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THE REINSDORF INTERGLACIAL (SCHÖNINGEN II) MAMMALIAN ASSEMBLAGE IN ITS EUROPEAN CONTEXT

In recent years, there have been significant developments in our understanding of the number and nature of late Middle Pleistocene temperate episodes in NW Europe, based in large part on the evidence from mammalian biostratigraphy. In Britain, four interglacials can be confidently recognised in the fluvial record of the lower Thames, correlated with MIS 11, 9, 7 and 5e and underpinned by a multiproxy range of stratigraphical, biostratigraphical and geochronological data. Each of these interglacial episodes is characterised by a highly distinctive mammalian assemblage that can then be used for correlation with other, more distant sites. Similar chronological schemes, equally based on long fluvial sequences, have also been proposed in France and other parts of Germany. Furthermore, climatic and environmental variability at the oxygen isotope substage level can now be addressed, thereby allowing the structure of an individual interglacial to be dissected at high resolution.

Comparison of British and German faunal records from the late Middle Pleistocene has demonstrated a remarkably close degree of correspondence, perhaps due to the importance of the Rhine-Thames river as a corridor for mammalian movement and dispersal. This paper presents the evidence for climatostratigraphical complexity across northern Europe, based upon observations of mammalian and stratigraphical evidence, before proposing likely correlatives for the temperate climate sediments represented in Channel II at Schöningen (Lkr. Helmstedt/D). The last has been attributed a broad late Middle Pleistocene age but further resolution has remained elusive.

THE STRATIGRAPHICAL SEQUENCE AT SCHÖNINGEN AND THE FAUNA OF THE REINSDORF INTERGLACIAL

In the Schöningen Palaeogene lignite mine, a series of Quaternary fluvial sediments has been deposited in a subsiding graben adjacent to a salt dome (Thieme / Maier 1995; Urban 1995; Urban et al. 1995). Three superimposed (overlapping) interglacial channel fills have been described between Elsterian and Saalian (Drenthe) glacial sediments, identified respectively as Holsteinian (Schöningen I), Reinsdorf interglacial (II) and Schöningen interglacial (III). All three channels have yielded pollen records, although vertebrate remains have, to date, been described only from the Reinsdorf interglacial (van Kolfschoten 1993). The depositional sequence in the Reinsdorf channel consists of five levels of organic muds and peats (Levels 1-5 from the base upwards), which represent a succession of falling and rising lake levels. Level 1 at the base is considered to reflect the warmest part of the sequence, whereas the upper levels represent later, cool temperate phases (Thieme 1997). The pollen evidence suggests that the very earliest part of the interglacial is apparently missing and that at least two interstadials follow the temperate maximum (Urban 1995). There has been considerable disagreement over the age of these deposits. According to Mania (1996), the palynological evidence supports correlation with Bilzingsleben terrace II of the Wipper sequence and favours an age within MIS 11, although an alternative interpretation, correlating the Reinsdorf interglacial with MIS 9, has been put forward by Urban (1995; Urban et al. 1995).

The mammalian assemblage from the organic muds and peat of the Reinsdorf Interglacial at Schöningen site 12B, Layer 1, is listed below (after van Kolfschoten 1993):

Insectivora
Sorex minutus, pygmy shrew
Sorex sp. (*Sorex araneus* group), indeterminate shrew
Desmana sp., desman

Rodentia
Trogontherium cuvieri, extinct beaver-like rodent
Castor fiber, Eurasian beaver
Lemmus lemmus, Norway lemming
Clethrionomys glareolus, bank vole
Arvicola terrestris cantiana, water vole (archaic morphotype)
Microtus (*Terricola*) *subterraneus*, pine vole
Microtus agrestis and/or *Microtus arvalis*, short-tailed field or common vole
Microtus agrestis, short-tailed field vole
Microtus oeconomus, northern vole
Apodemus sp., indeterminate mouse

Carnivora
Ursus sp., bear
Mustelidae sp., weasel or stoat

Proboscidea
Elephas (*Palaeoloxodon*) *antiquus*, straight-tusked elephant

Perissodactyla
Stephanorhinus kirchbergensis, Merck's rhinoceros
Equus sp., horse

Artiodactyla
Sus scrofa, wild boar
Cervus elaphus, red deer
Capreolus capreolus, roe deer
Bos or *Bison* sp., indeterminate large bovid

Additional faunal remains from a younger part of the Reinsdorf interglacial come from Level 4 at Schöningen Site 13 II-4. Here, the mammalian assemblage is the product of specialist Palaeolithic hunting and butchery activities and is overwhelmingly dominated by horse, with smaller numbers of large bovids (*Bos* and *Bison*) and probable red deer. Remains of horse comprise over 60% of the total sample from Site 13 II-4 and over 94% of the taxonomically determined bone material (2809 specimens), most of which display clear evidence of cutmarks and deliberate fracturing (Voormolen 2008).

Neither the macro- nor microfaunal assemblages contain any elements that are characteristic of the early Middle Pleistocene, thereby corroborating the post-Elsterian age indicated by the stratigraphy. In addition, certain dental features of the water vole (*Arvicola terrestris cantiana*), most notably the morphology of the first lower molars as expressed by enamel thickness (SDQ) measurements, suggested an age similar to
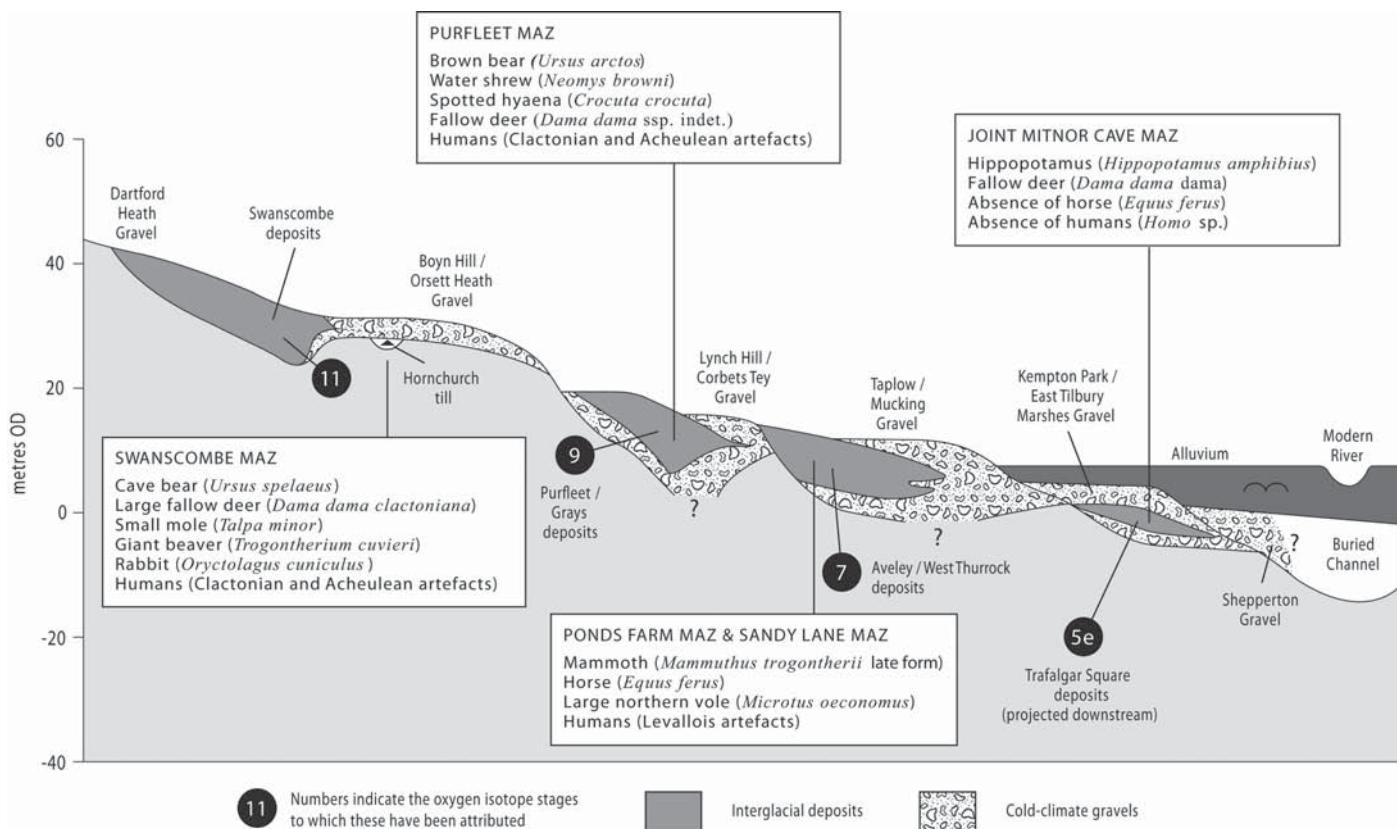
Fig. 1 Transverse section of the Lower Thames terraces (after Bridgland 1994). Proposed correlations with the oxygen isotope record and biostratigraphically diagnostic features of the mammalian assemblages from each interglacial are shown. – (From Schreve 2004).

Holsteinian sites such as Bilzingsleben (Lkr. Sömmerda/D), Swanscombe (Kent/UK) and Neede (prov. Gelderland/NL) (van Kolfschoten 1993).

THE EVIDENCE FROM LONG FLUVIAL SEQUENCES

An appreciation of the climatic complexities preserved within the marine oxygen isotope ($\delta\,^{18}$O) record has driven new methods of identifying and separating the more fragmentary interglacial deposits on land. In this respect, the combination of stratigraphical and mammalian biostratigraphical information derived from long fluvial sequences has provided a robust and testable framework for the recognition of discrete episodes of temperate-climate deposition (Bridgland 1994; 1995; 2000; Bridgland et al. 2004; Schreve 2001a; 2001b). Recent research has demonstrated that each successive major temperate climatic stage during the late Middle Pleistocene gave rise to a distinctive and unique mammalian faunal grouping, thus enabling a sequence of mammal biozonations or 'Mammal Assemblage-Zones' (MAZ) to be established (Schreve 2001a; 2001b) (fig. 1). In addition to establishing the existence of four separate post-Anglian interglacials, each with its own distinctive mammalian suite, indications of smaller-scale environmental and climatic oscillations have been identified within some of these interglacials. These oscillations were tentatively attributed to climatic variation at the sub-Milankovitch level (Schreve 2001b) and have been recently

upheld by the application of high-precision MC-ICP-MS Uranium-series dating to fossiliferous deposits (Candy / Schreve 2007).

The model further offers an opportunity for correlation with assemblages from isolated sites, for example lake basins or caves. This has been a particularly important development, since traditional methods of identifying interglacials based on palynology have failed to distinguish between successive temperate episodes. Thus, in Britain and Ireland, there has been apparent conflation of the pollen signature of the interglacial widely correlated with MIS 11 with that of MIS 9, and of MIS 7 with that of MIS 5e. This is equally the case for well-preserved pollen sequences from lacustrine and estuarine contexts as for the more poorly-preserved spectra from fluvial deposits (e. g. Dowling / Coxon 2001; Thomas 2001). The consequence is that many sites, which have been referred to the 'Hoxnian' (Britain) or 'Gortian' (Ireland) and 'Ipswichian' interglacials in the past, may in fact be better referred to one or other of the two intermediate interglacials, MIS 9 or MIS 7.

Building upon the mammalian biostratigraphical evidence from the UK, correlations have been established with assemblages from long fluvial sequences across continental Europe, most notably from France, Germany and the Czech Republic (Schreve et al. 2007). Important sequences yielding comparable mammal assemblages have come from the Somme (Antoine 1990; 1994; Antoine et al. 2000; Auguste 1995) and Seine (Antoine et al. 2000; Auguste et al. 2003) in northern France, from the Ilm (Soergel 1926; Schreve / Bridgland 2002), Wipper (Mania 1995; 1998) and Neckar (Adam 1954) in Germany, and from the Vltava in the Czech Republic (Tyráček et al. 2001; 2004). It must be noted that some taxa have a more extended chronological range on the continent than in Britain, for example *Ursus spelaeus*, which makes its last appearance in Britain during MIS 11 but is present on the European mainland until the last cold stage, and *Microtus subterraneus*, which is still extant on the continent but absent from Britain after MIS 11 (tab. 1). This is because Britain's position at the margin of the continental shelf and fluctuating island status have played a part in dictating which species can or cannot immigrate during successive interglacials. Nevertheless, pan-European comparisons have shown that the key biostratigraphical indicators that underpin the British mammalian scheme are widespread, thereby allowing correlations to be made with a high degree of confidence. For example, the presence of a characteristic late form of *Mammuthus trogontherii* unites the mammalian assemblages from the Ilm terrace travertine sequence at Weimar-Ehringsdorf, central Germany, the later part of the Tourville Formation in the Seine valley of western France and the Sandy Lane MAZ of the Mucking Gravel Formation in the Lower Thames (Essex/GB; Schreve / Bridgland 2002; Bridgland et al. 2004) (tab. 1), all of which can be confidently attributed to MIS 7 on a range of stratigraphical and geochronological grounds (Carpentier / Lautridou 1982; Mallik et al. 2000; Schreve 2001a; 2004; Schreve / Bridgland 2002; Antoine et al. 2007).

It is nonetheless apparent that the closest comparisons in mammalian signatures are between Britain and Germany. This is highlighted, for example, by disparities between the British and French assemblages regarding the sporadic occurrence of *Hippopotamus* (Schreve et al. 2007). Despite relative geographical proximity and the presence of dozens of sites with suitable depositional environments, hippopotamus is not present in Britain during either MIS 11 or MIS 7, although it has been recorded from two sites in the Somme, La Celle, a site attributed to MIS 11 (Limondin-Lozouet et al. 2006) and Montières, assigned to MIS 7 (Antoine et al. 2000). In contrast, hippopotamus is absent from Last Interglacial deposits at Caours, in a tributary of the River Somme (Antoine et al. 2006), despite being extraordinarily abundant in British assemblages during the Ipswichian/Eemian and also present in the German Rhine at this time (van Kolfschoten 2000). A possible reason for this may relate to the different immigration pathways of hippopotamus from southerly refugia, with these animals preferentially accessing Britain via the Rhine valley during the Last Interglacial.

suggested MIS correlation	11				9	7				5e	
site / taxon	Swanscombe MAZ	Bilzingsleben II	Schöningen II (Reinsdorf Igl.)	Steinheim (*antiquus* Schotter)	Purfleet MAZ	Ponds Farm MAZ	Ehringsdorf Lower Travertine	Sandy Lane MAZ	Ehringsdorf Upper Travertine	Joint Mitnor Cave MAZ	Burgtonna [6,7]
Talpa minor	X										
Desmana moschata/Desmana sp.	X		X								
Trogontherium cuvieri	X	X	X								
Ursus spelaeus	LAB	X	X	X				X	X		
Dama dama clactoniana	LAB	X									
Oryctolagus cuniculus	LAB										
Microtus (Terricola) subterraneus	LAB	X	X					X			X
Macaca sylvanus	X	X			LAB						
Stephanorhinus kirchbergensis	FAB	X	X	X	X	X	X				X
Equus ferus	X	X	X	X	X	X	X	X	X		X
Homo sp.	X	X	X	X	X	X	X	X	X		X
Stephanorhinus hemitoechus	FAB	X		X	X			X	X	X	X
Ursus arctos					FAB	X	X	X	X	X	X
Dama dama dama					FAB	X	X			X	X
Crocuta crocuta					X		X	X		X	X
Mammuthus primigenius (Ilford type)								X	X		
Coelodonta antiquitatis								X	X		
Hippopotamus amphibius										X	

Tab. 1 Presence/absence data of selected biostratigraphically important mammals from British and German Middle and Late Pleistocene interglacial deposits, with their suggested Mammal Assemblage-Zone (MAZ) grouping (Britain only) and proposed correlation with the marine isotopic record. – Data for the Swanscombe MAZ from Schreve (1996); Schöningen II from van Kolfschoten (1993); for the Purfleet MAZ from Schreve (2001a) and Schreve et al. (2002); for the Ponds Farm MAZ and Sandy Lane MAZ from Schreve (2001a); for the Joint Mitnor Cave MAZ from Currant / Jacobi (2001); and for Burgtonna from van Kolfschoten (2000 and Meyrick / Maul (2002). – X = confirmed presence. – FAB = first appearance in Britain. – LAB = last appearance in Britain.

COMPARISONS BETWEEN THE REINSDORF INTERGLACIAL MAMMALS AND THOSE FROM THE HOXNIAN INTERGLACIAL (MIS 11)

The oldest of the late Middle Pleistocene interglacials represented in the Lower Thames valley is best characterized by the Orsett Heath Gravel Formation in the Dartford-Swanscombe area of Kent. The Lower Thames sequence is, in its entirety, Anglian and post-Anglian in age, since the river was only diverted into this part of the valley by the Anglian glaciation. The Orsett Heath Gravels can be demonstrated to directly overlie Anglian till (Holmes 1894; Dines / Edmunds 1925), thereby implying that the ensuing temperate-climate sediments may be considered representative of the first immediately post-Anglian interglacial. The Anglian has been widely correlated with MIS 12 on account of the apparent severity of this episode within the deep ocean record, as estimated by high global ice volume (Shackleton 1987), with additional support from stratigraphy (Ehlers et al. 1991; Bowen 1999; Hamblin et al. 2005), aminostratigraphy (Bowen et al. 1989; Bowen 1992; Scourse et al. 1999; Penkman 2010), Uranium-series dating (Rowe et al. 1999) and

Optically-Stimulated Luminescence (OSL) (Pawley 2008). The interglacial represented at Swanscombe may thus reasonably be attributed to MIS 11.

The faunal grouping from the Orsett Heath Terrace has been assigned to the Swanscombe MAZ by Schreve (2001a), to which readers are referred for further details concerning the composition and inferred age of this assemblage. In summary, taxa of biostratigraphical significance include *Talpa minor*, *Trogontherium cuvieri*, *Oryctolagus cuniculus*, *Microtus (Terricola) subterraneus*, *Ursus spelaeus* and *Dama dama clactoniana* (**tab. 1; fig. 1**). Of these, *U. spelaeus* and *D. d. clactoniana* are unique to this interglacial in Britain, whereas the remaining species are known previously from the interglacials of the »Cromerian Complex«. Most critically, however, none of these 'indicator species' has been recovered from British Pleistocene deposits any later than those of the first post-Anglian interglacial. The Swanscombe MAZ also marks the first appearance in Britain of *Stephanorhinus kirchbergensis*, *Stephanorhinus hemitoechus*, *Megaloceros giganteus*, *Bos primigenius* and *Equus hydruntinus*. *Crocuta crocuta* is entirely absent and remains of *Arvicola terrestris cantiana* from the Swanscombe MAZ have mean SDQ values of 140 (Schreve 2001a; Ashton et al. 1998; Preece et al. 2007). The mammalian assemblage from the downstream correlative site at Clacton-on-Sea (Essex/GB), is very similar to that from Swanscombe, since all the species recorded at the former are also known from the latter. Two biostratigraphically significant elements, namely *T. cuvieri* and *D. d. clactoniana*, are present at Clacton, permitting the attribution of this assemblage to the Swanscombe MAZ.

Although there has been some debate concerning the age of the site at Hoxne (Suffolk/GB), the stratotype of the Hoxnian Interglacial in Britain (see Geyh / Müller 2005; 2006; Scourse 2005 for details), detailed comparison of the mammalian assemblages from Swanscombe and Clacton with that from Hoxne clearly indicates that these faunas should all be grouped within the Swanscombe MAZ and that the Hoxnian should consequently be correlated with MIS 11 (Schreve 2000; 2001a). This supports the original observations of West (1956), who described lithostratigraphical continuity from the Anglian glacial till into the interglacial lacustrine beds at Hoxne, together with an unbroken pollen sequence charting the transition from a cold-climate to a temperate flora. Furthermore, amino-acid racemization measurements reported by Bowen et al. (1989), which had originally placed Hoxne in a younger interglacial, correlated with MIS 9, have now been completely revised using new, more rigorous preparative and analytical protocols (Penkman et al. 2008; Penkman 2010). This method has consistently demonstrated clear separation of the ratios from calcitic opercula of *Bithynia tentaculata* from a range of MIS 11 and 9 sites in Britain and has corroborated the immediately post-Anglian age of Hoxne (Penkman et al. 2008; Ashton et al. 2008).

As explained above, not all of the mammalian species found in the Swanscombe MAZ will be of equal significance for continental European mammalian biostratigraphy, since their chronological ranges may be different on the mainland. Nevertheless, it is clear that there is very close correspondence between the species list from the Reinsdorf interglacial and that from the Swanscombe MAZ, with all of the species from the former noted in the latter (see **table 1** for a summary of the key taxa of biostratigraphical significance). Comparisons may also be made with the mammalian assemblages from the celebrated travertine site at Bilzingsleben II in the Wipper valley and the site of Steinheim an der Murr (Lkr. Ludwigsburg/D) in the Neckar (**tab. 1**).

In addition, there are further interesting parallels to be drawn in terms of faunal succession within this interglacial. Evidence for climatic complexity in MIS 11 is widely accepted in various proxy records, with at least two major temperate substages represented, separated by evidence for cold-climate conditions (e.g. Bassinot et al. 1994; EPICA Community Members 2004; Desprat et al. 2005). The records indicate rapid and sustained warming at c. 425 ka, at the onset of MIS 11, with a period of relative climatic stability until c. 390 ka, followed by a succession of more minor warm and cold oscillations until around 360 ka, after

which there is a period of pronounced climatic deterioration into MIS 10. These smaller-scale fluctuations have been detected in long pollen records across Europe, for example Tenaghi Philippon (Macedonia, Greece) (Tzedakis et al. 1997 2001, 2006), Osówka (Mazovia Province, Poland) (Nitychoruk et al. 2005), the Velay maar sites of Praclaux, Le Bouchet and Ribains (Haute Loire, France) (Reille / de Beaulieu 1995) and in the marine core MD01-2447 from the north-west coast of Portugal (Desprat et al. 2005). Although the records are not as complete as from the aforementioned long pollen sequences, in Britain there is now a substantial body of evidence to support climatic variability at the oxygen isotope substage level in terrestrial deposits of MIS 11 (Schreve 2001b; Ashton et al. 2008).

Fig. 2 Structure and sub-division of MIS 11. Isotope substages after Tzedakis et al. 2001, SPECMAP stack, Imbrie et al. 1984, MD900963, Bassinot et al. 1994.

The entire Swanscombe sequence was deposited by the Thames during a single interglacial. Within this, five small-scale intra-stage climatic oscillations have been identified, including three separate temperate phases, separated by breaks in deposition and/or lithological evidence for cold climate conditions (Schreve 2001b). During the first break in deposition, there is multi-proxy evidence that sea level fell sufficiently to permit re-connection to the European mainland. Mammalian assemblages from above and below this break differ considerably in terms of their inferred palaeoenvironment. Those from the early part of the interglacial (Phase I), tentatively assigned to MIS 11c (see **fig. 2**), are characterized by fully temperate climatic conditions (as warm as Britain at the present day), with the development of mixed or deciduous woodland and open grassland. An obligate woodland indicator, in the form of the large subspecies of fallow deer, *D. d. clactoniana*, is the dominant taxon during this part of the interglacial (up to 33% of the assemblage in some beds, from a total number of over 1600 specimens at the site; Schreve 1997). Following reconnection to the continent and a period of confluence between the Thames and Rhine, evidenced by the immigration of an exotic molluscan suite, many species of which today have central European distributions, a rather different set of mammals characterizes the deposits of Phase II. At this point, although climatic conditions remain temperate, there is a dramatic decrease in woodland indicators such as the fallow deer (only 5% of the assemblage from the combined beds of Phase II) and an increase in open grassland inhabitants, such as *Equus* sp. (never more than 3% of the assemblage from Phase I, rising to over 13% in some beds of Phase II). An unusual occurrence of *Lemmus lemmus* or *Myopus schisticolor* also appears in the faunal record at this time, together with an increase in the numbers of grassland voles of the genus *Microtus*.

In addition, the Phase II deposits witness a dramatic change in the archaeological record, with the replacement of Clactonian (non-handaxe) technology, seen in the Phase I deposits, by Acheulean (handaxe) assemblages. White / Schreve (2000) attributed this change to the immigration of handaxe-making peoples from France, Spain or Italy, made possible by the reconnection to the continent that marks the Phase I to Phase II transition. Since it cannot be confidently ascertained whether the period of continental reconnection was in response to a period of lowered sea level (and cold-climate conditions) or due to glacio-isostasy (Schreve 2001b), the Phase II deposits may represent either the same isotopic substage as Phase I (MIS 11c?) or the younger substage (MIS 11a) indicated in the SPECMAP stack (Imbrie et al. 1984) (**fig. 2**). The Phase II de-
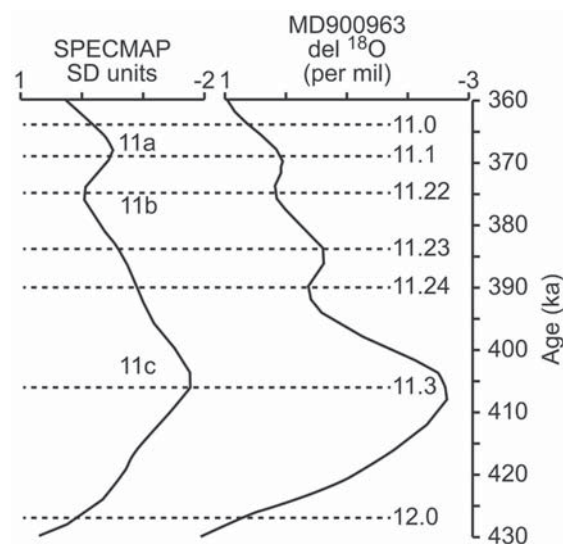
posits are followed by a cold episode reflected by ice-wedge casts, micro-faulting and cryoturbation structures (Phase IIIb) before a return to temperate conditions, as indicated by an interglacial pollen assemblage (Hubbard 1982), although the faunal characteristics of this phase are unknown because the deposits are decalcified (Schreve 2001b).

The sequence at Hoxne is similarly characterized by two warm phases, separated by evidence of climatic deterioration (the »Arctic Bed« of West 1956). The mammalian fauna of the early temperate phase is poorly-known, since few specimens have been recovered from the lake beds, although those that are present – *E. (P.) antiquus* and *T. cuvieri*, are exclusive to periods of temperate climate in association with the development of woodland during the Pleistocene. However, the upper part of the sequence (Bed 4/ Stratum C of Singer et al. 1993 and Stratum B of Ashton et al. 2008) is characterised by a very similar mammalian assemblage to that seen in the Phase II deposits at Swanscombe. Taxa consistent with warm conditions are still present but the assemblage is dominated by *Equus* sp. (over 38% of the total number of identified specimens from the site; Schreve 1997), with the significant additions of *L. lemmus* or *M. schisticolor* and boreal taxa such as *Felis* cf. *lynx* (Schreve 2000). The archaeology from the upper part of the sequence at Hoxne is characterised by a rich handaxe assemblage, again pointing to a later part of the interglacial (White / Schreve 2000). Ashton et al. (2008) tentatively correlated these two temperate phases with MIS 11c and 11a respectively, or with isotopic event 11.3 and 11.23/11.1 of Bassinot et al. (1994) (**fig. 2**). The intervening cold episode is accordingly correlated with MIS 11b and may equate to either event 11.24 or 11.22 of Bassinot et al. (1994) (**fig. 2**).

Figure 3 proposes correlations between Swanscombe and Hoxne and two further British sites, Barnham (Ashton et al. 1998) and Beeches Pit (Preece et al. 2006; 2007), both in Suffolk. The key transition in the mammalian record, from woodland to more open-ground assemblages, is paralleled by similar trends within the molluscan record, with assemblages in which *Discus ruderatus* is dominant being replaced by assemblages dominated by *Discus rotundatus* (Preece et al. 2007). Again, the same patterns are present of Clactonian assemblages appearing at an early stage in the interglacial and being replaced by Acheulean assemblages later on.

Examination of the mammalian assemblages from the various levels of the Reinsdorf interglacial reveals some striking parallels with the British MIS 11 sequences, in particular with Phase II at Swanscombe and Stratum B at Hoxne. While there is no doubt that the prevailing climate was still temperate, on account of the persistence of obligate woodland species, there is clear evidence from the mammals of a more open landscape with the development of boreal vegetation, highlighted by the predominance of horse (Thieme 1997) and the presence of lemming (van Kolfschoten 1993). This is supported by the palynological data, which indicate a boreal forest dominated by *Pinus*, with some *Picea*, *Betula* and *Larix* (Urban 2007), and of course by the famous Schöningen spears (made from *Picea*) in Level 4 and the worked branches of *Abies* from Level 1 (Thieme 1997). At the Polish MIS 11 site of Osówka, the later part of the interglacial sequence is equally characterized by a series of climatic oscillations with open, cold vegetation alternating with the development of boreal forest dominated by *Pinus*. Although the prevalence of boreal forest during a temperate episode may seem curious, it is not uncommon in interstadials in northern Europe, eg. MIS 5c and 5a (Behre 1989; Turner 1998), in clear contrast to the presence of deciduous forest further south in France (eg. Woillard 1978). The biogeographical reasons for this difference are not fully understood, although Turner (1998) proposed that either the phases were too short to permit the immigration of thermophilous trees, or that a climatic barrier restricted the spread of deciduous woodland to the north. There is no evidence that MIS 11 was substantially warmer than the Holocene (McManus et al. 1999; Candy 2009) but the climate in northwestern Europe may have been more continental, allowing the coexistence of warm summer temperatures and the development of boreal forest. The Reinsdorf interglacial sequence is incom-
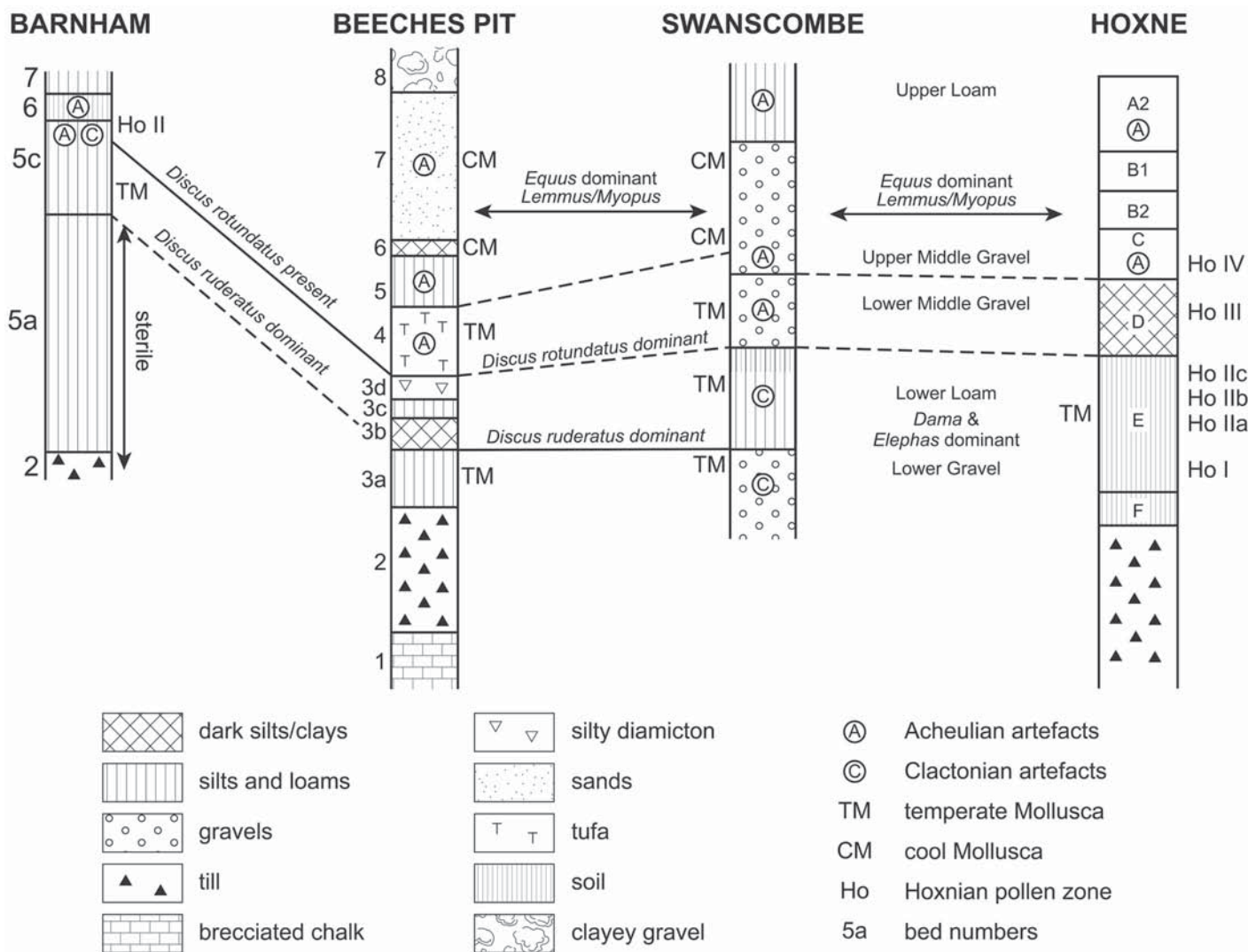
Fig. 3 Suggested correlations between critical horizons at the MIS 11 sites of Beeches Pit, Barnham, Swanscombe and Hoxne with the substages of the Hoxnian Interglacial and key molluscan and mammalian features indicated. – (Modified from Preece et al. 2006).

plete but the first temperate phase indicated in MIS 11 (MIS 11c) may be at least partially represented by the mixed oak forest spectra of pollen zone R1, at sites 13A and 13B (Urban 1995). It would therefore not be unexpected for the Reinsdorf interglacial pollen sequences to display some differences to the type Hoxnian pollen record, since the representative parts are not identical.

COMPARISONS BETWEEN THE REINSDORF INTERGLACIAL MAMMALS AND THOSE FROM THE ANTEPENULTIMATE INTERGLACIAL (MIS 9)

The above evidence would appear to offer strong support to the earlier claims (eg. Mania 1995; Thieme 1997) for an age for the Reinsdorf interglacial of around 400 000 years old. However, a possible correlation with a part or parts of MIS 9 must also be considered. Part of the problem stems from the lack of well-dated MIS 9 mammalian assemblages from Germany, since this hinders potential comparisons between

sites. As yet, therefore, a post-MIS 11 age cannot be unequivocally ruled out on the basis of the mammals from the Reinsdorf interglacial.

Nevertheless, there are two important observations that may have a bearing on the likelihood, or otherwise, of an age within MIS 9. The first is that there are clear differences between the inferred palaeotemperatures of MIS 11 and MIS 9. As with MIS 11, there is evidence of climatic complexity in MIS 9, with three temperate substages separated by evidence for colder conditions (Imbrie et al. 1984). Of these, the oldest (MIS 9e) is the warmest. However, in contrast to MIS 11, percentages of thermophilous tree pollen remain high throughout the entirety of the stage and, at Tenaghi Philippon, they are higher than for any other interglacial (Tzedakis et al. 2004). Whereas there is no evidence that MIS 11 was any warmer than the Holocene (see above), support for warmer conditions during MIS 9 in Britain has come from the coleopteran remains from a range of sites. Beetle assemblages from these sites include a number of exotic southern European species, many of which are only otherwise found during the Last Interglacial (MIS 5e) (Coope 2010). Mean summer temperatures using the Mutual Climatic Range method have been calculated between 17-26°C at Barling, Essex (Bridgland et al. 2001), and around 19°C at Hackney in north London (Green et al. 2006) and Cudmore Grove, also in Essex (Roe et al. 2009). These figures suggest that July temperatures during MIS 9 in Britain were, on average, at least three degrees centigrade warmer than at the present day. This would appear at odds with the evidence from the Reinsdorf interglacial, where there is no suggestion of elevated temperatures.

The second point is more tenuous but relates to the composition of the mammalian fauna during MIS 9. In Britain, MIS 9 mammalian assemblages have been attributed to the Purfleet MAZ and are clearly separable from those of the preceding interglacial on a number of important biostratigraphical grounds; the reader is referred to **table 1** and to Schreve (2001a) for further details. As explained above, a considerable difficulty is the lack of well-dated MIS 9 sites in Germany with which to compare the British assemblages. However, a significant feature of the British MIS 9 fauna is the first appearance of brown bear, *Ursus arctos*, and the reappearance (for the first time since the early Middle Pleistocene) of spotted hyaena, *Crocuta crocuta*. In order to have reached Britain, these animals must have dispersed from the European mainland and might therefore reasonably be expected in the Reinsdorf assemblage. Although carnivores are relatively rare components in the fossil record and this constitutes negative evidence, it is perhaps surprising that neither species has been recognised within the extremely large faunal assemblages from the Reinsdorf interglacial deposits. Furthermore, no evidence of the highly diagnostic gnawing of *Crocuta* has been witnessed on a single one of the Reinsdorf bones (Voormolen 2008); again this is perhaps surprising given the amount of food refuse remaining at the butchery site and may indicate a genuine absence of hyaena in the landscape at this time.

CONCLUSIONS

In summary, the mammalian assemblage from the Reinsdorf interglacial at Schöningen appears to fit best with the later part of the MIS 11 (Hoxnian) Interglacial in Britain. There is clear evidence within the Reinsdorf interglacial of considerable climatic complexity, with an early thermal optimum followed by two more muted interstadials. The pollen data reveal that the interglacial sequence is incomplete, since the profiles begin mid-way through a period of mixed oak forest development thought to represent the climatic optimum. The mammalian assemblages (from sites 12B and 13II-4) post-date this phase, reflecting later parts of the interglacial and providing a contrasting picture of open grassland and boreal forest. Strong

parallels exist with British sites such as Swanscombe and Hoxne, most notably with the later phases of these interglacials where temperate deciduous woodland mammalian and molluscan assemblages have given way to faunas typical of grassland and boreal forest. In particular, the dominance of horse and the unusual occurrence of lemming in association with temperate-climate conditions are considered here to be significant points of comparison. Although an age within MIS 9 cannot be definitively ruled out at this stage, there appear to be clear palaeoclimatic and palaeoenvironmental differences between the Reinsdorf interglacial and widespread evidence for prevailing conditions during MIS 9 from across Europe. Not only is MIS 9 characterised by higher mean summer temperatures than MIS 11 (which appears no warmer than the Holocene), it is also differentiated by the consistently high proportion of thermophilous tree pollen even in the late substages of the interglacial. Further differences may be apparent in the mammalian record although the paucity of well-dated assemblages of post-MIS 11, pre-MIS 5e age in Germany makes this harder to establish at this stage. A possible reason for this may be because successive interglacials have given rise to rather similar sequences of vegetational development, which make some temperate episodes difficult to recognise. The later parts of the MIS 11 interglacial sequences in Britain have been tentatively attributed to MIS 11a and a similar age for the Reinsdorf mammal assemblages is therefore proposed here.

ACKNOWLEDGEMENTS

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ZUSAMMENFASSUNG / ABSTRACT

Das Reinsdorf-Interglazial in seinem europäischen Kontext

Das Alter der warmzeitlichen Ablagerungen der Rinne II in Schöningen (Lkr. Helmstedt) ist in den letzten Jahren intensiv diskutiert worden, wobei die Autoren unterschiedliche Altersstellungen innerhalb des Mittelpleistozäns annahmen. In diesem Beitrag wird die Wirbeltiergemeinschaft des Reinsdorf-Interglazials untersucht, wie sie sich im Rahmen der gegenwärtigen Kenntnisse der klimatostratigraphischen Verflechtungen und des Wandels der Säugetierfauna in NW-Europa darstellt. In Großbritannien wurden in den fluviatilen Ablagerungen der unteren Themse vier Interglaziale zuverlässig unterschieden, die mit den marinen Isotopenstadien 11, 9, 7 und 5e korreliert werden können und durch eine Vielfalt an stratigraphischen, biostratigraphischen und geochronologischen Daten unterstützt werden. Jedes dieser Interglaziale ist gekennzeichnet durch eine deutlich eigenständige Säugetiergemeinschaft, die zur Korrelation mit anderen Fundplätzen genutzt werden kann. Ein Vergleich von britischen und deutschen Tierknochenfunden aus dem Mittelpleistozän zeigt gute Vergleichbarkeit, wobei die beste Übereinstimmung der Faunengemeinschaft aus der »Rinne II« mit dem jüngeren Bereich des Hoxnian-Interstadials (MIS 11) in Großbritannien besteht.

The Reinsdorf interglacial (Schöningen II) mammalian assemblage in its European context

The age of the temperate climate sediments represented in Channel II at Schöningen (Lkr. Helmstedt/D) has been the subject of extensive debate, with various ages within the late Middle Pleistocene age advanced by different authors. The vertebrate assemblage from the Reinsdorf interglacial is discussed here within the context of current knowledge of climatostratigraphic complexity and mammalian faunal turnover in NW Europe. In Britain, four interglacials can be confidently recognised in the fluvial record of the lower Thames, correlated with Stages 11, 9, 7 and 5e of the marine oxygen isotope record and underpinned by a multiproxy range of stratigraphical, biostratigraphical and geochronological data. Each of these interglacial episodes is characterised by a highly distinctive mammalian assemblage that can then be used for correlation with other localities. Comparison of British and German faunal records from the late Middle Pleistocene indicates close correspondence, with the best match for the Channel II assemblage proposed as the late interstadial of the MIS 11 (Hoxnian) Interglacial in Britain.