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Alteration of glacigenic landforms by gravitational mass movements, Ragnarbreen and Ebbabreen, Svalbard

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The extensive recession of Svalbard's glaciers exposed areas containing large amount of dead-ice covered by relatively thin - usually less than a couple of meters - veneer of debris. This landscape can be very dynamic, mainly due to the mass movement processes and dead-ice melting. Continuous redistribution of sediments causes several phases of debris transfer and relief inversion. Hence, the primary glacial deposits released from ice are subsequently transferred by mass movement processes, until they finally reach more stable position. Investigations of dynamics of the mass movement and the way in which they alter the property of glacigenic sediments are therefore cruicial for proper understanding of sedimentary records of previous glaciations. The main objectives of this study were to: (1) quantify short-term dynamic of mass wasting processes; (2) investigate the transformation of the sediment's characteristic by mass wasting processes; (3) asses the contribution of different process to the overall dynamic of proglacial landscape.

We focused on the mass-wasting processes in the forelands of two glaciers, Ebbabreen and Ragnarbreen, located near the Petuniabukta at the northern end of the Billefjorden, Spitsbergen. Repetitive topographic scanning was combined with sedimentological analysis of: grain size, clast shape in macro and micro scale and thin sections.

Debris falls, slides, rolls and flows were the most important processes leading to reworking of glacigenic sediments and altering their properties. Contribution of different processes to the overall dynamic of the landforms was related mainly to the local conditions. Four different morphological types of sites were identified: (1) near vertical ice-cliffs covered with debris, transformed mainly due to dead-ice backwasting and debris falls and slides, (2) steep debris slopes with exposed ice-cores dominated by debris slides, (3) gentle sediment-mantled slopes transformed due to debris flows, and (4) non-active debris-mantled areas transformed only by dead-ice downwasting. The amount of volume loss due to the active mass movement processes and dead-ice melting (including both backwasting and downwasting) was up to more than 1.8 m a^{-1}. In comparison, the amount of volume loss due to the dead-ice downwasting only was significantly lower at a maximum of 0.3 m a^{-1}. The spatial and temporal distribution of volume changes, however, was quite diverse and for the most part related to local geomorphic conditions (e.g. slope gradient, occurrence of streams, and meltwater channels).

We proposed a simplified model of spatio-temporal switching between stable and active conditions within the forelands of the studied glaciers. Transformations of landforms were attributed to the period of deglaciation and debris cover development. Stage 1 - shortly after deglaciation when the debris cover is thin (thinner than the permafrost active layer's thickness) mass movement processes become fairly common. They are facilitated by the dead-ice melting and steepness of the slopes. This stage can be observed in many lateral moraines, which are characterised by steep slopes, abundance of active mass movement processes, and by consequence a high degree of transformation. Stage 2 - ongoing mass-wasting processes lead to the transfer of sediments from steep slopes to more stable positions. As the thickness of the sediments increases, the debris cover starts to protect the dead-ice from melting and also contribute to the decrease in slope gradient. Thus, the resulting landscape is relatively stable and in equilibrium with current climatic and topographic conditions. This stage characterises most parts of the frontal (end) moraine complex of the studied glaciers; thus, their transformation rates are either very low or close to zero. Stage 3 - some parts of this stable landscape can be subsequently transformed again into an unstable state, mainly due to the effect of external factors such as streams or meltwater channels. This can lead to the development of mass movement processes and further slope instability, which could facilitate subsequent generation of debris flows. Stages described above can occur in a sort of spatio-temporal cycle, and, depending on local and external factors, the changes between stabilization of landforms and activation of mass flows can be repeated several times for any given area until the dead-ice is completely melted.