Introduction

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Abstract
This paper presents the primary academic context of the North Sea Palaeolandscapes Project (NSPP). It outlines the origins of the project, the manner in which it developed. The constituent parts of the project are described, the significance of the results considered and the potential for future research outlined.

Key Words
Archaeology, Geomorphology, Geophysics, 3D Seismics, Sea-level change, Global warming.

Eventually, all things merge into one, and a river runs through it. The river was cut by the world's great flood and runs over rocks from the basement of time. On some of the rocks are timeless raindrops. Under the rocks are the words, and some of the words are theirs. I am haunted by waters.

Norman Maclean (1902-90). A River Runs Through It

Introduction

The inundated prehistoric terrain of the North Sea basin remains one of the most enigmatic archaeological landscapes in north western Europe. Covered by the sea as a consequence of global warming following the last glacial maximum, the associated change in relative sea levels resulted in the loss of an area larger than the United Kingdom over a period of c.11,000 years (Coles 1998). The region therefore contains one of the most extensive and, probably, best preserved prehistoric landscapes in Europe. Moreover, during the Mesolithic, the period primarily covered by this report, the area was probably an important habitat for hunter-gatherer communities across north western Europe (Morrison 1980, 118). The vast area that contains the archaeology of the North Sea provides Europe with an immense challenge: how are we to investigate, interpret and manage the heritage of this extraordinary, but largely inaccessible landscape.

This latter point is of prime importance. Although inaccessible and, in most senses, invisible, the archaeology of the region is as fragile as any terrestrial correlate. The North Sea basin is also a strategic resource in terms of mineral and natural wealth to the United Kingdom and all the countries that surround it, whilst its geographical position ensures that this extensive region functions as a key infrastructural and communications locus. The area is therefore under intensive developmental pressure from a range of threats including mineral extraction, the direct impacts of construction, ranging from the laying of pipelines to, more recently, the development of wind farms, the wider issues of mineral extraction or the extensive generalised impact of fishing and commercial trawling (Dix et al. 2004, section 1.4). The implication of such threats, in environmental terms, is probably apparent to most aware individuals, or organisations, with an interest in the region. However, the significance of the southern North Sea is raised in cultural terms when one considers that whilst the continental shelf retains, arguably, the most comprehensive records of the Late Quaternary and Holocene landscapes in Europe (Fitch et al 2005), this

landscape was also extensively populated by humans, and at specific periods may well have been a core habitat at a European level (Coles 1998; Flemming 2004).

The context of study

This potential of the southern North Sea was actually recognised quite early, in both geological and archaeological terms, by Sir Clement Reid in his book on the submerged forests of the United Kingdom, published in 1913. Here he noted in a remarkably perceptive paragraph, "the geologist should be able to study ancient changes of sea-level, under such favourable conditions as to leave no doubt as to the reality and exact amount of these changes. The antiquary should find the remains of ancient races of man, sealed up with his weapons and tools. Here he will be troubled by no complications from rifled tombs, burials in older graves, false inscriptions, or accidental mixture. He ought to here find also implements of wood, basketwork, or objects in leather, such as are so rarely preserved in deposits above the water-level." (Reid 1913)

Following this, the pioneering work of Sir Harry Godwin on moorlog deposits, associated with the 1931 Colinda harpoon find from the Leman and Ower banks, demonstrated the terrestrial nature of these extensive submerged deposits as well as their capacity to provide paleoenvironmental evidence. (Burkitt 1932, Godwin and Godwin 1933) Shortly after, Sir Graham Clarke's (1936) seminal work on the "Mesolithic Settlement of Europe" acknowledged the probable settlement potential and the cultural significance of the area. It is notable, however, that after these early initiatives were not substantively built upon. Whilst this must have largely been the consequence of inaccessibility of the archaeological deposits Clement Reid (1913) had also, presciently, predicted of the deposits in the North Sea that "*the archaeologist is inclined to say that they belong to the province of geology, and the geologist remarks that they are too modern to be worth his attention; and both pass on."* The demise of active archaeological research across the North Sea basin from the mid twentieth century was paralleled by the marginalisation of the presumed archaeology of the area. Whilst not denying that some archaeologists were aware of the archaeological potential of the region, more generally the area was increasingly interpreted or presented as a land bridge from mainland Europe to Britain (Coles 1998). The largely unspoken implication was that the inundated area was unimportant in cultural terms. In many ways it might be said that there was a spiral of indifference towards the archaeology of the region.

More recently, the significance and potential of the archaeological and geomorphological record of the southern North Sea has become an emerging academic interest. Within archaeology this awareness can traced directly to the 1998 review article by Professor Bryony Coles, "Doggerland: a speculative survey " (figure 1 and 2). Equally notable has the contribution of Dr Nic Flemming in promoting the archaeology of the area, especially through his recent edited volume on the archaeology of the region (Flemming 2004). The assessment of the archaeological potential of the British continental shelf by Dix et al. (2000) has also provided a significant context for further research around the coast of Britain. The fundamental consequence of these publications, however, has been to emphasise the deficiencies of current knowledge in terms of the nature or extent of the archaeological deposits of the region. These sentiments have, more recently, been echoed in the publication of a series of Department of Trade and Industry regional strategic environmental

assessments or "SEA" volumes, for the mainland British marine territories (Flemming 2004, 2005, Wickham-Jones and Dawson 2006)

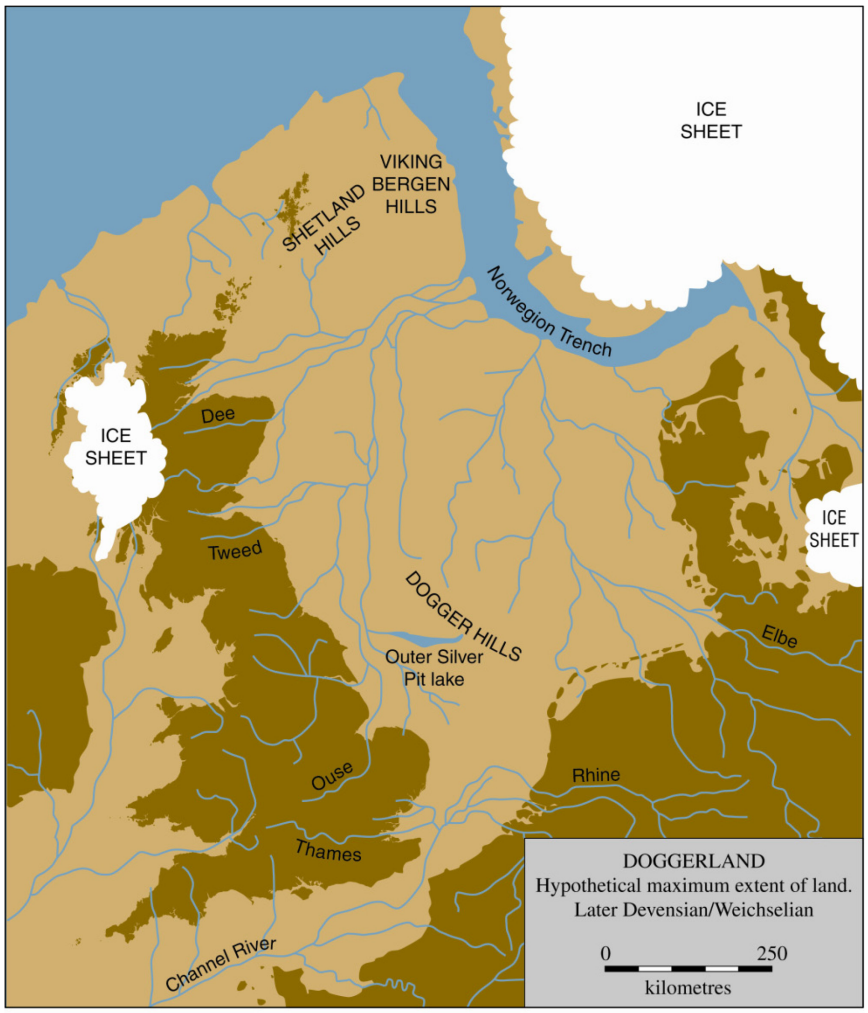

Figure 1 Hypothetical maximum extent of Doggerland (redrawn from Coles 1998)

Figure 2 Early Holocene Doggerland (redrawn from Coles 1998)

The lack of knowledge associated with the North Sea Holocene surfaces is so profound that as recently as 2004 Nic Flemming noted that the inundated landscapes of the Southern North Sea were essentially *terra incognita*. Yet, despite this, it should be noted that geological studies have suggested that sediments that might be associated with human occupation achieve depths of 1 to 5m thick and, locally, a maximum thickness of 30-40m (Laraminie, 1989). The potential of these largely unexplored deposits has been underscored by the significant number of human artefacts and mammal remains that are often trawled or dredged from the region. It is usually assumed that the finds have been retrieved from extant deposits eroding or disturbed from the seabed (Flemming, 2002; Glimmerveen et al. 2004). Flemming (2002) suggested that richer environments for the origin and preservation of archaeological materials would include Holocene fluvial valleys and the vast sea inlet which existed to the south of Dogger Bank from 8,000-7,500BP. These general impressions are supported by the density of contemporary sites and material located around contemporary coasts that can, presumably, be extrapolated onto inundated coastlines beneath the North Sea. This information, along with data now being produced by a number of Aggregate Levy Sustainability Fund projects clearly suggest that the lack of material associated with deeper waters indicates an absence of

evidence rather than evidence of absence (Fischer 2004, figure 3.3; Pedersen et al 1997, Murphy 2007). The paradox of the North Sea, therefore, is that although the environmental and cultural potential of the region remains largely unknown, it may still be correct to suggest the landscape archaeology of the region may be significant at a global level (Mithen 2003, 154-157). Sourcing inundated deposits, and therefore providing an option to protect surviving archaeology, is therefore a key, but problematic goal.

Previous methodological approaches

If our knowledge of the archaeological deposits of the North Sea is so tenuous, it might be hoped that the larger geomorphological context of the region could offer the opportunity to make general observations on the potential nature of preserved archaeological deposits. Unfortunately, although the North Sea has been the subject of extensive exploration for a variety of commercial or academic reasons for decades, this is probably not the case. Our current understanding of the morphology of the Holocene landscape of the Southern North Sea has been largely based on bathymetric data and maps generated by Jelgersma (1979) and supported by considerable exploratory activity of the geological services of countries bounding the sea and the exploratory work of commercial groups seeking to exploit the area. Work by Jelgersma produced a series of highly influential maps for the major changes in the coastline from 18,000BP to 8,300BP and, significantly, noted the formation of an island at the Dogger Bank around 8700BP. Attempts were then made to put this landscape within a human perspective with the emergent plain then referred to as "Doggerland" by Coles (1998). This work produced hypothetical reconstructions of the coastline from the Weichselian maximum through to 7000BP, but was ultimately based on the earlier work by Jelgersma. Whilst this approach has provided an overview to the area it remains true that the palaeogeography of the region remained lacking in critical detail. Researchers including Lambeck (1995), Shennan (2000), Peltier (2004) have used isostatic rebound models to help constrain and improve the present bathymetry-based models resulting in minor modifications to current coastal models but the lack of detail within the landscape (e.g. the location of fluvial systems, details of coastline etc), and the failure to incorporate late Holocene and recent sedimentation, still remain significant issues (Bell et al 2006, Box 1, 14). Inasmuch as these factors have the effect of masking the true relief of the palaeolandscape it is unlikely that an adequate appreciation of the human landscape could be achieved using previous studies

In methodological terms, therefore, the investigation of past marine environments has generally been limited by available data which, themselves, had serious limitations in their application. These have included:

1. Seabed sampling and shallow coring: These provide high quality chronological, sedimentological and environmental data. However, data is widely spaced and provides a poor spatial framework and thus limits its use in assessing the larger landscape and its archaeological significance or potential.
2. High resolution 2D seismic: Traditional shallow seismic techniques (e.g. Velegrakis et al., 1999) have provided detailed information on the architecture of sedimentary systems but as the data is generally acquired as a series of 2D profiles, a weak three-dimensional framework is created due to the necessary interpolation between the profiles.

3. High resolution 3D seismic: These data represent a significant advance in imaging shallow geology (Bull et al 2005), but the centimetre-scale resolution of the data dictates that only small areas (<1km2) can be realistically surveyed.
4. High resolution bathymetry: This may provide excellent images of the seabed topography and is capable of providing detailed images of Late Quaternary and Holocene features that have a bathymetric expression. Whilst the bathymetry provides a reasonable approximation for the land surface for the area it does not however consider, or attempt to resolve, any possible burial of features that may have occurred during or after submersion (Cameron et al., 1992). Consequently, many of the important geomorphological features and archaeological issues remain unresolved and the technique is unsuitable for areas such as the Southern North Sea and the Irish Sea where deposition has buried most of the Quaternary and Holocene. The scale of this problem was clearly stated by Dix et al. (2004, 89); "although modern bathymetry can correlate to surfaces relating to earlier periods, in many instance there may be a significant difference (up to c. > 20 m) between them. This can lead to inaccurate representations of shoreline positions (up to 60 km difference) and past topography can be markedly misinterpreted. The bedrock horizon represents a minimum value that could be used in reconstruction. However, modern bathymetry does not represent a maximum value as processes of erosion may have reduced its height over time".

The limitations of these methodologies are also apparent in the archaeological literature. Whilst there is considerable interest in the investigation of marine features and the identification of marine landscapes the available technology and scale of archaeological application has tended to restrict studies to the immediate coastal zone and to relatively small, intensively surveyed areas (Mueller et al 2006). Whilst this has been adequate for exploration of known sites (usually of the historic period, e.g. Paoletti et al. 2005) or microregional survey, it has largely precluded major landscape exploration. Prior to the current work, therefore, there was no plausible topographic or geomorphological context that would provide a credible proxy indicator for human activity across the former Holocene landscapes of the North Sea.

Towards an alternative methodology

The impetus and opportunity to develop a methodology to deal with this challenging landscape, using 3D seismic data, derived from doctoral research carried out at the University of Birmingham by Simon Fitch and under the supervision of the authors (Fitch et al. 2005). The 3D seismic datasets acquired on the United Kingdom continental shelf for exploring deep geology represent a major resource for understanding Late Pleistocene and Holocene geology. With extensive regional coverage and spatial resolutions of 12.5m such datasets provide the opportunity of mapping relatively recent geology at a regional scale and with relative speed. Standard geophysical interpretation techniques usually used on such data to explore deeper features, augmented by volume and opacity rendering, provide significant advantages in reconstructing palaeogeographies and allow the true 3D architecture of Late Pleistocene and Holocene systems to be established (see Thomson, this volume).

This original research at Birmingham coincided happily with an emerging requirement to manage the archaeological heritage of the region and the availability of

funding through the Aggregates Levy Sustainability Fund, administered by English Heritage. This provided the serendipitous opportunity to develop a methodology centred around the use of 3D seismic data sets across a large area of the southern North Sea. Accordingly, a team of three researchers was initially employed to work on this data; Kate Briggs, Simon Fitch and Dr Simon Holford, The papers presented in this volume present the results of this work using data collected to assist in mineral exploitation of the Southern North Sea, for the purpose of exploring the submarine archaeology of the region.

The surfaces investigated as part of this project effectively represent the Holocene landscape inundated between 10,000 and 7,500BP and, in archaeological terms, is associated with the Mesolithic period (Cameron et al. 1992; Jelgersma, 1979; Lambeck, 1995). Given the origin of the data the study area was defined by the extent of available data rather than the probable historic Holocene shorelines (figure 1) or notional areas defined for other purposes (see Cameron et al 1992 for the BGS definition of the Southern North Sea region).

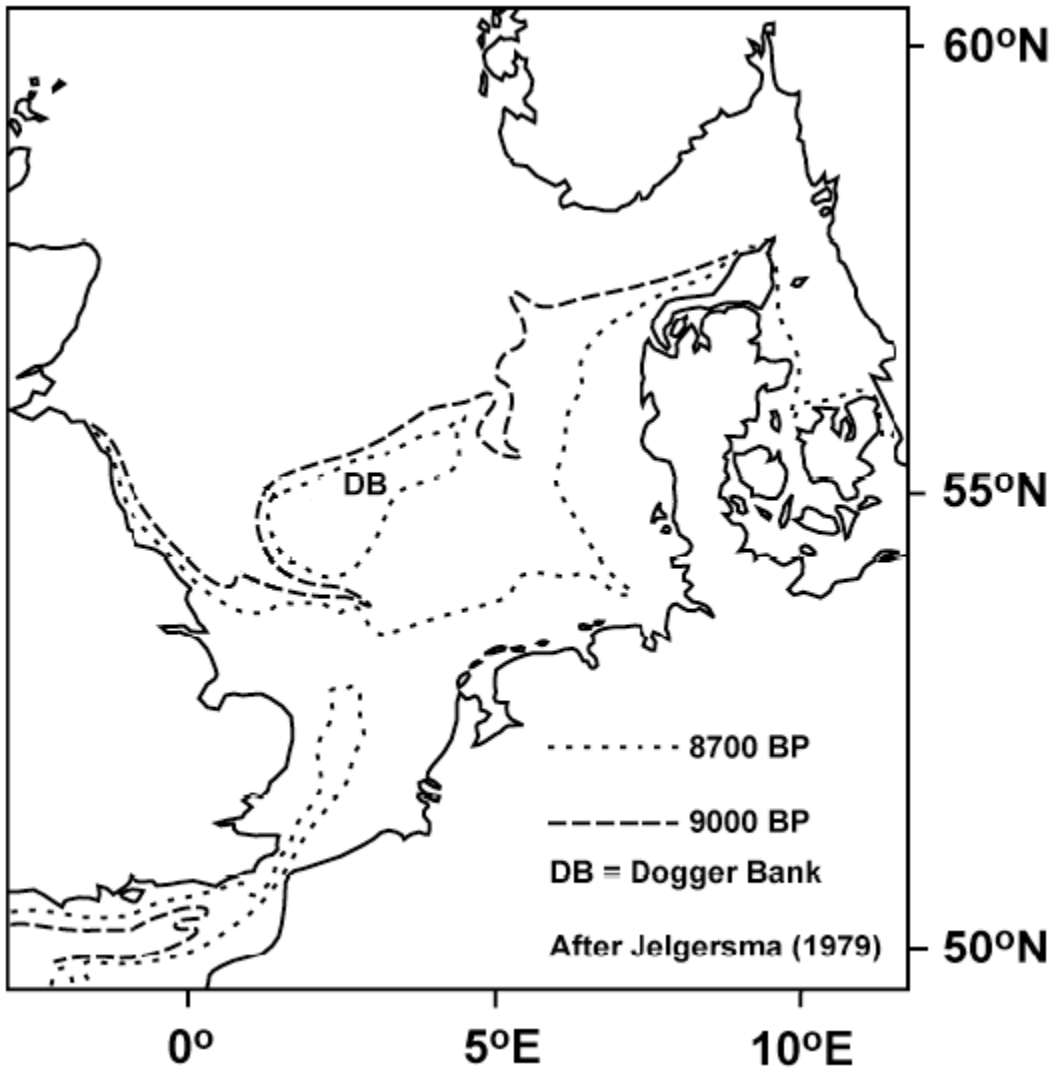

Figure 1 Holocene shorelines (after Jelgersma, 1979)

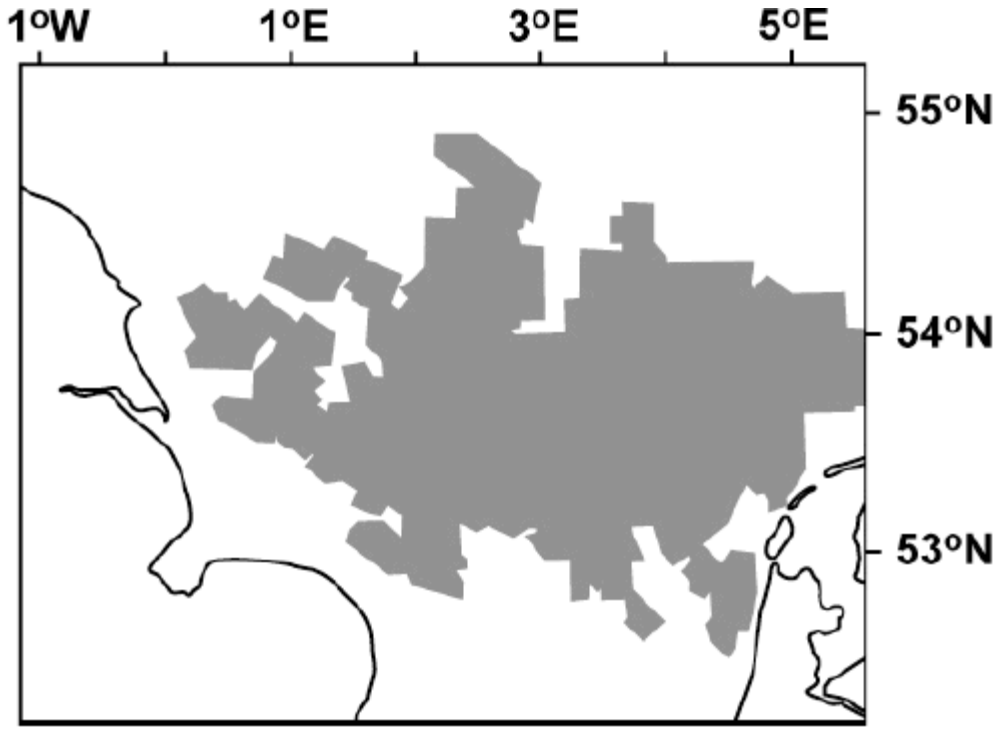

Figure 2 Current extent of Southern North Sea Megasurvey 3D seismic data (source PGS **http://www.pgs.com/business/products/datalibrary/nweurope/southernnorthsea/snsmegasurvey/)**

Data for the Southern North Sea is provided through a research agreement between the University of Birmingham and Petroleum Geo-Services (PGS http://www.pgs.com/) and we are particularly indebted to Mr Huw Edwards for facilitating access to this information. PGS MegaSurveys are based on seismic data that have been released by oil companies, PGS owned seismic surveys, and non-exclusive seismic data made available through other geophysical contractors. Usually these data are available as 3D time migrated seismic surveys. Although quality controlled the different age and data acquisition methods used to collect data demand that the seismics vary in quality. (http://www.pgs.com/business/geophysical/research/library/mc3d/dbaFile7567.html?1=1&print=true). Figure 2 illustrates that these data exist as a significant continuous data source across much of the Southern North Sea. Whilst the data does not currently stretch coast-to-coast the total full-fold area of coverage of the Southern North Sea Megasurvey is in excess of 22,000 km² and represents more than 60 original 3D surveys belonging to 20 different data owners. Altogether, this data set represents the largest available data source for the exploration of the palaegeography of the Southern North Sea region and, in archaeological terms, constitutes the largest contiguous archaeo-geophysical survey programme ever attempted. The work also follows the tradition of seismic study and large-scale archaeological remote sensing projects managed at Birmingham (Gaffney et al. 2000, Thomson 2004)

Within this context, the specific aims of the project were ;

- To use the existing 3D seismic datasets acquired on the United Kingdom continental shelf for exploring Late Quaternary and Holocene geology over an area of the Southern North Sea.

- To provide maps of the recent geological sequence at a regional scale.
- To provide detailed digital mapping of the topographic features of the region and to use voxel rendering to allow the true 3D architecture of Late Quaternary and Holocene systems to be established. See section 3.1.2 for technical detail of provision and dissemination of digital data generated through the project.
- To compare the Holocene topographic data with available core and borehole data to ground truth data and calibrate results.
- To provide a model of survival potential for environmental and archaeological deposits within the area of the Southern North Sea which may be used by the aggregates industry to plan extraction and mitigation strategies.
- To use data on environmental and archaeological potential to provide an extensive depositional map of the Southern North Sea for use for aggregate developmental purposes.
- To utilise seismic attribute analysis to map depositional systems in detail and to make calibrated lithological predictions which may be used in aggregate deposit modelling
- to provide palaeocoastline data, which may be used in the development and calibration of current sea level and palaeobathymetry models.
- Disseminate knowledge of the methodology and outcomes of the project for the purposes of supporting and developing the aggregate industry.

A full description of the technologies utilised to explore the available seismic data is provided in papers Thomson and Fitch et al. (this volume). It is enough to note here that the significance of the first results of this work was rapidly appreciated, and that mapping of the area proceeded apace, as is demonstrated in the atlas paper by Fitch et al. This is complimented by papers from Briggs and Holford et al. that demonstrate the detail of specific geomorphological structures, including the nature of internal features identified within the Outer Silver Pit.

It is true, however, that as the project proceeded there was an increasing concern within the team concerning not so much the extent of available supporting data (including 2D seismics lines, cores etc) but rather the quality or actual availability of some of this information. In particular, the spot-checking of cores for environmental potential suggested that the description of core data was, in some cases, misleading and also that the environmental potential of samples might have been compromised by their storage (Smith et al. this volume). Consequently, a project variation was submitted to English Heritage that permitted a general data audit to assess the extent of available 3D coverages and the potential and availability of any supporting datasets for the purposes of future research. Dr Mark Bunch was employed for these purposes and the results of this important work are presented in summary within this volume.

In presenting this extended introduction it is worth considering the wider significance of the work presented here. Initially, it should be stressed that the study represents our first tentative steps towards providing a robust methodology for the investigation of deeply buried and inundated historic land surfaces. The results of the North Sea Palaeolandscapes Project are, we firmly believe, a major contribution to our understanding of the structures and history of the Holocene land surfaces of the North Sea. From a methodological perspective this is of enormous significance. The Holocene landscapes studied here do not represent the total of available data for the

British Continental shelf. There is more work to be done within other areas of the shelf with similar data. Comparable, extensive areas of submerged, but previously inhabited landscapes, can also be found in the Black Sea (Ryan & Pitman 2000), the Florida Gulf (Faught 1988; Marks and Faught 2003; Faught 2004), the Gulf of Arabia (Lambeck 1996) and a number of other regions of the world and many of these areas have also been subject to extensive exploration for mineral extraction. The work presented here is therefore potentially replicable elsewhere and, if implemented, the results for regional research are likely to be as exciting and challenging as those derived for the Southern North Sea.

Of course, there is room for improvement. This project, which lasted for a mere 18 months, would have benefited from a more substantive integration of supporting data, including high resolution 2D seismic data and further core data. Unfortunately, the audit carried out as part of the study suggests that existing data will not always be available or sufficient for the purposes of refinement or ground truthing of results. There is, therefore, a real need for dedicated, expensive ship time to provide new data to ground truth and extend results of this study.

Despite these observations, the scale of the work and the fact that the landscape transcends national boundaries ensures that, aside from primary archaeological or geomorphological output, the implications of the results are of international significance in terms of heritage management at the very least. We have presumed, for nearly a century, that the North Sea contained a significant archaeological record but it has always been a challenge to manage a resource that was largely inaccessible, entirely unpredictable and, essentially, a hypothetical construct. The results presented here suggest that this record may be traced, in part, through the recreation of the topographic context of the region. As a consequence, the heritage agencies of countries bounding the North Sea may well have to re-assess their marine management strategies in the light of this information. In this context the steps toward a historic landscape characterisation methodology described in the final paper of the volume are, we hope, an important contribution towards the management of such problematic landscapes.

Ultimately, the principal achievement of the project has been to explore and begin to interpret in unparalleled detail one of the most extensive, yet least known, prehistoric landscapes in Europe. Whilst our knowledge remains imperfect the area is no longer the “terra incognita” pondered upon by Flemming less than 3 years ago (Flemming 2004). Indeed, in the light of our previous lack of knowledge the scale of the work carried out by this project is truly startling. The analysis of 23,000 square kilometres of seismic data is, essentially, comparable to carrying out a geophysical survey over a country the size of Wales. It is often a cliché to assert that the past is a foreign country but, in the case of the North Sea Palaeolandscapes project, it is hardly hyperbole to assert that, along with the outstanding contributions of Coles, Flemming, Dix and others, the project has effectively begun to create the archaeological record of a previously undiscovered European country.

The final point to be made here is more emotive. The loss of these extensive late Pleistocene and Holocene landscapes following the last glacial represents the only previous period during which modern man experienced the impacts of global warming at a scale now predicted for the next century. The North Sea

Palaeolandscapes Project provides quantitative and visual evidence for the nature and significance of such change. The recreation of the Mesolithic landscape and coastline may, ultimately, be factored into improved models of coastal change which may have relevance for future events. This is a practical and desirable outcome but we should never forget that this was a populated land. The loss of such extensive areas, insidious and slow overall but terrifyingly fast at times, must have been devastating for the Mesolithic populations of the great northern plains. The coastlines, rivers, marshlands and hills mapped during this project were, for several thousand years, parts of a familiar landscape to the hunter-gatherers of North Western Europe. The rivers and hills would have been named; some areas might have been revered and held personal associations or ancestral memories dear to these peoples. During this period whole territories may have disappeared within the memory of single generations, and the stress caused by the loss of environments and ecologies that supported communities, tribes and entire peoples is almost impossible for us to comprehend. All of this was lost, along with the landscape itself, as sea levels rose and the land retreated. As this project concludes the UN Intergovernmental Panel on Climate Change is finalising its report on the nature, scale and implication of climate change (http://www.ipcc.ch/), and, at a time when climate change, global warming and sea level rise are now accepted as amongst the greatest threat to our lifestyles, the fate of the Holocene landscapes and peoples of the North Sea may yet be interpreted not as an academic curiosity but a significant warning for our future.

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