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Three-dimensional structure of the frontal zone of a polythermal glacier revealed by borehole optical televiewing

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Digital optical televiewing (OPTV) of six hot-water-drilled boreholes is combined with surface mapping to recreate the englacial structure and sediment distribution of polythermal Midre Lovénbreen, Svalbard. OPTV-derived structural data are interpolated from six individual boreholes onto two three-dimensional grids at node spacing of 1 m vertically and 10 m horizontally. Eight types of structure are identified: (i) primary stratification; (ii) longitudinal foliation; (iii) transverse fracture traces; (iv) arcuate shear planes; (v) oblique fractures; (vi) large-scale lateral folds; (vii) medium-scale horizontal folds, and (iix) small-scale horizontal folds. OPTV reveals basally derived englacial sediment layers intercalated within primary stratification, elevated into near-vertical planes around a central fold axis by large-scale lateral folding. Supraglacial longitudinal debris ridges are classified into two types on the basis of their morphology and association with glacier structure. Type-I debris ridges are formed by the exposure of large-scale lateral fold-axes at the glacier surface in response to the convergence of multiple flow units into a narrow ice tongue. Type-II debris ridges, in contrast, undergo secondary deformation by small-scale horizontal folding in association with vertical displacements across arcuate shear planes in response to longitudinally compressive stresses at the glacier terminus. Three-dimensional structural data derived from multiple OPTV logs overcome many of the issues associated with interpretations of surface-based structural mapping of ice masses.