



## **Sub-glacial processes interpreted from 3D and high-resolution 2D seismic data from the Central North Sea**

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A near complete record of Quaternary deposition, comprising more than 1000m of sediments, is preserved within the Central North Sea (CNS). This study presents evidence interpreted from seismic data of sub-glacial processes at a variety of scales for several Pleistocene glacial events. The study area has been the subject of hydrocarbon exploration since the mid 1960s and is covered by 3D seismic datasets up to 1000km<sup>2</sup> as well as high-resolution 2D (HR2D) seismic datasets covering areas of 1-25km<sup>2</sup>. These data have been examined using a variety of techniques and attributes, including time-slicing, horizon slicing, topographic mapping and attribute analysis, to map erosion surfaces, depositional bodies, sedimentary textures and deformation events. An Early Pleistocene seismic event has been identified on 3D data, at 800-1000m MSL, within the southern part of the CNS, which marks the first appearance of iceberg ploughmarks. This event has been traced into the northern part of the study area, where iceberg ploughmarks are absent, but a set of mega-scale lineations at 700-800ms TWT are interpreted as ice-stream scour marks. A series of complex seismic events overlying the ice-scoured surface are interpreted as glacial deposits, at the top of which a network of channels, interpreted to be the result of glacial meltwaters, is associated with features interpreted as over-bank sand bodies. Higher in the sequence, timeslice images of Early to Middle Pleistocene deposits show trains of sub-parallel, curvi-linear, events, several km in length and 50-300m in width. Analysis of these events on HR2D data reveals them to consist of series of short, imbricated, dipping reflectors, terminated by complex, mounded structures. Individual sheets display up to 60ms TWT (55m) vertical displacement over horizontal distances of 200-250m. Two deformed packages are evident on HR2D data. A lower sequence, consisting of discrete thrust sheets lies above an erosion or dislocation surface (MP1). Top of the lower sequence is marked by a reflection termed MP2, above which is an upper sequence displaying lower reflection amplitudes, smaller scale deformation structures, but a more comprehensively deformed fabric. To the south of these tectonised intervals, deposits are completely undeformed and this lateral transtion is interpreted to mark an ice limit or lift-off point. Within a Middle to Late Pleistocene sequence a series of glacial and glacio-marine depositional units are bounded by surfaces characterised by tunnel valley development, recording at least three glacial advances and subsequent retreats. The uppermost surface displays various features indicative of an ice-moulded surface; the largest exhibit asymmetric long profiles and complex internal structures and are interpreted as drumlin-like structures, one of which extends into a long, broad ridge, approximately 800m across and 15m high extending for several km. Two or three smaller ridges, approximately 3-5m high and 30-40m across and interpreted as flute-like structures are traceable for more than 5km over several datasets. All of these features are oriented on a constant bearing of 316°, recording ice-flow orientation at the time of their formation. The bedforms are cut by a coeval or slightly later sub-glacial tunnel valley on a similar orientation.