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New models of North West European Holocene palaeogeography and inundation☆

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ABSTRACT

This paper presents new 500 year interval palaeogeographic models for Britain, Ireland and the North West French coast from 11000 cal. BP to present. These models are used to calculate the varying rates of inundation for different geographical zones over the study period. This allows for consideration of the differential impact that Holocene sea-level rise had across space and time, and on past societies. In turn, consideration of the limitations of the models helps to foreground profitable areas for future research.

1. Introduction

In this paper we present, and make available in an interactive format, new high-resolution (500 year interval), palaeogeographic models for Britain, Ireland and the broader area shown in Fig. 1 from 11,000 BP to present day. In addition, we use these data to address the longstanding call (Reid, 1913, 10; Clark, 1936; Coles, 1998, 45; Leary, 2009, 227; Van de Noort, 2011) for more detailed consideration of the extent, timing and significance of landscape transformation over the Holocene. In so doing we demonstrate the variable histories of change across the North West European continental shelf, and the impact that scale of analysis has upon interpretation.

The archaeological significance of the changing palaeogeography of Europe has long been established, since Reid's (1913) work on submerged forests. There, and in subsequent publications by a range of scholars (Clark, 1936; Coles, 1998, 1999; Gaffney et al., 2007), maps of the changing shape of land and sea boundaries have proven pivotal to discussion of prehistoric activity and social connectivity. These outputs have been used to demonstrate the size of past habitable landscapes now submerged offshore, and to allow perspective to be gained on the impact such changes may have had on past communities.

This paper utilises a recent Glacial Isostatic Adjustment (GIA) model (Bradley et al., 2011) and data from bathymetric surveys, to generate new high temporal and spatial resolution reconstructions. In turn, these outputs are queried to allow for quantification of variable rates and extents of inundation over the study area. This helps progress discussion as to both the changing shape of North West Europe over the Holocene, and the possible significance of those changes for people in the past.

2. The palaeogeography of North West Europe: a history of research

The presence, implications and archaeological potential of submerged landscapes in North West Europe have long been

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known. Reid's (1913) pioneering work on the submerged forests and offshore peats surrounding Britain not only led to one of the first palaeogeographic reconstructions of the North Sea basin as terrestrial space (1913, 40), but also gave a clear call for more detailed work on this topic in future. The recovery of a Mesolithic antler harpoon from the Leman and Ower banks in 1931 led Clark and Godwin (1956) to build on Reid's work, investigating the submerged deposits of the North Sea for themselves. For Clark (1936) this saw a transformation of the North Sea plain from a marine environment into an undervalued and under-investigated submerged terrestrial landscape.

However, as Coles (1998, 48) notes, following this early development of interest, the North Sea Plain receded from archaeological view. It became at best a hypothetical bridge between Britain and the continent. Thus, while Jacobi (1976) saw the North Sea as land in the Mesolithic, little weight was given to that space beyond being a corridor for past movement. In this context, Louwe Kooijmans' pioneering (1971) documentation of faunal material recovered from the Brown Bank failed to receive the attention it deserved in mainstream archaeological discourse. However, while archaeology may have shifted its focus away from this topic, great advances were made in the Earth Sciences. In particular Jelgersma's (1979) work in the North Sea helped to communicate the extent and rate of change via new relative sea-level curves. This work would prove fundamental to later developments, establishing a crucial baseline from which archaeologists could work.

It was not until the 1990s that publications by Wymer and Robins (1994) and Coles (1998, 1999, 2000) helped to re-establish the significance of understanding the changing shape of Northwest Europe within the context of British and Irish archaeology. Critically, Coles (1998, 45) made clear that our approach to this topic should move beyond seeing submerged spaces as bridges, but instead view them as once inhabited landscapes. Concomitant with this was an appreciation of the fact that palaeogeographic change did not occur in a social or physical vacuum. As such, Coles (1998, 77) pushed researchers to attempt to grapple with the specifics of the rate, nature and social impact of sea-level change.

The degree to which this space could be accurately described accelerated through the late twentieth and early twenty first century. Improvements in computer power and software aided the construction of graphical outputs combining different data sets. This saw the creation by Shennan et al. (2000) of some of the most heavily reproduced palaeogeographic maps for the UK. Here data from regional relative sea level (RSL) curves were integrated to generate time slice maps at 1000 year intervals. Subsequent work (Shennan and Horton, 2002; Brooks et al., 2011) served to further refine this understanding through integrating new relative sea-level data and outputs from Glacial Isostatic Adjustment models.

Over the same period, pioneering use of 3D seismic data for offshore landscape reconstruction by Gaffney et al. (2007), (Gaffney and Fitch, 2009) helped demonstrate and map the survival of submerged Holocene landscape features. In addition, increased marine development in the UK led to large-scale review of offshore data (Ward et al., 2006; Selby, 2009; Tappin et al., 2011), helping to bind together geophysical and geotechnical renderings of the offshore zone. Work across the European North Sea coastline (Peeters et al. 2009; Hijma et al. 2011) continued to demonstrate recovery of Palaeolithic and Mesolithic material from both the Brown and Dogger Banks, but with additional large amounts of in situ material recovered from buried strata closer to the Dutch coast (Weerts et al., 2012). In the UK, finds from the submerged Mesolithic site at Bouldnor Cliff (Momber et al., 2011) further demonstrated the potential for the recovery of material in situ. As such, Reid's (1913) hypothetical spaces were more readily modelled and had their potential proved through recovered finds and geotechnical data.

While the above work has helped to shape our understanding of the submerged record, continued advances in sea-level reconstruction techniques, and acquisition of new data, mean that palaeogeographic models need to be updated to provide the broader context for this material. In addition, while the issues we are interested in as archaeologists mesh with those of earth scientists, archaeologists often call for consideration of change at higher temporal and spatial resolutions. Thus, while Shennan et al. (2000) and Brooks et al.'s (2011) palaeogeographic models provide a good sense of change at one thousand and two thousand year intervals respectively, they are still at odds with archaeology's desire (Coles, 1998, 77) to understand rates of change at a more human scale. As such, this paper moves to a five hundred year temporal interval and a higher spatial resolution for outputs than have previously been made available. In addition, it uses the model outputs to quantify varying rates of change across different zones within the study area. As such, through the models created here we seek to establish how the shape of North West Europe changed over the Holocene, and how variability in the rate of change may have impacted on people in the past.

In recent years, much archaeological attention has been focused on events which appear dramatic when viewed at a macro temporal and spatial scale – such as the total loss of Doggerland (Coles, 1998, 1999, 2000; Weninger et al., 2008) or the separation of Britain from the continent (Tolan-Smith, 2008). In this paper, we also seek to investigate changes which may appear less dramatic, but were in fact no less important, across the study zone. In addition, just as Coles (1998, 77) argued that the North Sea plain needed to be seen as more than a corridor, so we argue for the need to better understand the changing qualities of maritime space. The opening up of channels, the formation of islands and changes in depths of water along maritime routeways, will have impacted on both movement over the water and the distribution of ecosystems within it. This is not a trivial concern for archaeologists interested in issues of connectivity and social change (Bell and Warren 2013; Sturt and Van De Noort, 2013; Van de Noort, 2011).

3. Theory and method

As Lambeck et al. (2010, 65) have clearly stated, resolving differences in relative sea-level through time is a complicated matter, requiring consideration of:

> "(1) changes in ocean volume, (2) radial displacement of the land surface by changing load, (3) changes in the gravitational potential as a result of the deformation of the planet and redistribution of mass across its surface, (4) changes in the shape of ocean basins and, (5) the redistribution of water within these basins"

Researchers have collected empirical evidence for the impact of these changes for over a hundred years (Reid's (1913) submerged forests stand as one coarse grained proxy indicator). More recently rigorous standards have been set (Shennan, 1982, 54) with regard to what can be counted as a robust sea level index point (SLIP). Collection, auditing and analysis of SLIP data has enabled the creation of high resolution regional relative sea-level curves (Shennan et al., 2006; Brooks and Edwards, 2006; Smith et al., 2011, 2012) for Britain and Ireland. As Brooks et al. (2011, 13) note, the only problem with these records is that they are often confined to the present coastal margins. Due to this distribution there is remarkably little direct evidence from submerged areas of the continental shelf through which to construct RSL curves (see Ward et al., 2006). The result of this is that for offshore landscapes we hold little robust evidence for the rate at which submergence occurred.

Glacial Isostatic Adjustment (GIA) models help to move beyond this problem through simulating the five points listed above,