Geophysical Research Abstracts
Vol. 15, EGU2013-5646, 2013
EGU General Assembly 2013

Glacitectonic rafting and associated deformation of mid-Pleistocene glacigenic sediments, near Central Graben, central North Sea; results of a 2D High-Resolution Geophysical Survey

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Glacitectonic rafts are defined as dislocated slabs of bedrock or unconsolidated sediments, transported from their original position by glacial action. These relatively thin, slab-like bodies feature transport distances ranging from tens of meters to hundreds of kilometers. They occur as either single rafts, or multiple stacked bodies associated with a variety of ice-pushed landforms. Internally, rafts frequently appear undeformed although at a larger scale, they may be folded or cut by shear zones and brittle faults. However, the processes leading to the detachment, transport and subsequent emplacement of the rafts remain uncertain.

This work describes the results of a geophysical 2D seismic survey of thrust-bound glacitectonic rafts and associated deformation structures, occurring within mid-Pleistocene glacigenic sediments of the Central Graben, central North Sea.

The total shortened length of the rafted section is 2.4km, comprising a series of nine discrete rafts which individually range from 235m to 1018m in length. The principle basal detachment occurs at the erosive contact between Aberdeen Ground Formation and overlying Ling Bank Formation. The ice-proximal (northern) limit of rafting is defined by the presence of a large-scale palaeo-channel oriented perpendicular to the direction of rafting, composed of sediments of the Ling Bank Formation and the Forth Formation. The observed deformation structures infer a mean tectonic direction of 178°, indicating that they are associated with an active glacial advance from the north. The resulting deformation creates a minimum lateral shortening throughout the observed sequence of 35%, typifying a strongly compressional regieme associated with rafting.

Throughout the surveyed area, structurally younger rafts are found to be emplaced towards the south, compared to the structurally older rafts which are emplaced towards the south-east. This distinction is suggested to be caused by early rafts creating an obstacle to transport for later stages of deformation, resulting in strike-slip basal detachment being associated with the later rafts.

Localised distributions of high amplitude surfaces located adjacent to the primary detachment surface are identified through amplitude extraction techniques. These are indicative of migration and collection of gas along the inclined lower surfaces of rafted blocks. They represent a gas risk for drilling operations and demonstrate the significance and possible hazards of glacitectonic deformation to the exploration industry.

A model for raft detachment and emplacement is proposed whereby; i) saturated sediments within the palaeo-channel are subject to pressurisation associated with overburden caused by over-riding ice, ii) elevated pore-water pressure develops along the principle detachment surface of the rafts, iii) early stages of deformation consist of ice-distal (southern) blocks becoming emplaced at relatively low angles of inclination, iv) with more proximal blocks accumulating as an imbricate thrust-stack sequence at relatively high angles of elevation.

This interpretation suggests a significant subglacial hydrological control upon raft detachment and transport, with fluctuations between an extensional and compressive deformation regime caused by a switch from actively advancing glacial conditions to an oscillating ice-margin at this location. Tectono-stratigraphic evidence indicates that rafting occurring throughout the site is likely to be associated with a glacial advance of the Anglian (MIS 12).