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Three-dimensional imaging of landforms produced by ice streams draining former Eurasian ice sheets

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Three-dimensional (3D) seismic interpretation and imaging techniques provide unique means of investigating submarine geomorphic features produced by former ice sheets. We use an extensive two-dimensional (2D) and 3D seismic data base, covering a 240 000 km^2 large study area of the north-Norwegian shelf to image the imprints left behind by ice stream complexes that flowed out a major cross-shelf trough (Bjørnøyrenna) during repeated glacial episodes. Fast flow is inferred from mega-scale lineations on former subglacial beds, long chains of megablocks and rafts buried in thick till units between the glacially eroded horizons, and large sediment accumulations that indicate focused sediment delivery.

Mega-scale glacial lineations characterize the seafloor geomorphology of Bjørnøyrenna and smaller, contributing cross-shelf troughs, and are inferred to represent flow-lines of former ice streams that where active during the most recent (Weichselian) glacial period. Similar features are commonly observed on buried horizons, spanning stratigraphic records that correspond to over a million years of glacial activity. The streamlined landforms observed are up to 180 km long, have widths varying from a few hundred meters to five km, reliefs from a few meters to 10 m and length:width-ratios varying from 33:1 to over 105:1. Large-scale seafloor imprints from an early readvance after the last glacial maximum are especially well preserved. Streamlined landforms and associated lobe-shaped ridges indicate that the Bjørnøyrenna trough hosted six separate ice stream lobes that diverged fan-like at their margins, but were not all active simultaneously. A 300 km long, 68 km wide and 85 m high end moraine zone, filling the whole width of this major cross-shelf trough, results from high sediment flux within sub-ice stream deformable beds.

A 2-3 km thick stratigraphic record of glacigenic sediments is preserved at the mouth of Bjørnøyrenna, in the Bjørnøya Trough Mouth Fan. The preservation of up to several hundred meters of till units between the buried, glacially eroded surfaces, provides here the opportunity to study the internal structure of glacigenic sediments between beds of former ice streams. 3D seismic volumetric attribute maps reveal that megablocks and rafts commonly occur within the till units. The sediments blocks are often aligned in chains that may be up to 2 km wide and over 5m km long. The largest individual megablocks have an areal extent of over 2 km^2. The sediment chains are interpreted to have been eroded, transported and deposited by grounded ice, most probably fast-flowing ice streams. This is based on the relationship between the sediment chains and associated beds with mega-scale glacial lineations, and internal structure of individual sediment blocks. A borehole documents that one of the sediment blocks consists of a 15-25 m thick sequence of consolidated mid Cretaceous sedimentary rock, buried in a muddy till.

We infer that both mega-scale glacial lineations and chains of mega-scale sediment blocks and rafts are products of fast-flowing ice streams, and hypothesize that they represent different modes of ice-stream erosion. Mega-scale glacial lineations are most probably related to deformation of subglacial unfrozen sediments, whereas glacial transportation of megablocks and rafts is usually interpreted to be related to freezing onto the base of the glacier.