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Glacio-tectonic thrust and deformation structures in the Vejle Fjord, Denmark revealed by high-resolution subbottom-profile data

Katrine Juul Andresen (1), Lars Ole Boldreel (2), Katrine Bak Wahlgreen (2), Marit-Solveig Seidenkrantz (1), Hans Røy (3), Egon Nørmark (1), and Verner Brandbyge Ernstsen (2)

(1) Department of Geoscience, Aarhus University, Aarhus, Denmark (katrine.andresen@geo.au.dk), (2) Department of Geosciences and Natural Resource Management, University of Copenhagen, Copenhagen, Denmark, (3) Center for Geomicrobiology, Department of Bioscience, Aarhus University, Aarhus, Denmark

Surface geomorphological features and partial cliff exposures up till now represent the predominant source of information of glaciation related deformation in Denmark. In this study we apply high-resolution marine reflection seismic data from the Vejle Fjord area, supported by gravity and Rumohr coring, to document intense glacio-tectonic deformation in the shallow subsurface of Denmark. The subbottom profiler seismic data have a peak frequency around 13 kHz and a vertical resolution in the order of 10-20 cm. The data reveal several variations of glacio-tectonic deformation structures, primarily observed near the edges of the fjord where coarse-grained and sandy deposits are present. These sediments allows for an exceptionally good and high-resolution imaging of the marine shallow subsurface. Within the central regions of the fjord, widespread shallow gas accumulations probably generated from biodegradation of post glacial organic-rich fine-grained marine gytja and clay deposits, effectively blank and absorb the seismic signal. This leads to a very poor imaging of the subsurface within the deeper parts of the fjord.

Glacio-tectonic deformation is observed at both the northern and southern edge of the fjord. To the north, the deformation is expressed by complex internal reflection patterns within discrete sedimentary units including faults and smaller thrust-structures and associated small-scale folding. Channel incisions and clear reflection relations (i.e. truncations, onlaps and downlaps) reveal more decollement surfaces and furthermore constrain the timing of deformation. At least three episodes of deformation can be recognized at the northern edge of the fjord. To the south, a large thrusted fold belt (c. 3 km long and up to 10 m high) with faults, folds and thrust sheets is observed indicating severe deformation which most likely reflects ice progression from a southerly direction; for instance by the Young Baltic Ice Stream c. 19-17 ka. A thick and undisturbed build-out sequence can be observed to the north and in front of the thrust-belt probably representing meltwater sedimentation related to the retreat of the ice advance. Steeply inclined reflections observed c. 10 km northwest of the thrust-belt and within the inner parts of the fjord, indicate rapid and westward prograding deposition and filling of the fjord. Such rapid infill probably reflects sudden failure of temporary thresholds sheltering the inner parts of the fjord, i.e. large ice chunks left behind during ice retreats.

Besides of documenting the intense glacio-tectonic deformation in the Vejle Fjord region, our study demonstrates the utility of integrating subbottom profiler data with already known information on ice movements from outcrops and shallow cores. The subbottom profiler data provides larger (longer and deeper) sectional views on for instance deformation and deposition complexes related to ice progressions and retreats and thus represents a very good supplement and valuable input to field mapping and outcrops studies concerned with the Quaternary and youngest geological evolution in Denmark.