Quaternary seismic stratigraphy of the Flemish Bight (southern North Sea)

a re-evaluation

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Background

The Quaternary story of the North Sea has been one of constant environmental change. In the southern North Sea (Fig. 1), geophysical and geological data have been acquired since the 1960s. Two stratigraphic frameworks (Rijsdijk et al (2005) & Stoker et al (2011)) are currently in use. Nevertheless, major questions about the southern North Sea's palaeo-landscape evolution and stratigraphy remain. Particularly in the upper tens of metres of the seabed, low spatial data density and vertical resolution make interpretations ambiguous.
The area is also a hotspot for Pleistocene palaeontological and Mesolithic archaeological finds (Fig. 1) trawled up by fishermen.
However, the stratigraphic origin of the finds is still unknown.
The present study re-evaluates the current stratigraphic framework of an area known as the Flemish Bight (Fig. 1), and eventually aims to put the finds into a stratigraphic context.

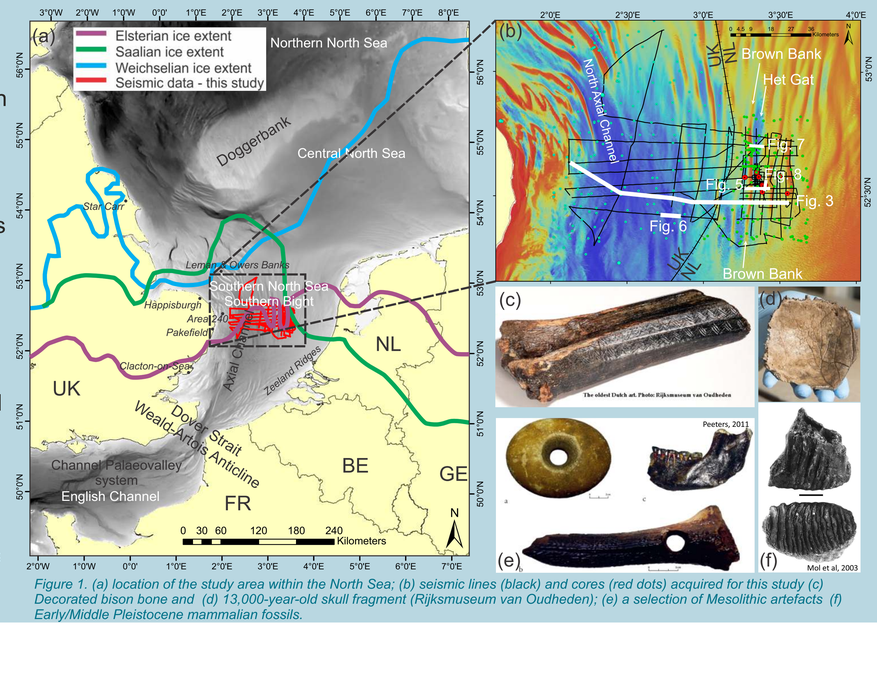

Figure 1. (a) location of the study area within the North Sea; (b) seismic lines (black) and cores (red dots) acquired for this study (c) Decorated bison bone and (d) 13,000-year-old skull fragment (Rijksmuseum van Oudheden); (e) a selection of Mesolithic artefacts (f) Early/Middle Pleistocene mammalian fossils.

Methods

A multi-disciplinary consortium of Belgian, Dutch and British research entities has been set up with the aim to collectively advance palaeo-landscape research in the southern North Sea: **the Deep History Consortium**.
As part of the consortium, five surveys (Fig. 1) have been conducted between 2018-2021 onboard 3 research vessels (Fig. 2a). Seismic surveys were conducted using Sparker (150 m penetration; c. 1 m vertical resolution), and Parametric Echosounder (PES) (10 m penetration; up to 5 cm resolution) (Fig. 2b), and ground-truthing consisted of vibrocoring, dredging and trawling (Fig. 2b).

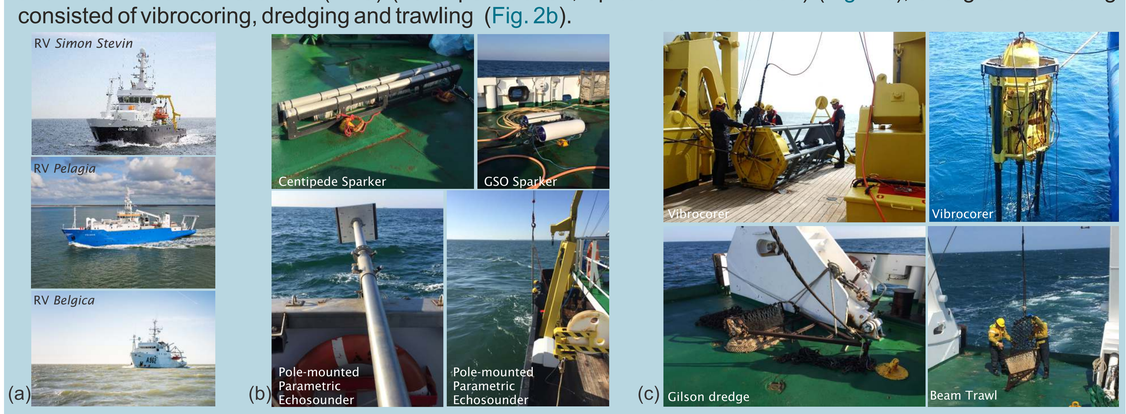

Figure 2. (a) Research vessels used; (b) seismic and acoustic equipment deployed (Sparker & PES); (c) groundtruthing with vibrocorer, dredging and trawling.

Seismo-stratigraphy

The Sparker profiles (Fig.3a,b) allowed the regional seismo-stratigraphy to be reconstructed and compared to the current Quaternary stratigraphic framework (Fig.3c). Seven seismic units were identified, two of which (U4 & U5; Fig.3b) had not previously been described in the literature.
The PES data allowed the top 10 m to be resolved in unprecedented detail. For the first time, the complexity of the uppermost seismic units could be imaged. Most notably, it has revealed: (i) the Brown Bank Formation is composed of at least 4 distinct subunits (Fig. 4), and (ii) a Holocene inundation surface has been preserved in the area of the Brown Bank sand ridge (Fig.5). A distinct and traceable reflection in the PES data was ground-truthed (14 core locations, 31 dredge transects) and proven to be a (Holocene) peat layer, overlain by intertidal sediments.

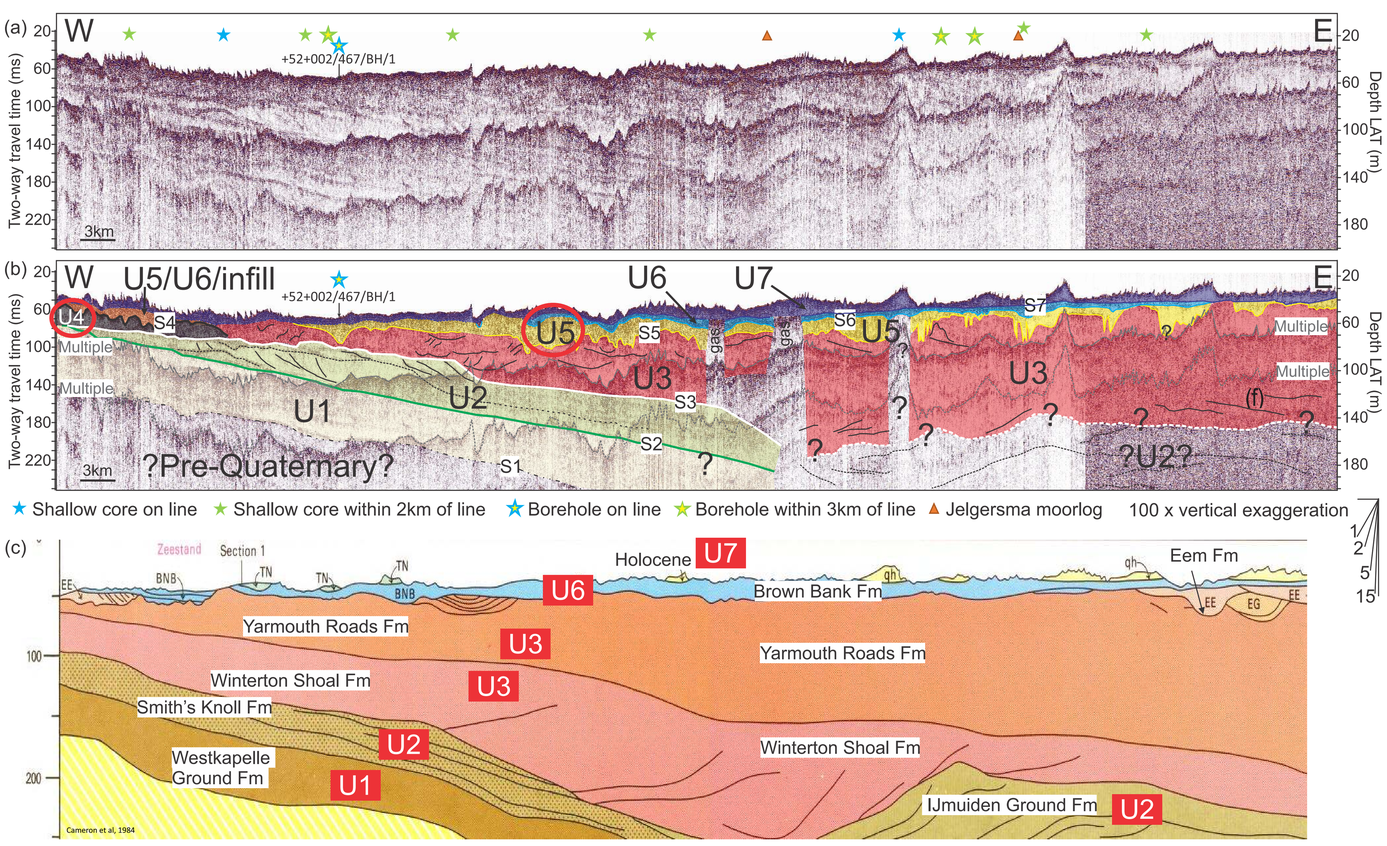

Figure 3. (a)Typical west-east oriented Sparker profile across the study area. (b) In total, seven seismo-stratigraphic units have been recognised, representing the Quaternary sequence. (c) Comparison of a cross-profile published on the region's offshore Quaternary geological map (Cameron et al, 1986).

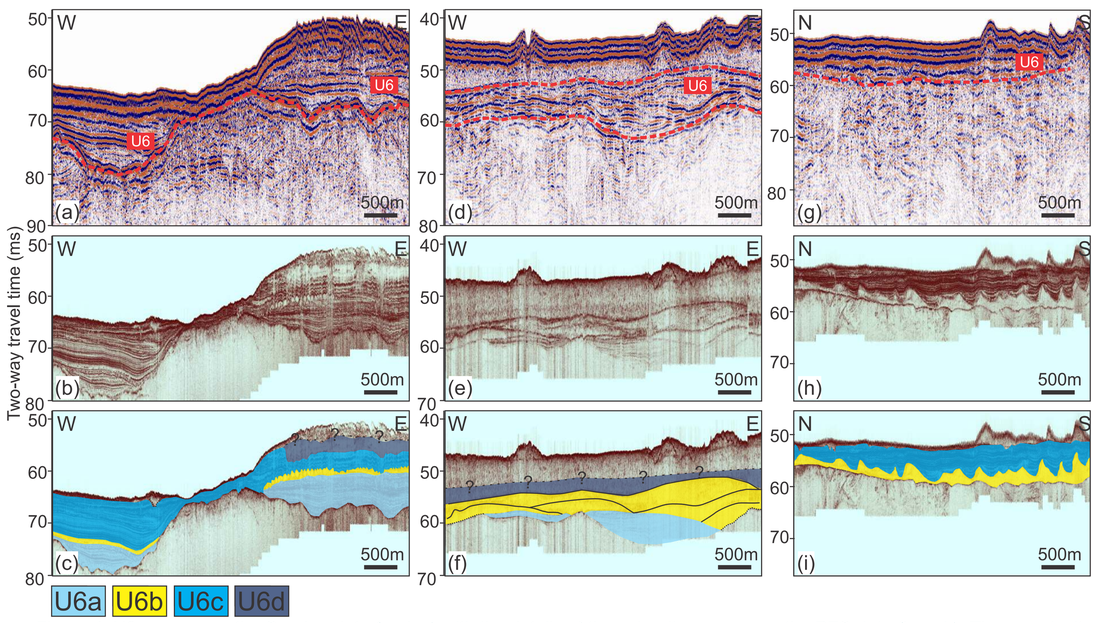

Figure 4. U6 as seen on the Sparker data (a, d, g) with the details of the subunits as seen on the PES data (b, e, h). The complexity of the Brown Bank Formation is revealed

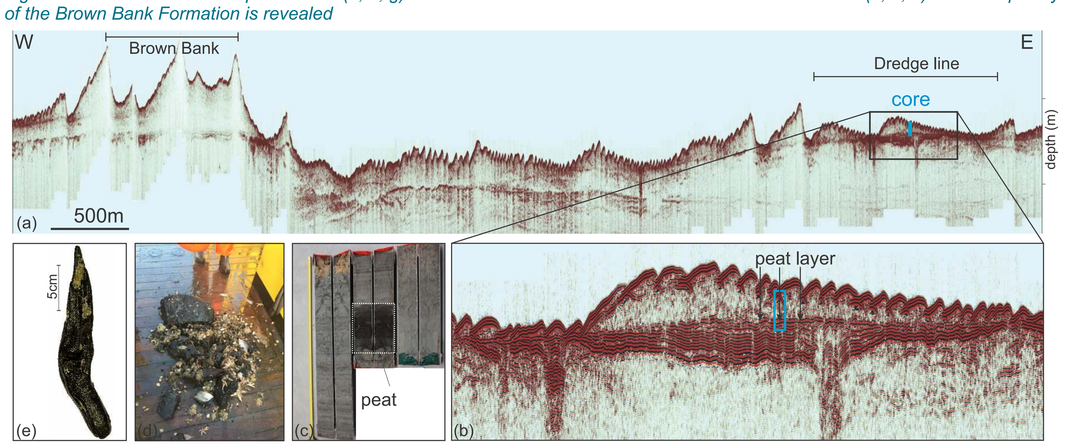

Figure 5. (a) Typical PES profile over the Brown Bank sand ridge; (b) high amplitude reflections, targeted for the ground-truth survey; (c) typical vibrocore showing transgressive sequence; (d) peat blocks recovered with dredge; (e) piece of wood recovered from the dredged material.

Landscape features

As well as the regional stratigraphy, some geomorphological features were detected. Channel cuts are particularly important to understanding when the southern North Sea was a terrestrial plain, an intertidal environment, a marine inlet, or fully marine. This in turn has relevance for archaeological studies.
Towards the top of U3 (Yarmouth Roads Fm), a wide multi-phase channel has been imaged (Fig. 6) suggestive of episodes of base-level change during the end of the Early to start of the Middle Pleistocene.

Within this same unit, features previously interpreted as Elsterian ice-pushed sediments (Cameron et al, 1984), instead appear to represent a channel cut and fill feature (Fig.7). This may have implications for the (re)interpretation of the position of the Elsterian ice margin across the southern North Sea.

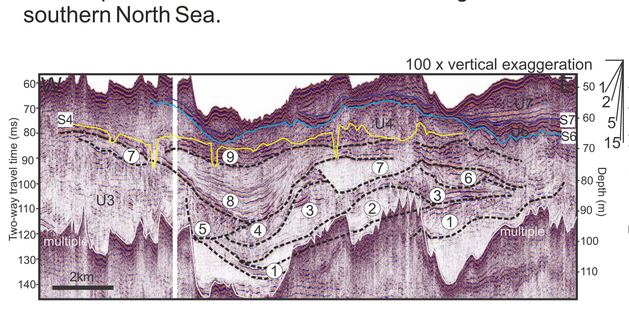

Figure 6. Channel complex within U3 (Yarmouth Roads Fm).

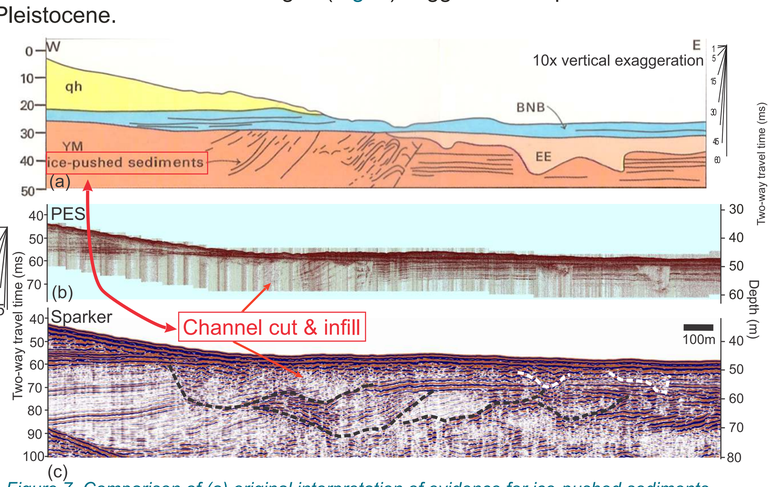

Figure 7. Comparison of (a) original interpretation of evidence for ice-pushed sediments within U3 (Cameron et al, 1984), versus (b,c) a new interpretation of channel cut with infill.

Holocene inundation

Ground-truthing of a strong horizontal reflection recognized on the PES data (Fig. 8) revealed this to be a peat surface. The dredged peat blocks are largely rounded, suggesting they have been eroded from a nearby location, and have been reworked on the seabed. Within the peat, wood, twigs, seeds and some land snails were found. Several of the max. 3-4 m long cores recovered sediments representing a typical transgressive sequence: from fluvial sands at the bottom, overlain by peats, intertidal sands/silts/clays and marine sand at the top (Fig. 9b). Radiocarbon dates from these peats suggest that they formed around c. 10 ka cal BP. With this dataset, we can further constrain existing relative sea-level curves (Fig. 9a).

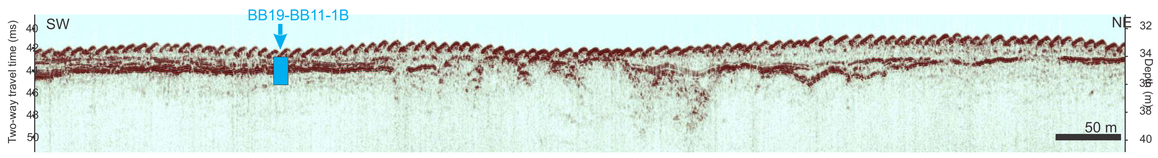

Figure 8 (above). Typical PES profile showing a strong horizontal reflection a few metres below the seafloor; blue rectangle shows the position of the core shown in Figure 9b.

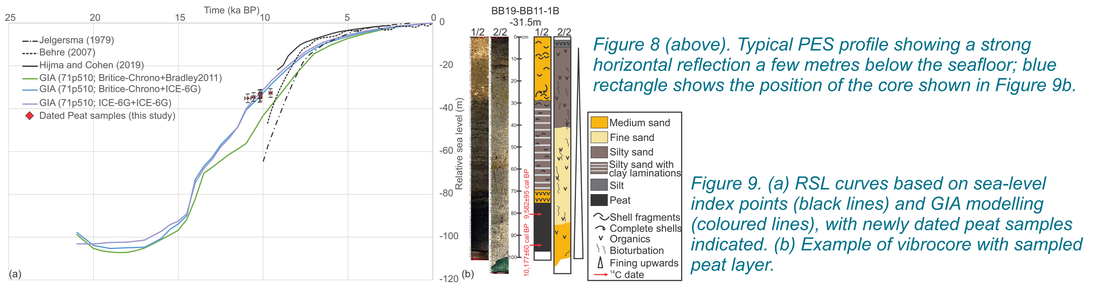

Figure 9. (a) RSL curves based on sea-level index points (black lines) and GIA modelling (coloured lines), with newly dated peat samples indicated. (b) Example of vibrocore with sampled peat layer.

Conclusion and future work

- Sparker and PES data have demonstrated that the seismo-stratigraphic framework of the souther North Sea needs further refining.
- Seven acoustic facies have been recognised, two of which were not previously described.
- The Brown Bank Formation in particular is composed of several subunits, and warrants further detailed analysis.
- A number of large valley systems have been recognised. Other features recognised as ice-pushed sediments, have been re-evaluated.
- A strong reflection recognised on the PES data has been positively identified as a peat layer. This layer was successfully ground-truthed with cores and dredging. Analysis of the peat shows that this terrestrial surface was formed when sea-level was at least 35 m below present, about 10,000 years ago.
- At least two more surveys are planned by the **Deep History Consortium** in 2022, which will concentrate on tightening the geophysical grid, conduction additional ground-truthing as well as attempting to locate potential archaeological material or sites.

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