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Ostracod-based palaeotemperature reconstructions for MIS 11 human occupation at Beeches Pit, West Stow, Suffolk, UK

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A B S T R A C T

The Mutual Ostracod Temperature Range (MOTR) method is applied to ostracod assemblages from the well-documented Middle Pleistocene (MIS 11) human occupation site of Beeches Pit, West Stow, Suffolk, England. The results provide palaeotemperature reconstructions which are compared against other proxy data from molluscs and ostracod indicator species. Ostracod assemblages from the lower part of the sequence (Beds 3 and 4) suggest a temperate climate with mean monthly temperatures (January and July) not dissimilar to those of today, while those of the overlying Bed 7 indicate a climatic shift to a more continental climate with winter temperatures at least 4 °C colder than today. These results corroborate previous suggestions that the evidence of human occupation at Beeches Pit occurs not only in the interglacial (MIS 11c) but also in a succeeding cold phase (possibly MIS 11b) and provide the first quantitative palaeotemperature reconstructions for this site and interval.

1. Introduction

The palaeoclimatic conditions under which early humans occupied northern Europe, and the associated implications for behaviour and adaptation, have been debated for several decades (e.g. Gamble, 1986; Roebroeks et al., 1992; Parfitt et al., 2010). The complex climate of Marine Isotope Stage (MIS) 11 is well studied in both terrestrial and non-terrestrial (ice sheet isotope and marine sediment) environments, though correlations between the two are difficult due to the fragmentary nature of terrestrial records (see Candy et al., 2013). At Hoxne (Fig. 1), the type Hoxnian interglacial sediments and overlying temperate deposits of Stratum B (suggested to correlate with MIS 11c and MIS 11a respectively; Ashton et al., 2008) are separated by the cold 'Arctic Bed' of Stratum C, with recent reinterpretation of the stratigraphy by Ashton et al. (2008) placing the earliest evidence of human occupation at the site after Stratum C, where temperate substages are thought to have been 'considerably cooler' than that of MIS 11c (Ashton and Lewis, 2012: p. 58).

Of the well age-constrained MIS 11 sites in south-eastern England (Fig. 1), few contain firmly contextualised evidence of human occupation, limited to Beeches Pit, Swanscombe, Barnham (all MIS 11c; Ashton and Lewis, 2012, and references within) Hoxne (Singer et al., 1993), Elveden (Ashton et al., 2005), Hitchin (Boreham and Gibbard, 1995), Foxhall Road (White and Plunkett, 2005) and Clacton (Singer et al., 1973). The presence of ostracods in the Beeches Pit deposits therefore offers a valuable opportunity to address ongoing research themes (see Ashton et al. (2006a)) relating to the climate of MIS 11 and the potential to provide a quantified environmental context for a period of human occupation at this site.

The aim of this investigation is to apply the Mutual Ostracod Temperature Range (MOTR) method (Horne, 2007) to the published ostracod assemblages of Preece et al. (2007), providing the first quantification of palaeotemperatures for this important Middle Pleistocene human occupation interglacial site.

2. Beeches Pit, West Stow

At the site of Beeches Pit at West Stow, Suffolk (Fig. 1), glacial deposits of Anglian (MIS 12) age fill a subglacial channel and are overlain by interglacial fine-grained sediments containing ostracods, mollusc shells and vertebrate remains (Preece et al., 2006, 2007, Fig. 2), though lacking in pollen. Through uranium series (Holyoak et al., 1983; Preece et al., 2007), amino acid (Preece et al., 2007), optically stimulated luminescence (Preece et al., 2007) and thermoluminesence (Lewis, 1998; Preece et al., 2007) dating as well as lithostratigraphical and biostratigraphical evidence (Preece et al., 2007), Beeches Pit has been attributed to MIS 11.

This Palaeolithic site was first described in the late 19th Century (Whitaker et al., 1891) and has recently been the subject of

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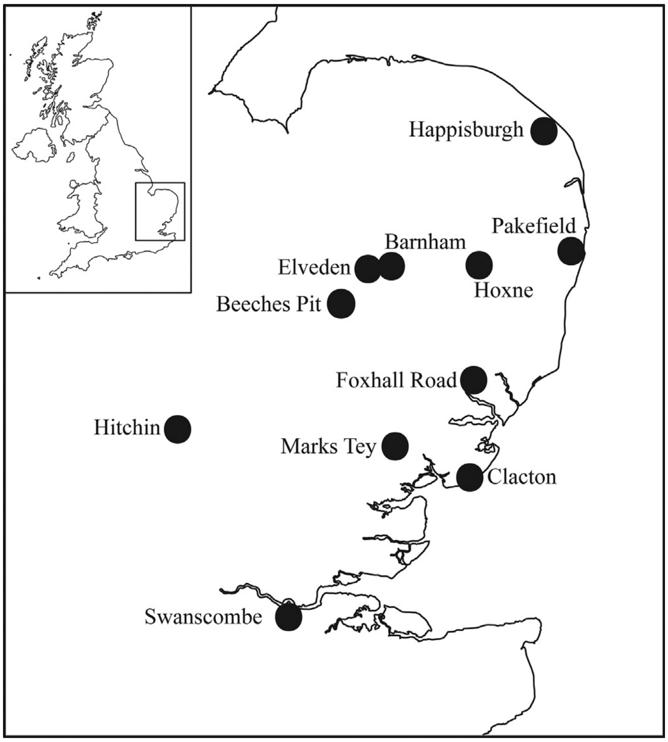

Fig. 1. Location map of Beeches Pit, in relation to other MIS 11 and human occupation sites in south-east England and the UK (inset).

extensive multidisciplinary investigations by Preece et al. (2006, 2007), including identification of ostracod species through the sequence (Fig. 2). The site provides evidence of recurrent human occupation in a fully interglacial climate as well as into the ensuing cold phase and represents one of the two earliest European Pleistocene sites containing possible evidence of fire use (Roebroeks and Villa, 2011). Known to contain Lower Palaeolithic flint artefacts, with the oldest evidence represented by Acheulian handaxes in Bed 3b, the site is of particular interest as indications that Beeches Pit was a knapping site are coincident with the earliest evidence of burning at the site; two small handaxes providing evidence of continued human occupation and evidence of burning events and burnt bone occur in Bed 6 (Preece et al. 2006).

An account of the site given here includes only the information most relevant to the aim of this paper; a comprehensive account of recent investigations at the site, covering many years of collaborative work, is given by Preece et al. (2007). Further detail relating to evidence of human occupation at this site is given by Preece et al. (2006) and Gowlett and Hallos (2000).

3. Method

The Mutual Ostracod Temperature Range (MOTR) method (Horne, 2007) uses the Nonmarine Ostracod Distribution in Europe (NODE) database (Horne et al., 1998) and a modern climate dataset (Hijmans et al., 2005) in DIVA-GIS (Hijmans et al., 2001) to calibrate the present day distribution of extant species in climate space. Known temperature parameters of species within the NODE database allow the application of a mutual climate range method, similar in principle to the beetle MCR method (Atkinson et al., 1986, 1987), to ostracod assemblages to estimate past mean January and July air temperature ranges.

Of the 23 species identified by Preece et al. (2007; Table 8), 13 were calibrated for mean January and July air temperature ranges (Table 1). Excluded from calibration and analyses were those species which are extinct (*Limnocythere falcata, Limnocythere suessenbornensis*, *Eucypris heinrichi)*, not adequately (i.e., <10 records) represented in the NODE database (*Amplocypris tonnensis, Ilyocypris lacustris, Trajancypris laevis)*, unidentified to species level (*Leucocythere* sp., *Pseudocandona* sp. and *Ilyocypris* sp.) or present only in samples with very low total valve counts (<10; *Pseudocandona lobipes*).

Though absent from the NODE database, *Amplocypris tonnensis* is present in the Ostracod Metadatabase of Environmental and Geographical Attributes (OMEGA; Horne et al., 2011) database where it is calibrated for January and July temperature ranges; however, its inclusion in the MOTR analysis failed to show a mutual overlap with the other species (i.e. a non-analogue fauna). This is attributed to its narrow calibrated range of January temperature of just 2 °C, between −20 °C and −22 °C, which is almost certainly due to the low number of records available for calibration (Horne et al., 2012). This species is therefore not included in calculations of palaeotemperatures in this study but is instead utilised as a cold indicator species, since it is at least possible to conclude that from its association with other cold-climate taxa (see, e.g., Whittaker and Horne, 2009) it represents cold January temperatures. Similarly, the extinct species *Limnocythere falcata* cannot be used in palaeotemperature calibrations in the absence of any modern records but is known to be a cold indicator by association (Whittaker and Horne, 2009).

4. Results

Reconstructions using ostracod assemblages from Beeches Pit (Fig. 3) show wide palaeotemperature ranges for beds 3 and 4, where there is often an overlap between maximum January and minimum July values. For example, maximum January and minimum July air temperature estimates for the upper section of Bed 3a are +12 °C and around +10 °C respectively. In contrast, estimated palaeotemperature ranges for Bed 7, towards the top of the succession, generally indicate a cooler climate with sub-zero winters (typically ranging from −10 to −1) and narrower July air temperature ranges (typically +15 to +21) compared to those of the lower beds. The transition to cooler winter temperatures appears not to occur in the Bed 4/Bed 7 hiatus, but between the two lowermost Bed 7 samples, coinciding with the appearance of *Fabaeformiscandona balatonica* and *Fabaeformiscandona protzi*, with calibrated maximum January temperatures of −1 °C and +3 °C respectively (Table 1). The presence of two cold indicator species, *Amplocypris tonnensis* and *Limnocythere falcata,* in Bed 7 supports the MOTR indication of a climatic cooling. There exists a strong relationship between the number of ostracod species used to reconstruct the palaeotemperatures and the size of the temperature range; the large January temperature range for Bed 4 sample 'Basal 10 cm' is a result of this sample containing just one calibrated species, *Cyclocypris laevis*, while the more diverse samples of Bed 7 reconstruct generally more constrained temperature ranges. Though this demonstrates a shortcoming of the MOTR method, where assemblages of limited diversity (or at least those with limited species that can be calibrated for January and July temperature ranges) will typically reconstruct very broad temperature ranges, the utilisation of indicator species allows for greater confidence in inferred climatic changes.

The interpretation using ostracods of a cold climate for Bed 7 is supported by the presence of the bivalve mollusc *Pisidium obtusale* in both Beds 6 and 7, a species indicative of cold climates (Ellis, 1978; Preece et al., 2007). Molluscan, fish and mammalian remains from Bed 7 similarly indicate climatic deterioration during deposition, with the presence of lemming (*Lemmus* or *Myopus*,