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1 Laboratory Experiments constrain the Origin of Bedded Tills

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Bedded tills often occur in the record of Quaternary glaciations. Such tills typically consist of cm-thick, subhorizontal layers of sorted sediments within massive, diamictic till matrix. Despite numerous, well-documented structure-geological studies on such tills in outcrop-scale and microstructure-scale, there is no consensus as to their origin. Main interpretations trends include formation due to (1) tectonic shearing of overridden outwash sediments, (2) melt-out of debris layers at the ice sole and partial sorting by water seepage, (3) basal de-coupling by pressurised meltwater and washing at the ice-bed interface, and (4) re-freezing of sorted subglacial sediments to the ice sole, e.g. by supercooled water. Much attention has been focussed on the tectonic processes in the context of the subglacial deforming bed model.

In order to test the behaviour of layered sand/till diamictons when subjected to shear stresses as under ice sheets, especially their structural evolution, we conducted a series of laboratory experiments in a big ring-shear device (outer diameter 60 cm, sample thickness 8 cm, sample width 12 cm, shearing gap in the middle of the sample). The sediment was a synthetically prepared diamicton consisting of a layered till-sand pancake. Shearing was run under fully saturated conditions with constant shearing velocity of 0.69 mm/min and constant normal stress of 85 kPa. Relevant geotechnical parameters were continuously monitored during the experiment, and the sediment strain profile was measured by marker displacement. Box samples were taken incrementally up to a final shearing displacement of 15.9 m. Impregnated, sliced and thin-sectioned, the samples document structural evolution of the bedded diamicton under conditions simulating a natural subglacial environment.

The sediment exhibits progressive mixing and homogenisation up to a completely structureless diamicton at the end of shearing. Both brittle and ductile deformation styles are observed, with microstructures including fractured grains, shear planes, grain stacking and rotational structures. Diffusive grain mixing across lithological contacts led to attenuation of contacts already after ca. 12 cm of shearing displacement. This may indicate that a bedded till with sharp lithological contacts is inconsistent with pervasive deformation, which should soon lead to sediment homogenisation. The total strain of such a till may be constrained by the degree of intergranular diffusion using laboratory experiments conducted under well-defined conditions as a reference. Our preliminary results suggest that mechanisms other than subglacial shearing may be more relevant for the formation of bedded tills.