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Subglacial till deformation constrained by laboratory experiments

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In a detailed study of mega-scale glacial lineations (MSGLs) left by a Weichselian palaeo-ice stream in Poland, Spagnolo et al. (2016) analysed multiple parameters of the land-forming till and concluded that it originated by a combination of lodgement and thin-skinned deformation whose cumulative effect was the formation of the MSGL field.

To advance our understanding of till formation and deformation postulated by Spagnolo et al. (2016) we conducted a series of experiments on this till in a large ring-shear apparatus intended to mimic subglacial shearing to a total cumulative strain of 640. Undisturbed, oriented samples for micromorphological analyses were taken at displacement increments of 0, 9, 18, 36, 72, 144, 288, 576 and 1152 cm.

Till microstructures mapped on thin sections across the zone of shearing gave intriguing and hitherto unmatched insights into the development and evolution of till properties during the shearing under controlled boundary conditions. The deformation signatures often varied non-systematically between the sampled increments. Three-dimensional microtomographic scanning showed intervals of relatively stable till fabrics intervening with phases of fabric re-orientation towards new equilibria. Shear stresses during the deformation showed a distinct cyclicity possibly indicating formation and collapse of grain bridges.

Collectively, we interpret the ring-shear data supported by discrete elements numerical modelling as a signature of permanent and largely unpredictable evolution of till structure with a general trend towards more ductile and less brittle deformation with increasing strain. These results bear on the reconstruction of past subglacial processes, deposits and landforms and we advocate extreme caution with interpreting the history of natural tills based on the micromorphological signatures alone.

Reference:
Spagnolo, M., Phillips, M., Piotrowski, J.A., Rea, B.R., Clark, C.D., Stokes, C.R., Carr, S.J., Ely, J.C., Ribolini, A., Wysota, W. & Szuman, I., 2016. Ice stream motion facilitated by a shallow-deforming and accreting bed. Nature Communications 7:10723, doi: 10.1038/ncomms10723.