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Response of till to subglacial shear stress simulated in ring-shear experiments derived from X-ray computed microtomography

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Limited accessibility to the subglacial environment leaves processes operating therein poorly constrained. Understanding these processes is imperative for deciphering the dynamic behaviour of past ice sheets, in particular related to glacial erosion and sediment advection at the ice-bed interface. Their legacy is typically studied through investigating deposits left behind the ice sheets, but conclusions often remain equivocal due to the scarcity of well constrained reference studies and modern analogues (e.g. Menzies et al., 2016).

Here we report preliminary results of a project sponsored by the Bundesgesellschaft für Endlagerung (BGE) in which we used a ring-shear apparatus to simulate the response of a subglacial traction till from northern Germany to stresses imposed on it by an overriding glacier. Bearing in mind all the simplifications and limitations inherent to *in-vitro* laboratory settings, these experiments intend to mimic as closely as possible the conditions beneath ice sheets. A homogenized natural water-saturated till was continuously sheared at an effective normal pressure of 85 kPa and shearing velocity of 2 mm/min (i.e., parameters considered representative for ice sheets) to a total displacement of 800 mm. In the course of shearing, five undisturbed oriented 8x6x4-cm-large samples were taken at the displacements of 0, 100, 200, 400 and 800 mm. Subsequently, these samples were scanned using X-ray computed tomography (µCT) with a spatial resolution of 60 µm to constrain the structural evolution of the till as a function of the shearing distance. In focus was the progressive development of till fabrics and pore spaces resulting from intergranular advection of sediment mobilized by subglacial shearing. In each sample, between 1612 and 2195 clasts with mean lengths of ca. 1 mm were manually selected and automatically measured. The long axes of clasts revealed eigenvector values' increase during the shearing, showing that the clasts tend to become progressively aligned parallel with the shear direction as the strain accumulates. This indicates a plastic mode of deformation. There is also a distinct relationship between the elongation of clasts (a/b axis ratio) and their orientation; the orientation of clasts with a/b ratios above 2.0 differs by ca. 5° from clasts with a/b ratios above 1.5. During the shearing, the volume of pores steadily decreased, suggesting progressive compaction, pore-water expulsion, and lack of dilatant behaviour of the sheared till (possibly due to its fine-grained composition).

Our data show progressive evolution of till microfabrics broadly consistent with a similar study based on a two-dimensional micromorphological analysis of Phillips & Piotrowski (2023). The observed reduction of porosity entails a decrease of hydraulic conductivity of the sediment and thus its ability to conduct meltwater, with possible consequences for the mechanical characteristics of the ice-bed interface.

References

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