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Visualising, segmenting and analysing heterogenous glacigenic sediments using 3D x-ray CT.

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Whilst there has been significant application of 3D x-ray CT to geological contexts, much of this work has focused on examining properties such as porosity, which are important in reservoir assessment and hydrological evaluations. There has been considerably less attention given to the analysis of the properties of sediments themselves. One particular challenge in CT analysis is to effectively observe and discriminate the relationships between the skeleton and matrix of a sediment. This is particularly challenging in glacial sediments, which comprise an admixture of particles of a wide range of size, morphology and composition within a variably-consolidated sediment body.

A key sedimentological component of glacial sediments is their fabric properties. Till fabric data has long been applied to the analysis of the coupling between glaciers and their deformable substrates. This work has typically focused on identifying former ice-flow directions, processes of till deformation and emplacement, and such data is often used to reconcile the sedimentary evidence of former glaciation with the predicted glacier and ice-sheet dynamics derived from numerical models. The collection and interpretation of till fabric data has received significant criticism in recent years, with issues such as low sample populations (typically $\sim$50 grains per sample), small-scale spatial variation in till fabric and operator bias during data collection, all of which compromise the reliability of macro-scale till fabric analysis. Recent studies of micro-scale till fabrics have substantially added to our understanding, and suggest there is systematic variation in particle fabric as a function of particle size. However, these findings are compromised by the 2D nature of the samples (derived from thin sections) capturing only apparent orientations of particles, and are again limited to relatively small datasets. As such, there are fundamental limitations in the quality and application of till fabric, especially with regard to using such data to improve understanding of mechanisms of particle motion and fabric development during subglacial strain.

In this study, we present detailed investigation of subglacial tills from the UK, Iceland and Poland, to explore the challenges in segmenting these highly variable sediment bodies for 3D microfabric analysis. A calibration study is reported to compare various approaches to CT data segmentation to manually segmented datasets, from which an optimal workflow is developed, using a combination of the WEKA Trainable Segmentation tool within ImageJ to segment the data, followed by object-based analysis using Blob3D. We then demonstrate the value of this analysis through the analysis of true 3D microfabric data from a Last Glacial Maximum till deposit located at Morston, North Norfolk. Seven undisturbed sediment samples were scanned and analysed using high-resolution 3D X-ray computed tomography. Large ($\sim$5,000 to $\sim$16,000) populations of individual particles are objectively and systematically segmented and identified. These large datasets are then subject to detailed interrogation using bespoke code for analysing particle fabric within Matlab, including the application of fabric-tensor analysis, by which fabrics can be weighted and scaled by key variables such as size and shape. We will present initial findings from these datasets, focusing particularly on overcoming the methodological challenges of obtaining robust datasets of sediments with highly complex, mixed compositional sediments.