Recent landscape changes in terminoglacial area of the Nordenskiöldbreen, central Spitsbergen, Svalbard

Short communication

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During the last few centuries, Svalbard archipelago has experienced significant environmental changes related to fluctuations of local glaciers (*e.g.* Hagen et al. 2003a, b). Most glaciers in Svalbard are currently receding from their Neoglacial maxima and exposing extensive zones of unconsolidated sediments and landforms between their terminal moraines and current snouts (Glasser et Hambrey 2003).

On Svalbard, an abrupt warming since the termination of the Little Ice Age (LIA) at the end of 19th century was moderated in the middle of 20th century by cooler period with minimum temperatures in the 1960-ies, followed by a continuous warming till today (Isaksson et al. 2001). The mean annual temperature in the central Spitsbergen has increased by 4°C since the LIA (Førland et Hanssen-Bauer 2003). At present, the climate of the region is influenced mostly by the warm West Spitsbergen current. The mean annual temperature is about –6°C and the average annual precipitation is about 200 mm (Hanssen-Bauer et al. 1990).

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Nordenskiöldbreen, with an area of 242 km^2 and length of 26 km, represents a tidewater outlet polythermal type of glacier located in the northern part of the Billefjorden fjord in central Spitsbergen (Hagen et al. 1993). The outlet flows from a large ice plateau of Lomonosovfonna with a summit at 1237 m a.s.l. towards the Adolfbukta and its present front can be divided into an actively calving part and a land-terminating part (van Pelt et al. 2012). The Nordenskiöldbreen front was known to be calving along its full width during most of the 20^{th} century (Plassen et al. 2004). The ice flow of Noredenskiöldbreen is high, with est. velocities of 50–60 $m.a^{-1}$ (Den Ouden et al. 2010).

All of the glaciers in the Billefjorden area have been retreating since the end of the LIA (Rachlewicz et al. 2007). The highest retreat rate has been observed right in the case of the Nordenskiöldbreen (mean average linear retreat rate of 35 m a^{-1}; Rachlewicz et al. 2007) and therefore its terminoglacial and proglacial area is characteristic by abrupt landscape changes associated with active glacial, glaciofluvial and paraglacial processes (for overview of the wide range of these processes *see* e.g. Benn et Evans 2010; Matthew 2008).

Fig. 1. Reconstructed phases (a-e) and suggested future phase (f) of proglacial river pattern on the northwestern flank of the Nordenskiöldbreen snout.
Grey lines - streams, thick black line - glacier extent, black point in (e) - location of outcrop shown on Fig. 2.
a) LIA - stream direction was determined by the course of glacier margin and lateral moraine, b) mid-20th century - downcutting of a stream present in middle and upper parts, braiding present in lower parts of the catchment, c) summer 2011 - change of the position of the main stream closer to the glacier snout connected with glacier retreat and moraine seeping, formation of new minor streams, d) June/July 2012 - change of the main stream direction perpendicularly to the glacier margin, initial lake formation, e) mid July 2012 - headward erosion and vertical cutting of a stream, maximum extent of the lake, f) headward erosion caused by moraine seeping, subsequent event of river piracy.

According to aerial photographs provided by Norwegian Polar Institute and our field survey in July 2012, post-LIA proglacial river system on the right flank of the glacier snout passed several flow-pattern changes (Fig. 1). Large amounts of fresh glacigenic, glaciofluvial and glaciolacustrine material in the vicinity of the glacier allowed excellent preservation of these events and thus its reconstruction from geomorphological and sedimentological point of view. Position of glacial landform assemblages and sedimentary evidence suggest series of changes from braided streams to straight incised channels and *vice versa*.

Most recently, during the ablation season of 2012, the river piracy caused the abandonment of former main braided channel-belt. A new channel was formed perpendicularly to the abandoned braided channel-belt, heading towards the glacier snout (Fig. 1d). The blocking of this stream by a glacier body resulted in meltwater accumulation and formation of up to 30 m deep ice-dammed lake. The sedimentary sequences documented in the field (Fig. 2) support the hypothesis of a stream prograding into the lake connected with concurrent rise of the lake level. The sudden subglacial drainage of the lake was followed by subsequent vertical incision of a new high-energetic stream several meters into the glaciofluvial and glaciolacustrine sediments and also into the mica-schist bedrock.

Field evidence suggests rapid landscape changes in terminoglacial zone of the Nordenskiöldbreen taking place annually during the ablation period. Further retreat of the glacier snout will most likely be connected with similar changes in the proglacial landscape as outlined above. Future ablation season will show, whether the formation of ice-dammed lake takes place annually or this was a single event.

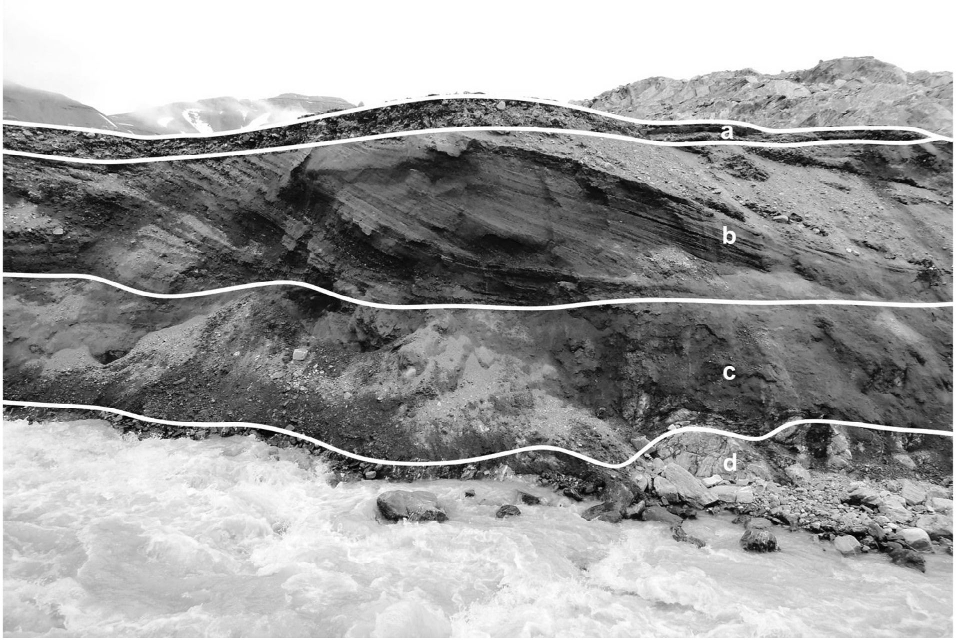

Fig. 2. Main lithofacies present in ~4 m high outcrop in a lower part of the studied catchment in the vicinity of glacier snout exposed due to the vertical incision of the stream - a) braidplain formed by massive gravel (*sensu* Miall, 2006), b) coarse grained fan delta foresets formed by planar cross-bedded sand and gravel (*sensu* Miall, 2006), c) sandy to intermediate diamicton (subglacial till), d) mica schist bedrock.

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