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Comment on Lønne and Lyså (2005): "Deglaciation dynamics following the Little Ice Age on Svalbard: Implications for shaping of landscapes at high latitudes", Geomorphology 72, 300–319

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In a recent article Lønne and Lyså (2005) describe geomorphological conditions and processes at a small, cold-based glacier in central Spitsbergen and from their observations make inferences about de-icing processes and their significance for the interpretation of the palaeoglacial geomorphological record in high-arctic landscapes. While we are delighted to see contributions to this important topic, we would like to draw attention to what we see as a few crucial misunderstandings that have found their way into Lønne and Lyså's (2005) work. In this comment, we would particularly like to compare Lønne and Lyså's (2005) observations and interpretations with our own from the same glacier and two surrounding glaciers, published recently in Polar Geography (Lukas et al., 2005). We have divided our comments into five areas of criticism which we will address below.

1. Use of the term "ice-cored moraine"

Lønne and Lyså (2005) refer to the margin of Platåbreen as an "ice-cored moraine" throughout the text. In contrast, their Fig. 10 correctly shows glacier ice inferred to be continuous underneath the debris cover. We feel that this ambiguity confuses and misleads the reader. Use of the term ice-cored moraine implies a body of dead ice covered with debris detached from an active or stagnant glacier farther upvalley. Thus, usage of the term should be restricted to landforms where this is the case (cf. Østrem, 1965; Dyke and Savelle, 2000; Lukas et al., 2005). The incorrect use of the term ice-cored moraine for debris-covered terminal areas of glaciers (underneath which the glacier is intact and not detached from a coherent and intact body of clean glacier ice upglacier) has led to some confusion in the past as to the significance of inferred frontal retreat in arctic areas (cf. Ziaja, 2001, 2002; Humlum, 2002).

The transition between clean ice and debris-covered ice is inferred by Lønne and Lyså (2005, Fig. 3B) to represent the present "glacier front". In the summer of 2003 we dug test pits into the consolidated debris cover along a 130-m-long transect (Fig. 1) to identify the nature, thickness and lateral extent of the marginal debris cover. This transect (Fig. 1) covers about one quarter of the debris cover width and does not extend to the margin of the debris cover because of the increasing difficulty encountered with digging into the silt-rich, thaw-consolidated diamicton at regular intervals.

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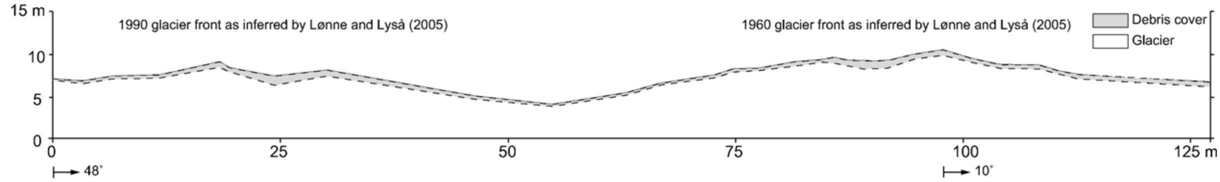

Fig. 1. Cross profile across an upglacier portion of the debris cover of Platåbreen from the centre (SW, left) to its perimeter (NE, right). Arrows at the bottom mark the azimuth of the profile line across the debris cover. The interpretation of two ridge-structures that trend perpendicular to the profile as ice-marginal retreat stages by Lønne and Lyså (2005) are indicated above the profile.

Individual test pits between the NE (right) end of our transect and the margin of the debris cover, however, confirm the presence of only a debris cover similarly thin (0.1–0.7 m) to that shown in Fig. 1. The data from this transect thus show that supraglacial debris covers a body of glacier ice that is continuous with clean glacier ice upglacier. Hence, the real glacier front is presently located at the distal limit of the debris-covered ice. The evidence from our transect is corroborated by the presence of numerous exposures of clean glacier ice exposed along large debris flows in the frontal area (cf. Lønne and Lyså, 2005, Fig. 5A; Lukas et al., 2005, Fig. 5). All evidence clearly should be interpreted in terms of a coherent body of glacier ice rather than an isolated lens or body of ice within an ice-marginal accumulation of sediments. Our observations also indicate that the thickness of the debris cover is relatively uniform, with the only major change occurring towards the snout where the debris cover thickens to what we have termed the “frontal wedge” (Lukas et al., 2005). The uniform debris thickness underneath ridges and troughs alike indicates that the debris layer merely mimics the underlying ice surface. It does not indicate dead-ice topography as found in other areas where true ice-cored moraines are found (e.g., Boulton, 1968; Kjær and Krüger, 2001).

On this basis we would argue that the features referred to as an ice-cored moraine by Lønne and Lyså (2005) are better described collectively as a ‘marginal debris-covered zone’ or ‘debris-covered terminus’ to avoid confusion.

In addition, Lønne and Lyså (2005) describe the longitudinal debris stripe visible in their Fig. 2 as a medial moraine and in Fig. 10 show this feature extending down to the bed. On the basis of this medial moraine they describe Platåbreen as comprising two lobes. However, our excavations revealed this feature to be a surface deposit of ~10 cm in thickness, and we found no evidence for an extensive vertical debris septum continuing into the ice. In the light of this, we dispute their interpretation of this feature as a medial moraine separating eastern and western flow lobes. Instead we see it as a surfacial debris deposit with source area at the headwall, partially spread downslope by supraglacial flow processes following meltout below the equilibrium line.

2. Identification of the Little Ice Age maximum and recessional stages during deglaciation

Based on four aerial photographs, Lønne and Lyså (2005: 309) identify the maximum of the Little Ice Age (LIA) and reconstruct “five former ice-front positions […] within the moraine complex”. Based on our own mapping of the whole debris-covered terminus of Platåbreen, and the indications for a coherent body of ice underneath it, we question this inference.

Firstly, the interpretation is based on aerial photographs that show the same glacier from different angles and under different extents of snow cover. In particular, the latter makes a clear and unbiased interpretation very difficult and certainly does not allow individual ice-marginal positions to be identified or compared by the reader. Secondly, and perhaps more importantly, the “moraines” are not constructional features as implied by Lønne and Lyså (2005), but rather surface features of glacier ice overlain by debris cover of near uniform thickness. The “moraine ridges” are merely a result of differential ablation at the ice-debris interface (Lukas et al., 2005). Our transect crosses two ridges inferred by Lønne and Lyså (2005) to represent ice-marginal positions of 1990 and 1960, but does not show any evidence of a substantial thickening of debris that would have to be expected if these ridges were indeed constructional moraines (Fig. 1). Thirdly, the extent of individual ice fronts is not logical and reconcilable with the present-day distribution of glacier ice. In the western part of the glacier, Lønne and Lyså (2005, Fig. 5A) show the inferred ice-marginal positions to meet the clean part of the glacier at an almost orthogonal angle. By this the inferred ice fronts terminate in the middle of the present-day glacier surface, trending parallel to foliation traces on the glacier surface. Based on the above arguments we strongly oppose the inference of retreat stages within a continuous debris cover and would reinforce our interpretation of a thinning rather than incrementally-retreating glacier since the LIA maximum position was reached.

Lønne and Lyså (2005, Fig. 6A) argue for the existence of a proglacial fan outside the "ice-cored" moraine, as support for frontal retreat since the LIA. In addition, Fig. 6B shows a number of assumed ice-front parallel meltwater traces, inferred to support the notion of gradual frontal retreat. We disagree with these interpretations. Our results show the "proglacial fan" not to represent an accumulation form, but instead an erosional landform of local bedrock, draped with a thin veneer of mainly periglacial sediments. This bedrock high was partly overridden by the glacier during the LIA advance, presumably continues some distance beneath the glacier and is not a likely site for significant subglacial drainage. The convex surface topography beyond the glacier terminus, however, ensures that surface water drains in a diverging pattern, giving rise to the apparent fan-structure when seen in aerial photographs. The ice-front parallel meltwater traces (Lønne and Lyså, 2005, Fig. 6B) are not erosional meltwater phenomena produced during frontal retreat, but are caused by periglacial earth stripes that follow the local terrain slope. Rain and meltwater naturally tend to follow this shallow surface pattern; there is no relation to frontal glacier retreat. Similar periglacial phenomena are found at many places on the plateau beyond the glacier terminus.

The arguments for classifying area 4 (Lønne and Lyså, 2005, Fig. 4) beyond the terminus as deglaciated by frontal retreat since the LIA therefore disappear. The special character of the area, e.g., the lack of vegetation, merely indicates the past (LIA) larger extent of the snow drift forming along the glacier terminus each winter. The present glacier terminus is represented by the distal limit of debris-covered glacier ice, which is effectively still at the maximum LIA position, having undergone no significant frontal retreat, only thinning.

3. Clast shape, origin and glacier transport path

Lønne and Lyså (2005, p. 304) attribute a subglacial source for the surface debris found on Platåbreen on the basis that the shale material which dominates the supraglacial debris underlies the ice. However, the source shales are also found in the shallow headwall of the basin, and the authors provide no conclusive evidence that these faces were below the ice surface during the LIA. Today, incorporation of metre-sized blocks of shale can be studied along the upper headwall, and this represents a more likely source for much of the debris in the glacier. Indeed, using detailed clast shape measurements (Benn and Ballantyne, 1993, 1994) and certain lithologies with restricted outcrop areas as tracers, we were able to show that the dominant debris source in fact is supraglacial (Lukas et al., 2005). Clasts are dominantly angular and platy with only a small proportion showing the characteristic edge-rounding and blocky shapes of subglacially-transported clasts. Only a combination of rockfall onto the ice and burial with subsequent englacial (passive) transport along flow lines and meltout is able to explain this distribution and the presence of large rafted blocks in the debris cover near the terminus (Lukas et al., 2005).

Clast shape data obtained by us from Platåbreen, Larsbreen and Longyearbreen are very similar and hint at a typical combination of processes at these small high-arctic valley glaciers. Shale that crops out underneath Platåbreen is more likely to be incorporated into the ice as small particles and would be crushed to smaller grain sizes in areas where basal sliding (evident in only a few instances) took place. With little doubt, metre-sized blocks of shale, such as those found near the terminus, are not likely to survive a rigorous subglacial transport as inferred by Lønne and Lyså, but would be shattered into smaller fragments.

Lønne and Lyså (2005, Fig. 5A) indicate the presence of a large number of thrusts in the marginal zone, although no conclusive evidence for these features is detailed. Such thrusts would presumably be an important mechanism for delivering subglacial debris to the surface. In contrast, our own excavations at this site failed to reveal any evidence of thrusting in the near-marginal zone.

4. Thermal regime during the LIA

Lønne and Lyså (2005, p. 313) argue that "the glacier was temperate" at the time of formation of the debris cover, i.e. the LIA. Such a condition, where the glacier is at the pressure melting point throughout, however, is highly unlikely to have existed during the LIA in the cold and arid climate of central Spitsbergen for several reasons. Neighbouring Larsbreen and Longyearbreen, which are both much larger than Platåbreen, have both been shown to be dominantly cold-based at present (Etzelmüller et al., 2000; Humlum et al., 2005). Evidence for some subglacial transport in the form of a limited number of striated boulders justifies an interpretation of enlarged warm-based patches underneath the glaciers during the LIA, but certainly not a fully temperate glacier, as evident from a largely V-shaped subglacial topography that suggests minimal Holocene subglacial erosion (Etzelmüller et al., 2000) and from clast shape measurements (Lukas et al., 2005). This argument is further supported by the fact that present-day Platåbreen is smaller and thinner than the two neighbouring glaciers. Deep permafrost, as occurs at the study site (Humlum et al., 2003), would presumably lead to a thoroughly frozen marginal zone of Platåbreen (e.g., Björnsson et al., 1996). Our hourly air temperature measurements since 1999 at different altitudes in the area suggest a mean annual air temperature of about −7.7 °C at the Platåbreen terminus. At best a polythermal regime can be assumed for Platåbreen during the LIA. This reasoning corresponds well to work from the surroundings (e.g., Etzelmüller, 2000; Etzelmüller et al., 2000; Lyså and Lønne, 2001; Sletten et al., 2001; Ziaja, 2001) which also suggests a polythermal regime with larger temperate patches but not entirely temperate bed conditions during the LIA. In addition, as demonstrated above, neither the "proglacial fan" (Lønne and Lyså, 2005, Fig. 6) nor other meltwater features can be taken as evidence for Platåbreen being temperate during the LIA.

For all the reasons listed above, in our opinion, the picture of a highly active temperate glacier that retreats incrementally and is characterised by dominantly subglacial transport, such as described by Lønne and Lyså (2005), is not supported by the field evidence in the surroundings of Platåbreen.

5. Controls on high-arctic deglaciation processes

In their introduction, Lønne and Lyså (2005, p. 302) make a statement on the mode of deglaciation in Svalbard, noting that: "The scarcity of moraines and the strong imprint of fluvial and colluvial activity indicate a deglaciation where the thin debris cover and related glacial landforms were reworked and transformed into a landscape dominated by running water and slope processes." While we agree with this broad observation and Lønne and Lyså's (2005, p. 311) attribution of the lack of evidence of hummocky moraine as an end product to reworking during deglaciation, we contest their interpretation of the primary control on this process. They relate the degradation of the debris-covered ice and loss of moraine-forming material directly to warm summers with thicker than normal active layer, while we argue that it is primarily a result of deglaciation under permafrost conditions, which may operate without a direct link to summer temperatures. Our data and process observations over the last five years (including automatic daily photos) highlight the importance of debris flows initiated by fluvial undercutting (cf. Lukas et al., 2005) as the main process by which surface debris is reworked, rather than backwasting and relief inversion as observed along belts of ice-cored moraines or at the surface of debris-covered glaciers elsewhere on Earth (e.g., Kjær and Krüger, 2001; Benn et al., 2001). Debris flows of saturated sediment, triggered by lateral undercutting or roof collapse of englacial channels, or by rainstorms, expose large expanses of slightly dirty ice, which are subject to rapid melt, thereby initiating the onset of a positive feedback of degradation of the debris-covered area by debris flow and ice melt. While an increase in meltwater supply, and active layer depth due to warm summers, could facilitate the onset of this "cycle of degradation" as we term it (Lukas et al., 2005), the positive feedback can be triggered by any amount of water and, once initiated, the decay of the ice. Therefore, evacuation of debris from the system by meltwater is not primarily associated with high air temperatures, but, to a much higher degree, with the amount of running water.

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