conway Spitsbergen Expedition, Scott Polar Research Institute (Cambridge, U.K.) photographic library, reference P49/11/11) (Fig. 2). Field photographs taken in 2001 indicate glacier recession of several hundred metres during the intervening 104 years and the presence of a new looped moraine higher up-glacier than in 1897. Vertical aerial photographs dating from 1948, 1966, 1977, 1995 (photographs S48-760, S66-4454, S77-0729 and S95-1078, Norwegian Polar Institute, Tromsø) and field photographs taken in 2001 enable the down-glacier movement of this later moraine to be mapped from 1948 to the present. By 1966, a second looped moraine had formed a

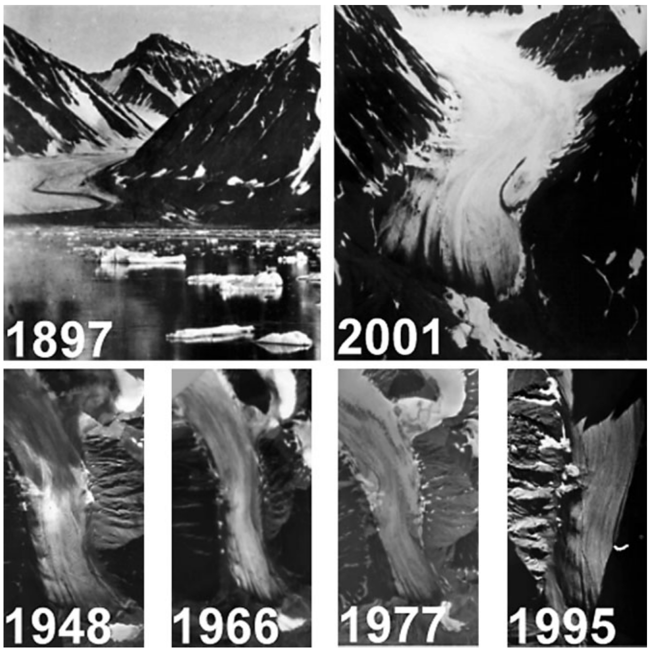

Fig. 2. Photographs tracking the down-glacier movement, elongation and deformation of the looped moraines (dates indicated). See text for details of sources. Note heavy shadowing on the 1995 photograph caused by low angle of the sun; a white line indicates the position of the moraine, which is visible on the original.

little way down-glacier from the tributary glacier. This moraine moved progressively down the glacier in 1977, 1995 and 2001. Elongation and subsequent deformation of this moraine between 1966 and 1995 are clearly visible (Fig. 2).

The moraines indicate that periodic advances of ice have entered the main Pedersenbreen flow unit from the tributary glacier in the western cirque (Fig. 1). This corresponds with structural distortion of the longitudinal foliation on the glacier surface noted by Bennett and others (1996). The size and position of the looped moraine are most satisfactorily explained by a surge of the tributary glacier and are not consistent with formation by longitudinal compression at the glacier snout.

Since the moraine in 1897 clearly occupied a lower position (closer to the ice front) than in later photographs, it is possible to infer that the duration of the quiescent phase of the surge cycle is ~50 years (elapsed time from 1897 to 1948). However, given Pedesenbreen's inactive and depleted profile on the 1897 image, it seems reasonable to suggest that the surge took place a number of years (10–20 years?) before 1897. This raises the estimate of the duration of the quiescent phase of the surge cycle from 50 to 70 years. A second way to estimate the surge return period is to compare the position of the 1948 moraine with the 1995/2001 moraine. It appears that with ~20 more years of flow, the appearance of the current moraine will be much like that of 1948, again giving a surge return period of ~70 years (although because of contemporary ice recession the moraine will not look exactly the same as in 1948).

Between 13% and 90% of the glaciers on Svalbard have been classified as surge-type (Lefauconnier and Hagen, 1991; Hamilton and Dowdeswell, 1996; Jiskoot and others, 1998, 2000). Previous studies of their periodicity, based primarily on estimates from mass-balance studies of seven glaciers, have calculated surge return periods of 50–510 years (Hagen, 1987; Solheim, 1991; Hamilton, 1992; Liestøl, 1993; Dowdswell and others, 1995). Such calculations depend on the accuracy of field data and flow modelling, and are necessarily theoretical. Historical records, by contrast, provide a more certain method for determining surge cycle periodicity. Such records have been used to describe isolated glacier advances and recession on Svalbard but not to calculate periodicity. For example, Liestøl (1990) used sketches of the fjord in 1837 and 1869 to document an advance of the Kongsvegen/Kronebreen tidewater complex in ~1800, followed by a rapid recession and subsequent readvance in ~1860. Aerial photography of Kongsfjord, commencing in 1936, details another 20th-century cycle of advance and recession of this same glacier complex (Liestøl, 1990; Bennett and others, 1999).

The calculated surge cycle of ~5070 years for the Pedersenbreen tributary glacier is at the lower end of the range of stated estimates for Svalbard glaciers (Hagen, 1987; Solheim, 1991; Hamilton, 1992; Liestøl, 1993). Library archives may similarly provide further evidence for surges of other Svalbard glaciers and thus shed more light on their dynamics.

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