The Potential of the Organic Archive for Environmental Reconstruction: An Assessment of Selected Borehole Sediments from the North Sea.

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Introduction

The identification of peat deposits in the present intertidal zone fringing the North Sea Basin (e.g.,Horton *et al*., 1999) and further offshore (e.g. Shennan *et al.*, 2000) demonstrates the potential for organic preservation and environmental reconstruction using a range of proxy indicators. As a result, environmental reconstruction within a rigorous geochronology are an integral part of the research framework developed for the Southern North Sea Project. Many of the landform assemblage maps and associated landscape interpretations resulting from the analysis of the 3D siesmic survey data, which are reproduced in the atlas maps will have to be be 'ground truthed' and assessed for their environmental potentialThis will allow previous interpretations of landscape evolution to be assessed (e.g. Ward *et al.* 2006) as well as the development of new models.).

Obtaining suitable material from the sedimentary deposits beneath the southern North Sea is both problematic and expensive. However, the British Geological Survey (BGS) has an archive of Late Pleistocene-Holocene material recovered from shallow scientific boreholes and vibrocores. Therefore, a clear aim of this project was to assess whether any of the existing material stored at BGS offices (National Geoscience Data Centre, Keyworth; Murchison House, Edinbugh) could be used to provide proxy records of environmental change.

Potential and rationale

River valley systems of the scale recorded in the 3D seismic survey data are widely recognised as key locations for the preservation of environmental and biological archives (Brown 1997; Howard and Macklin 1999). Classic 'landward' examples of this can be demonstrated from a range of studies from Holocene river systems such as those on the Trent (Knight and Howard 2005), the Thames (Sidell *et al.* 2000) and the Severn (Brown 1983). Abandoned (in-filled) channels, wetlands and associated sand and gravel splays in river valleys can all contain well preserved organic sediments, which can produce detailed palaeoenvironmental reconstructions spanning considerable time periods (i.e. Brayshay & Dinnin, 1999; Smith *et al.* 2006, Sidell *et al*. 2000). In terms of the southern North Sea, it is probable that the channel deposits identified during 3D seismic survey data analysis also contain valuable archives of this type. If well-stratified material from these landform-sediment traps could be obtained, it would allow to the reconstruction of past environments of a now submerged landscape, which formed a considerable resource for early hunter gatherers and colonsiers of the UK mainland. In addition, subsequent reworking of early Holocene organic materials seems to be a common factor in many 'landward' river valleys resulting in poor preservation and under representation of deposits from these earlier periods in the archaeological record (i.e. Knight and Howard 2005; Greenwood and Smith 2005). The now submerged landscapes of the southern North Sea have the potential to fill this missing gap in our existing knowledge of the nature and potential human use of these early Holocene landscapes.

The potential of the sedimentary archive from such locations for environmental reconstruction and the dating of sea level rise are clearly demonstrated by a number of recent intertidal studies (e.g. Bell *et al*. 2000). Again, the deposits of the North Sea

basin have the potential to provide more than just additional information to that from 'landward' coastal peats. There is clear evidence that many 'coastal' peats, and the archives they contain, have suffered erosion during Later Holocene sea level rise and, particularly along the northeast coast of Britain, during extreme events such as the 'tsunami' associated with the Storegga landslide (Boomer *et al.* 2007). These are factors that should not have affected early Holocene coastal material from the bed of the southern North Sea away from the coastal margin.

Core selection

Two groups of site-investigation material held by the BGS in low-temperature storage facilities at Murchison House, Edinburgh and the the National Geoscience Data Centre, Keyworth were deemed worthy of further investigation. These comprised a seriesof shallow borehole cores drilled from the 1960s onwards, as part of a programme of systematic mapping of the offshore geology of the United Kingdom Continental Shelf (UKCS). In total, twenty-nine boreholes were drilled within the UKCS quadrants that cover the 3D seismic study area (Figure 1). Vibrocore samples were acquired to aid in the drafting of 1:250,000 seabed sediment maps.

Initially, a sample of 19 cores was requested from the BGS (Figure 2). The selection of these data was based on the results of previous inspection of a greater number of core records, as documented in published British Geological Survey (BGS) reports. Vibrocores were selected due to their proximity to landform features of interest that had been identified during preliminary analysis and interpretation of the 3D seismic data. 0f the (19) cores requested, 6 were not available and 4 existed only as paper archives. As a result, only four shallow boreholes (79/01, 81/49, 82/21, 89/05) and four vibrocores (53/02/395, 54/00/205, 54/02/80 and 54/02/215) from the area under study were available for examination (Figure 3). Given the low numbers of cores available, it was also decided to request shallow core 81/50, based on the field descriptions, which suggested it contained organic inclusions; however, it should be noted that this core was drilled to the south of the area of the 3D seismic survey.

Between the 21st and 24th of March 2006, one of the authors (Simon Holford) recorded the selected nine cores at Edinburgh, describing their sedimentary characteristics, condition and potential for further environmental analyses. Key to this was identifying the presence of organic sediments that might relate to Holocene 'peat' formation in potential sediment traps identified in the analysis of seismic data; previous authors have identified the Holocene 'Elbow Formation', a unit of fine-grained muddy sands and interbedded clay, which is mappable in the eastern part of the current survey area (Cameron *et al.* 1992, Ward *et al*. 2006).

In terms of quality of storage and general degree of preservation, the core samples were found to be in a good condition given their age (the shallow boreholes are named after the year and order in which they were drilled i.e. 79/01 was the first borehole drilled in 1979). However, some areas of the cores were covered in mould (sections 89/05 and 54/02/215) and all were largely desiccated. Both of these conditions inhibit the preservation of organic material and mould growth certainly limits any potential to date materials using radiocarbon techniques. Although abundant shell fragments (possibly *Spisula subtruncata,* a mollusc, which is reported to be present in the early Holocene Elbow Formation (Cameron *et al.* 1992)) are present in some cores, these fragments were considered to be too small (i.e. mostly <1 cm in diameter) for detailed (e.g. stable isotope) analyses or dating using amino acid racemization techniques. A full description of the cores examined and their condition is given in Appendix 1.

F*igure 1. Location of the total boreholes in the area included in the 3D seismic survey*

Figure 2. Location of the requested boreholes in the area included in the 3D seismic survey

Figure 3. Location of the boreholes inspected from the area included in the 3D seismic survey

Palaeoenvironmental selection

Sampling

Sampling of the remaining five borehole cores occurred on the 15th June 2006. After discussions with curatorial staff at the BGS core store, it was agreed that sampling quotients should be limited to a maximum of four samples per 1 metre section of core and the size taken should be limited to 50g of material. In total, fifty samples were obtained from three vibracores (6 samples from 53/02/395, 19 samples from 54/02/215 and 23 from 54/02/80) and a single sample and a wood fragment from one

shallow borehole (81/50). The borehole details, sample numbers and sample depths are summarised in Table 1.

Visual Assessment
Samples from vibracore 53/02/395 (samples NSP01-06) were mainly medium grained, light yellow-brown sands with a relative abundance of dis-articulated shell fragments. Samples from vibracore 54/02/215 (samples NSP07-25) were fine to medium grained, light yellow-brown sands, which appear to become slightly darker yellow-brown with depth, possibly in response to an increase in humic organic content. There also appeared to be a gradual reduction in abundance of dis-articulated shell fragments with depth. Samples from vibracore 54/02/80 were fine-grained, light yellow-brown sands with occasional dis-articulated sand fragments (although in lower abundance than found in the previous two vibracores). A small wood fragment was obtained from the BGS offshore shallow borehole 81/50 (NSP49), but it was decided not to attempt to radiocarbon date this fragment since it had a limited palaeoenvironmental context and only one associated sedimentary sample was extracted from the borehole; NSP50 (a sample of light yellow-brown medium grained sand).

Assessment of macrofossil (insects and plant) inclusions
Initially, it was intended to use the assessment procedures for insect and plant remains outlined by Kenward *et al.* (1986) and to assess the degree of preservation following Kenward and Hall (2006). However, the visual inspection clearly indicated that it was unlikely that such macroscopic remains were present. As a result all 49 of the sedimentary samples were rapidly scanned under a low-power, binocular microscope in order to establish that organic macrofossils were not present; none were observed

Only one organic sample was present which had potential for dating. This was a small fragment of poorly preserved wood from Borehole 81/50 (NSP49), but since it came from unconsolidated sands, its context was poorly constrained. Furthermore, a pollen assemblage identified from the sample was also poorly preserved suggesting a degree of degradation and weathering; for these two reasons, it was decided not to date this wood fragment (NSP50)

Pollen Assessment
Dr Tom Hill and Dr Ben Gearey carried out the assessment of plant microfossils (i.e. pollen grains, moss fragments and plant spores). Only 16 samples were chosen for pollen assessment. This selection was based on the conclusion that the sediment samples from towards the base of the borehole/ vibracores would afford the greatest palynological potential, especially since the upper parts of the cores might be reworked. In addition, the slightly darker yellow-brown nature of some of the deeper sediments was also considered to be an indicator of the potential presence of organic remains, which in turn, increases the likelihood of pollen preservation.

Preparation for pollen assessment followed the standard techniques including KOH digestion and acetylation (Moore *et al*. 1991). Due to the high inorganic content of all samples, a very small amount of residue remained once pollen preparation had been completed. Each sample was mounted on a 24x40mm coverslip and glass slide for counting. The pollen assessments were carried out on a Meiji MX5000 microscope at x400 magnification. To ensure a fair palaeoenvironmental assessment is achieved, pollen analysis would normally require a minimum of 125 total land pollen grains (TLP) excluding aquatics and spores to be counted for each sample. However, pollen abundance was very low in all samples, resulting in the minimum 125 TLP not being achieved in any sample. A complete microscope slide was therefore traversed for each

sample in order to assess species abundance, diversity and conditions of preservation. Pollen nomenclature follows Moore *et al*. (1991).

Results

The results are presented as pollen diagrams produced using the computer program TILIA (Grimm 1991). Whilst percentage values were calculated, these data are not discussed in detail due to the generally low counts for the samples. None of the pollen spectra recovered reach the recommended assessment count of 125 let alone the 350 recommended for full analysis.

Vibracore 53/02/395

Six samples (6.68, 7.13, 8.24, 9.13, 10.23 and 11.25m) were assessed from this core (Figure 4). The low counts of pollen recovered preclude detailed interpretation. Concentrations were low although increasing with depth. Trees and shrubs are well represented (80%+ TLP), initially dominated by *Pinus* (pine) and *Quercus* (oak) with and to a lesser extent by *Alnus* (alder) and *Betula* (birch). *Corylus* (hazel) increases in abundance with height through the sequence. *Ulmus* (elm) and *Salix* (willow) are recorded at trace values. Herbs are recorded in the form of Poaceae (wild grasses) and Cyperaceae (sedges) and Chenopodiaceae (fat hen), whilst *Pteridium* (bracken) and *Sphagnum* (bog moss) spores are also present, the former increasing after 9.13m.

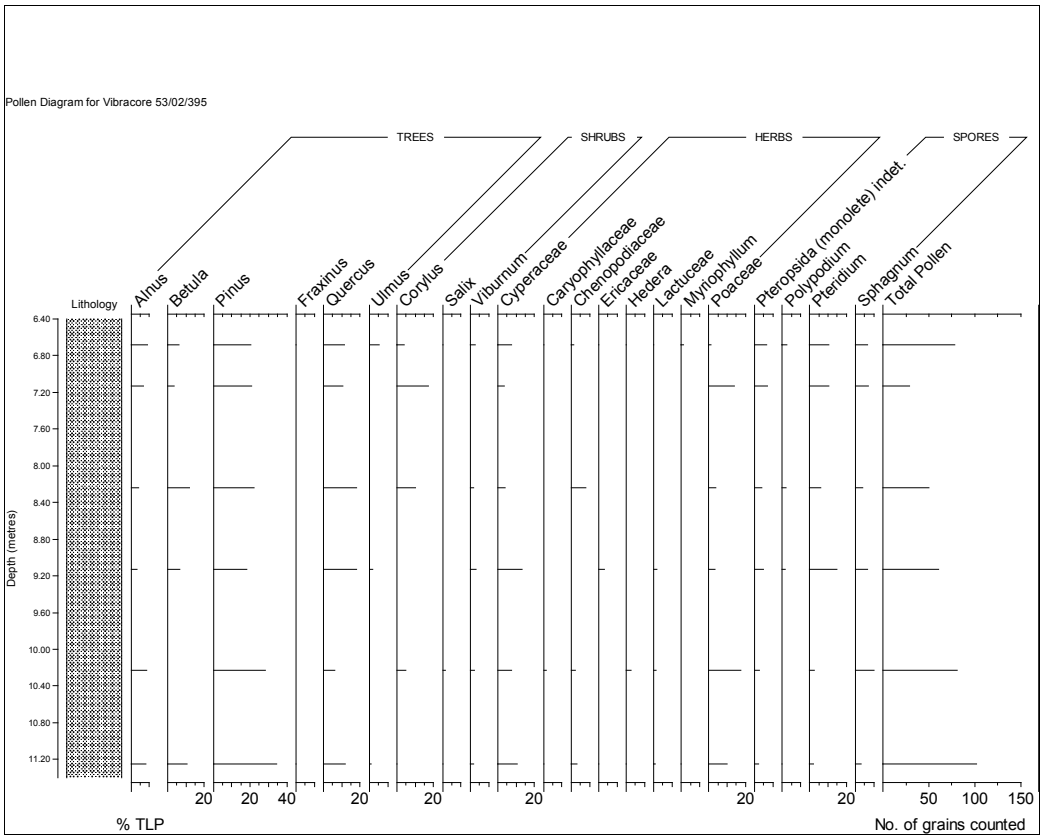

Figure 4. Pollen diagram for Vibracore 53/02/395

Vibracore 54/02/215

A total of four samples were assessed for pollen from Vibracore 54/02/215. All samples were taken from towards the base of the core profile; 4.20m, 4.60m, 5.20m and 5.60m (Figure 5). The impression is of mixed dense woodland with oak, pine and hazel into which alder seems to have subsequently expanded. Tree and shrub pollen (85%) again dominate the spectra, initially with *Pinus*, *Quercus*, *Corylus* and *Betula*, with lower values for *Tilia* (lime), *Ulmus, Fraxinus* (ash), Ericaceae (heather family) and *Salix*. *Alnus* increases above 4.60m with *Fagus* (beech) also appearing in the uppermost sample. Clearance and openings in the woodland are suggested by trace

values for Poaceae (grasses) and Cyperaceae (sedges), along with *Plantago lanceolata* (ribwort plantain), Chenopodiaceae, Lactuceae (dandelions etc.) and *Artemisia* (mugwort). Spores in the form of *Pteridium*, *Sphagnum* and Pteropsida (fern) are present across the spectra. However, the scale and causes of these clearances are difficult to judge.

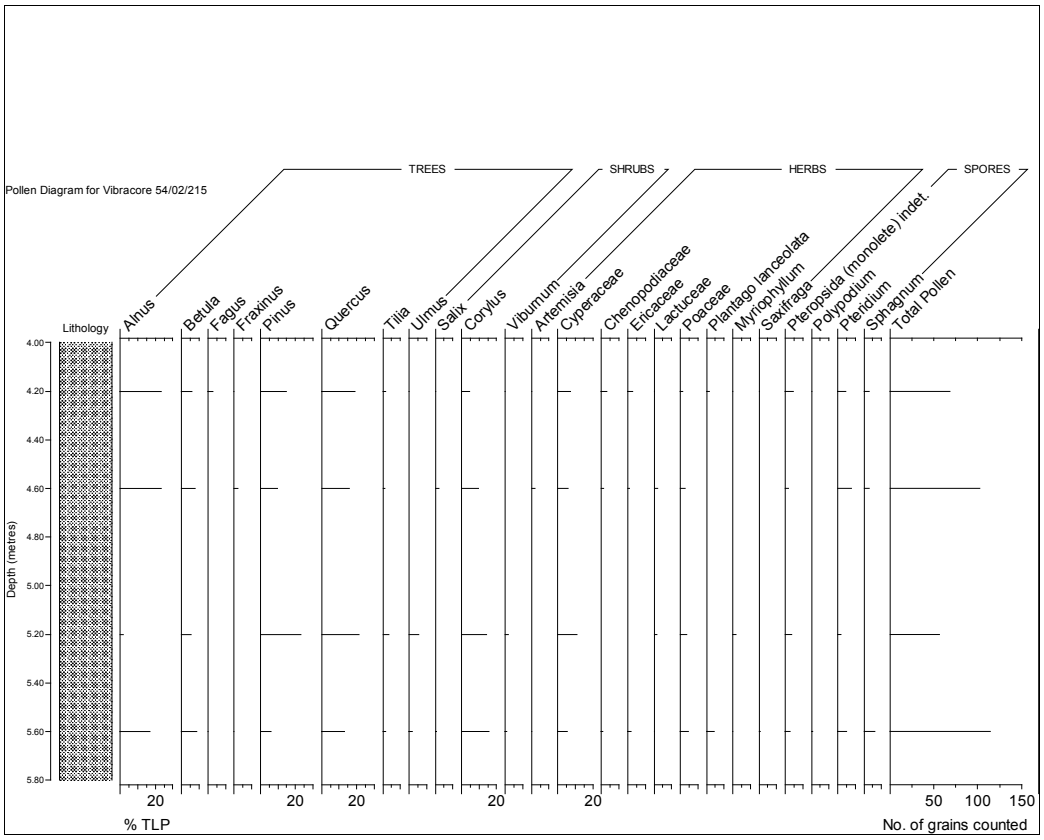

Figure 5. Pollen diagram for Vibracore 54/02/215

Vibracore 54/02/80

Five samples were assessed for pollen from Vibracore 54/02/80. All samples were taken from towards the base of the core profile; 3.80m, 4.40m, 4.80m, 5.40m, 5.80m (Figure 6). Pollen concentrations were again generally low, however despite this, pollen preservation was reasonable for most of the samples. Tree and shrub pollen dominate the spectra (90%+TLP), with *Alnus*, *Betula*, *Pinus*, *Corylus* and *Quercus*. Trace values for *Tilia*, *Ulmus* and the shrubs *Salix* and *Viburnum*. Few herbaceous taxa are present, although low values for Poaceae and Cyperaceae increase slightly towards the top of the sequence. The only other herbs present are *Plantago lanceolata*, Chenopodiaceae and Caryophyllaceae (pink family). *Sphagnum* and Pteropsida spores are found in low quantities towards the base of the core.

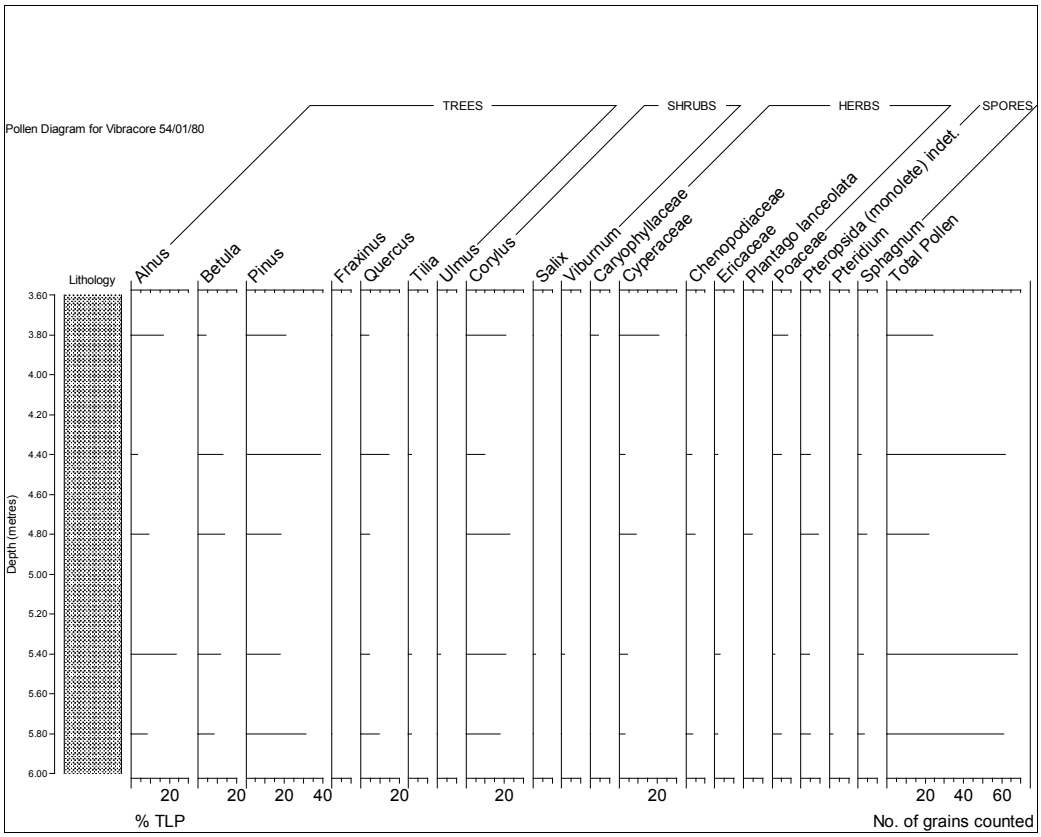

Figure 6 Pollen diagram for Vibracore 34/02/80

Borehole 81/50

At a depth of 11.90m in Borehole 81/50, a wooden fragment was observed within the sedimentary profile. This sample was therefore subsequently also assessed for pollen. Pollen abundance was extremely low within the sample, with only 8 pollen grains counted. As a result, pollen concentrations were too low in this sample to permit any tentative conclusions to be drawn.

Discussion

The generally low concentrations of pollen in all the sequences discussed preclude detailed interpretation. All samples assessed contained grains that showed evidence of fragmentation, whilst grains also were commonly distorted and occasionally corroded. Species identification was commonly hindered as a result of the poor pollen preservation. The low pollen abundance within all samples, combined with the poor pollen preservation, could be indicative of sediment reworking, with previously deposited pollen grains being re-eroded and subsequently deposited within the sedimentary archive.

The overall vegetation reflected is generally similar for all three sequences, although some differences are observed, such as slightly higher values for grasses and sedges in Vibracore 53/02/395. The dominance of tree and shrub taxa including pine, birch, oak and alder above suggests a Holocene timeframe, probably early to middle Holocene, rather than later. However, mid-Holocene pollen assemblages commonly have lime present, but this is absent within these sequences. In addition elm, which is also only present in low abundances, tends to be present at higher values in the early part of the Holocene. It is however unclear if this reflects a taphonomic/depositional bias (see below), or an absence of lime and elm near to the sampling site due to local edaphic or other factors. Pine for example is often well represented in fluvially derived sediments due to the buoyancy of this pollen grain; given the nature of the samples it is possible that taphonomic factors such as this are affecting the composition of the assemblages. If this is the case, then little meaningful interpretation can be made.

Alternatively, the spectra may be an accurate reflection of the woodland implying poor, sandy soils where pine was able to out-compete other deciduous trees. This may be supported by the fact that pollen preservation tends to be moderate for most of the samples, implying that re-working may not have biased the samples.

Sandy, nutrient poor contexts may also be implied by the presence of bracken, low values for Ericaceae and also possibly by the presence of bogmoss spores recorded consistently across Vibracore 53/02/395. The presence of grasses and sedges also suggest more open habitats, although these could derive from wetter soils near to the sampling site rather than in the wider landscape. Some impression of the 'extralocal' context is perhaps evident in the presence of ribwort plantain and dandelions (Vibracore 54/02/215 and Vibracore 54/02/80). These taxa suggest open, perhaps disturbed dryland contexts, although the precise nature and location of such areas cannot be established on the basis of these limited datasets. It is possible that the record of these herbs derive from the effects of anthropogenic activity on vegetation somewhere in the pollen catchment. Other herbs, namely fat hen and perhaps mugwort (Vibracore 54/02/215), may suggest the proximity of coastal contexts such as salt marsh, although both are also found in other communities.

Despite the low pollen counts, there is some indication that the sequences have some biostratigraphic integrity and hence may record conformable sequences of vegetation change. For example, the increase in hazel in the upper part of Vibracore 53/02/395 and rise in grasses and sedges in Vibracore 54/02/80 would seem to make some ecological sense in the context of the general picture of vegetation change suggested by these sequences.

The pollen sequences discussed above are all clearly derived from Holocene contexts, and may reflect the presence of woodland growing in more 'marginal' situations such as sandy soils near to the sampling sites. Possible taphonomic bias to the samples cannot be ruled out. Whilst all three sequences discussed contain some pollen with evidence for biostratigraphic integrity, the low concentrations in most of the samples would make any more detailed analysis time consuming. Hence no further work on these samples is recommended.

Conclusions

There is no doubt that deposits associated with the landscape features identified in the southern North Sea have clear environmental and dating potential. However, the late Pleistocene-Holocene sedimentary archivesretained by the BGS have limited research value. They do not appear to be of the preservation quality required for further environmental work and are not extracted from the most promising locations, as identified through analysis of the seismic data. This should not surprise us. Given the size of the landscape involved; it was always unlikely that 'untargeted' boreholes would puncture the most promising environmental archives.

In order to provide more substantial palaeoenvironmental understanding of the stratigraphic archive within the southern North Sea, further 'targeted' sampling from the seabed is necessary with locations pre-determined by the 3D seismic atlas. Any further environmental analysis should be undertaken within a well developed radiometric dating framework.

In summary, we conclude that further sampling is required with the following provisos:

- deeper boreholes and vibracores are drilled and sampled in an attempt to obtain complete stratigraphic sequences that contain organic units more suitable for palaeoenvironmental work, and

- immediate palaeoenvironmental assessments are undertaken prior to storage in order to prevent sample loss through decomposition and/or desiccation.

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Table 1. Summary of sedimentary samples and environmental assessment undertaken from the Southern North Sea vibracores and boreholes

Borehole/core name	Sample number	Depth	Pollen Analysis	Beetle Analysis	Plant macrofossil Analysis
53/02/395	NSP01	6.68 m	*	*	*
53/02/395	NSP02	7.13 m	*	*	*
53/02/395	NSP03	8.24 m	*	*	*
53/02/395	NSP04	9.13 m	*	*	*
53/02/395	NSP05	10.23 m	*	*	*
53/02/395	NSP06	11.25 m	*	*	*
54/02/215	NSP07	0.2 m		*	*
54/02/215	NSP08	0.4 m		*	*
54/02/215	NSP09	0.6 m		*	*
54/02/215	NSP10	1.2 m		*	*
54/02/215	NSP11	1.5 m		*	*
54/02/215	NSP12	1.8 m		*	*
54/02/215	NSP13	2.2 m		*	*
54/02/215	NSP14	2.5 m		*	*
54/02/215	NSP15	2.8 m		*	*
54/02/215	NSP16	3.2 m		*	*
54/02/215	NSP17	3.5 m		*	*
54/02/215	NSP18	3.8 m		*	*
54/02/215	NSP19	4.2 m	*	*	*
54/02/215	NSP20	4.4 m		*	*
54/02/215	NSP21	4.6 m	*	*	*
54/02/215	NSP22	4.8 m		*	*
54/02/215	NSP23	5.2 m	*	*	*
54/02/215	NSP24	5.4 m		*	*
54/02/215	NSP25	5.6 m	*	*	*
54/02/80	NSP26	0.4 m		*	*
54/02/80	NSP27	0.6 m		*	*
54/02/80	NSP28	0.8 m		*	*
54/02/80	NSP29	1.2 m		*	*
54/02/80	NSP30	1.4 m		*	*
54/02/80	NSP31	1.6 m		*	*
54/02/80	NSP32	1.8 m		*	*
54/02/80	NSP33	2.2 m		*	*
54/02/80	NSP34	2.4 m		*	*
54/02/80	NSP35	2.6 m		*	*
54/02/80	NSP36	2.8 m		*	*
54/02/80	NSP37	3.2 m		*	*
54/02/80	NSP38	3.4 m		*	*
54/02/80	NSP39	3.6 m		*	*
54/02/80	NSP40	3.8 m	*	*	*
54/02/80	NSP41	4.2 m		*	*

54/02/80	NSP42	4.4 m	*	*	*
54/02/80	NSP43	4.6 m		*	*
54/02/80	NSP44	4.8 m	*	*	*
54/02/80	NSP45	5.2 m		*	*
54/02/80	NSP46	5.4 m	*	*	*
54/02/80	NSP47	5.6 m		*	*
54/02/80	NSP48	5.8 m	*	*	*
81/50	NSP49	11.9 m			
81/50	NSP50	11.9 m	*	*	*

Appendix 1: Sediment and preservation descriptions of the Holocene / Late Pliestocene sections of the cores examined in this survey

Shallow boreholes

79/01

This borehole was chosen for inspection due to its location at the southern extreme of the PGS southern North Sea 3D seismic survey. Though the 3D seismic data in the vicinity of this borehole is confused), the Elbow Formation deposits of potential fluvial origin are thought to be present in the area (Cameron *et al.* 1992). Offshore peat deposits with a radiocarbon age of 8425±75 BP have been described from the nearby Leman Bank (Godwin 1960). Unfortunately the drilling of this borehole was dogged with technical problems (as documented in the completion reports held at Murchison House) that resulted in limited recovery of late Pleistocene-Holocene deposits, which were only available to inspect in jar samples. The inspected sediments comprised mostly brown, shelly sand. It was therefore concluded that material from this borehole had limited potential.

81/49

This borehole is located in seismic survey j06, in the western part of the PGS megasurvey. The Pleistocene succession in this part of the study area is considerably thinner than in the east, and although covered by a thin veneer of Holocene sediments, the shallow sections of the seismic data are often dominated by the underlying geological structure, making it difficult to image potential geomorphic features. This borehole was chosen for inspection therefore in an attempt to shed additional light on the late Pleistocene-Holocene geomorphic evolution of this part of the study area. A BGS completion report for this borehole stated that between 0 and 11.3 meters, this borehole contained deposits of Pleistocene-Recent age. Examination of the available core material over this depth range revealed it to be largely very fine-grained, soft sand-mud deposits, dark grey-brown in color, often interbedded with fine clay laminae. Towards the base of 'Pleistocene-Recent' succession the sediments are more consolidated, desiccated and richer in sand, lacking the clay laminae observed at shallower levels. The entire 'Pleistocene-Recent succession' is lacking in shell fragments or organic matter. At around 11 metres there is a clear transition to dark grey, indurated mudstones of Jurassic age. In summary, no material of potential palaeoenvironmental use was found to be present in this borehole.

81/50

This borehole is located outside the extent of available seismic coverage, 48 km E of Lowestoft. However, a BGS report on both onshore and offshore boreholes acquired during 1981 stated that this borehole contained a horizon of wood fragments at shallow levels (<15 metres) within the Pleistocene-Recent succession, raising the possibility that it sampled organic material, potentially early Holocene in age. Between depths of 0 and 10 metres, the retrieved sediments are characterized by yellow-brown, medium-grained unconsolidated sands, often with abundant shell fragments. In places the core is in quite poor condition, although this is most likely a consequence of the unconsolidated nature of the Pleistocene-Holocene deposits. In places the core has also clearly been extensively sampled. A basic completion log for this borehole noted the presence of abundant wood fragments at a depth of around 10 metres. Inspection of the core at this and adjacent levels however noted the presence of only a few wood fragments, generally <2-3 cm long and dark brown in colour, within depths of 11.82 to 12.0 metres. The apparent paucity of wood fragments is probably a function of previous sampling efforts.

82/21

This borehole was selected for inspection due to its location within the Outer Silver Pit. Overall, the core samples from this borehole were found to be in excellent condition (with some local exceptions where the core material was comparatively desiccated and fragmented), and contained a great deal of potentially useful sedimentological information. Between 0 and 6 metres the inspected sediments comprised mostly dark olive-grey, fine-grained shelly sands and gravels. Below 6 metres the lithologies record a transition to interbedded fine sands and silty clays, with grey scattered shells (Figure 4*b*). Organic materials were not observed at any levels within the examined section of core, however, even within the more clay-rich units.

89/05

This borehole is located several km to the west of 82/21, and hence was chosen for examination for similar reasons. The completion log stated that this borehole encountered Holocene sediments (mostly muddy sands) down to depths of *c.* 14 metres, below which it penetrated sands of Middle Pleistocene and older ages. The first few metres of the Holocene succession, containing homogenous, soft muddy sand (but no observable organic matter) was in excellent condition. Between 1.5 and 10.0 metres however, much of the core material was covered by variable amounts of mould meaning that any organic material, if present, could potentially have been contaminated. Although the presence of numerous wood fragments within the Middle Pleistocene succession had been noted in the completion log, it was apparent upon inspection that this borehole had been extensively sampled for micropalaeontological analyses at an earlier date meaning that few horizons containing organic matter remained.

Vibrocores

54/02/80

This vibrocore was an obvious candidate for examination given its proximity to the large NW/SE trending early Holocene fluvial system recorded by seismic data from blocks k08 and j08 (the so called Shotten Channel). This vibrocore recovered 5.8 metres of sedimentary succession, most probably all Holocene in age. The sediments are in a good condition and comprise mostly fine-grained well-sorted sands, grey-brown in colour with some bands of shell fragments, and slightly muddy layers that may contain dateable organic material. These sediments are very similar to accounts of the early Holocene Elbow Formation which are described as fine or very fine-grained muddy sands with interbedded clay layers (Cameron *et al.* 1992).

53/02/395

This core was obtained near the southern margin of the Outer Silver Pit, in seismicsurvey i08. 5.98 metres of core were recovered as grab samples, and 5.90 metres of vibrocore were recovered below this. Lithologically the sediments are very similar to vibrocore 54/02/80; yellow-grey, fine-grained bioturbated sands with fragmented mud laminae and scattered shell debris. Some dark horizons, possibly containing organic material were identified, but no definitive wood fragments or peat horizons were observed. The core samples were generally in good condition, but some sections were covered with mould.

54/02/215

This core was drilled on the opposite side of the Outer Silver Pit, in seismic survey j08. As well as a grab sample, 6 metres of vibrocore were available for inspection. Interestingly, the accompanying BGS report described the vibrocore as having penetrated "probably into the top of a small palaeovalley in this area". The vibrocore samples are best described as soft, olive-coloured muddy sands, well sorted and fine

grained, and these sediments probably belong to the Elbow Formation. No organic material was observed. Although the cores were in a largely excellent condition, again some sections were covered with mould.

54/00/205

This vibrocore was drilled in the extreme east of the study area, in block k06. Whereas most of the vibrocores were soft and damp, the sediments from 54/00/205 was completely dry and desiccated. Overall, the sediments, which are in an excellent condition, are best described as olive-brown fine-grained sands. The shallower units often contain abundant shell fragments and pebbles, although the quantities of both of these decrease with depth. Again, no material deemed suitable for palaeoenvironmental analyses was found during the examination of these deposits.