Glacistore: Understanding Late Cenozoic Glaciation and Basin Processes for the Development of Secure Large-scale Offshore CO_2 Storage (North Sea)

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I Background

The sedimentary strata of the North Sea Basin (NSB) record the glacial and interglacial history of environmental change in the Northern Hemisphere (**Figure 1**), and are a proposed location for the engineered storage of carbon dioxide (CO_2) captured from power plant and industrial sources to reduce greenhouse gas emissions. These aspects interact in the geomechanical and fluid flow domain, as ice sheet dynamics change the properties of potential seal and reservoir rocks that are the prospective geological storage strata for much of Europe's captured CO_2.

The central part of the NSB preserves a unique history of the depositional record spanning at least the last 3 Ma, which also forms the overburden and seal to the underlying CO_2 reservoirs. There is good evidence that these ice sheets created strong feedback loops that subsequently affected the evolution of the Quaternary climate system through complex ocean-atmosphere-cryosphere linkages.

An increased understanding of the overlying sequence will inform quantitative predictions of the performance of prospective CO_2 storage sites in glaciated areas in Europe and worldwide; to include improved resolution of glacial cycles (depositional and chronological framework), characterise pore fluids, flow properties of glacial landforms within the sequence (e.g. tunnel valleys) and the geomechanical effects (quantify compaction, rock stiffness, strength and stress profiles) of advancing and retreating ice on the underlying strata to verify and constrain models of glaciation.

This presentation describes current work and introduces a proposal submitted to the International Ocean Discovery Program (852-Pre) by the authors.

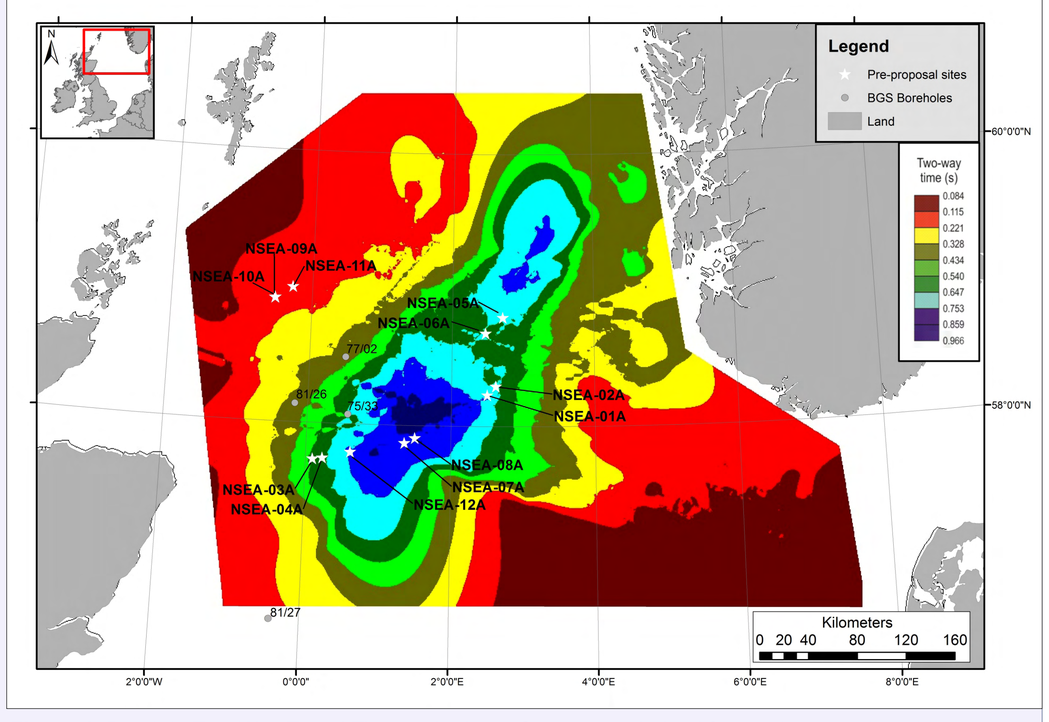


Figure 1. Depth in Two Way Travel Time to the base Quaternary derived from seismostratigraphic interpretations (University of Oslo and the Norwegian Petroleum Directorate) and proposed IODP drill sites.

II The Overarching Project

A consortium of researchers from Norway and the UK has been established to:

- Develop a regional seismic sequence stratigraphic framework for the Paleogene - Quaternary reservoirs, seals and overburden in the Central North Sea – applicable on both sides of the UK /Norway median line.

- Improve our understanding of the sedimentological, reservoir and seal properties of the Paleogene to Quaternary strata in this area and the hydraulic connectivity of the potential reservoirs within them. This will inform modelling of potential migration paths for CO_2 injected into, and formation water migrating out of, reservoir formations.

At present we think the main potential CO_2 storage reservoirs on the UK side are the stacked fans deposited between 61.6 and 56 Ma (the Maureen, Mey and Forties Sandstones), though we know they are hydraulically connected – oil and gas fields are always in the highest of these sandstones. On the Norwegian side the Utsira Sand is a major potential reservoir and the storage formation for the active Sleipner CO_2 storage project.

Figure 2a

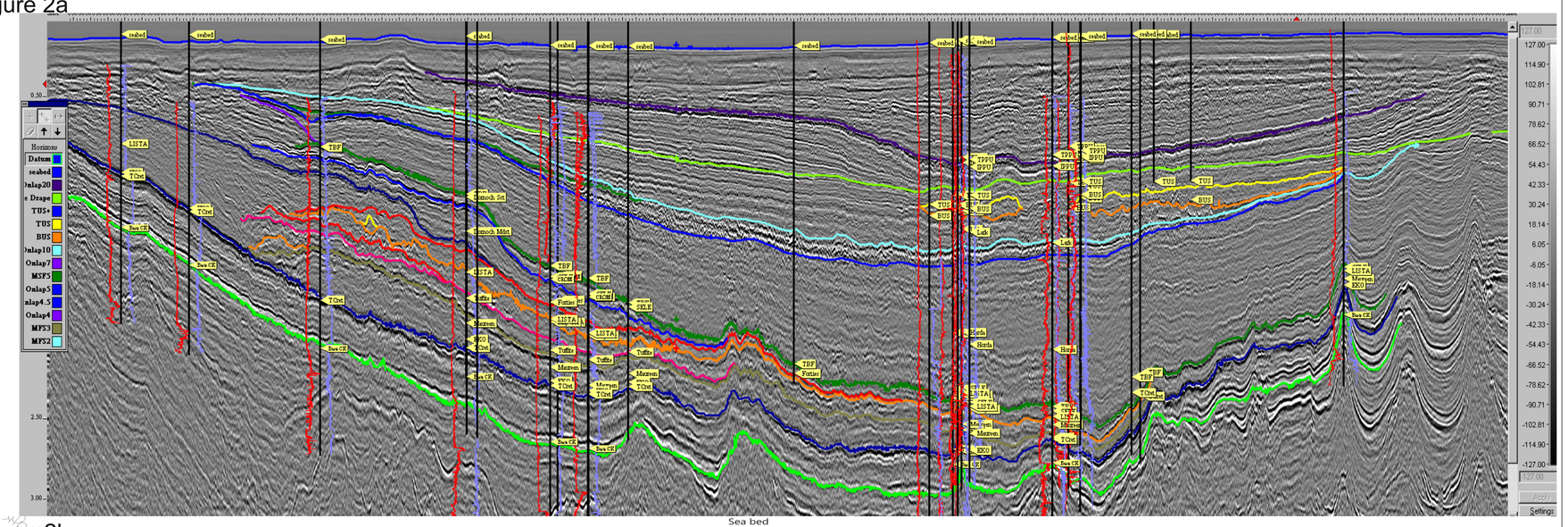
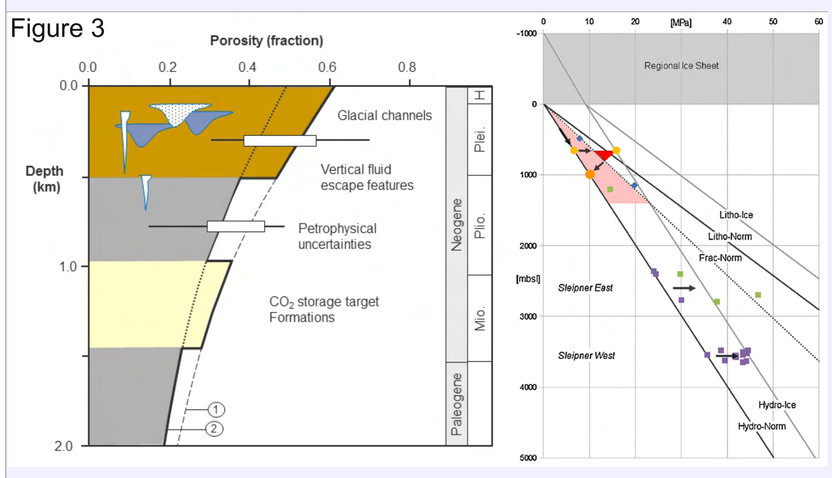


Figure 2b

Seismic data courtesy of Schlumberger WesternGeco

Figure 2a is an interpreted regional seismic line across the Central North Sea. **Figure 2b** is the depth converted interpretation. Recent revision of the Pliocene - Pleistocene boundary is not yet incorporated (base Pleistocene is now though to be close to the top of the Utsira Sand).

Figure 3



III The IODP Proposal

Very little directly measured data is known from the Neogene and Quaternary sediments of the Northern and Central NSB. These sediments, comprising heterogeneous sedimentary sequences, are bypassed by exploration and production wells that target the region's deeper hydrocarbon fields, whereas environmental and glacial investigations seldom penetrate deeper than 10m. Rigorous assessment of the complex architecture, physical properties, geochemistry, and geomechanical behaviour of these sediments will add new scientific insights in a variety of research fields and can only be reliably determined from scientific drilling and sampling (**Figure 3**).

Figure 3 ***left.*** (a) Conceptual sketch showing essential elements of the shallow stratigraphic sequence to be investigated by the drilling programme. (b) Suggested pressure-depth trends at the Sleipner field during and after ice-shield loading.

Figure 4 ***right.*** Distribution of tunnel valleys mapped from 3D seismic datasets in the North Sea region. Tunnel valleys formed during the Weichselian glaciation are not shown. The suggested limits of the three main glaciations are shown (blue - Weichselian; green - Saalian; orange - Elsterian).

Correlation between tunnel valley episodes (assuming that the oldest tunnel valleys mapped are MIS 12 in age) suggests that there have been seven (or more) extensive glaciations in the North Sea Basin prior to the most recent and provides direct geomorphic evidence for repeated advance and growth of Pleistocene ice sheets in northwest Europe from the Bruhnes-Matuyama reversal onwards.

After: Stewart, M.A., Lonergan, L., Hampson, G. 2013. 3D seismic analysis of buried tunnel valleys in the Central North Sea: morphology, cross-cutting generations and glacial history. Quaternary Science Reviews, v. 72, 1–17.

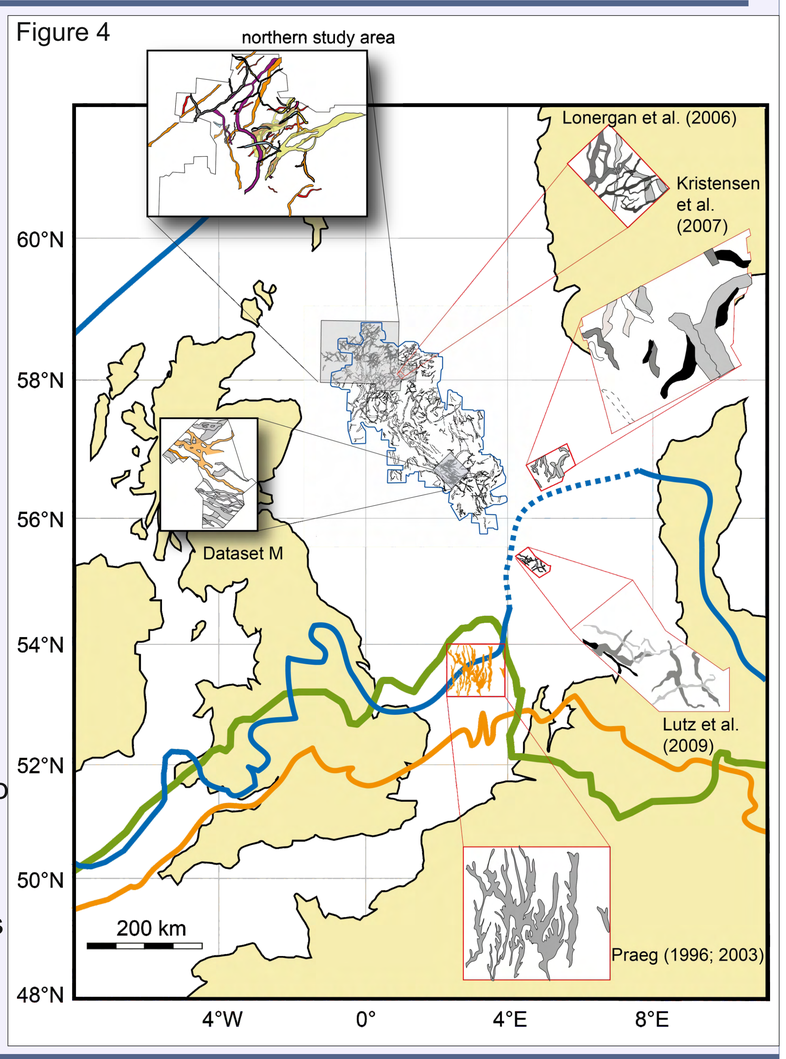
IV IODP Proposal Scientific Objectives

Scientific Objective 1
Establish a depositional and chronological framework for multiple cycles of glacial advance and retreat (**Figure 4**) preserved in the centre of the North Sea Basin which can be tested by scientific drilling, sampling and detailed analysis.

Scientific Objective 2
Characterise the pore fluids (dissolved gases, salts and isotopes) to identify fluid history, age, and degree of mixing.

Scientific Objective 3
Determine the measurable impact on the geomechanical properties (porosity, rock stiffness, in-situ stresses, pore pressure) of underlying strata caused by cycles of glacial loading and unloading **Figure 3**.

Figure 4



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