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Late Pleistocene temperate deposits in Lincolnshire, England and their implication for the history of the River Trent system

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Abstract. This article examines the interpretation and implications of Ipswichian (Eemian) Stage temperate deposits discovered by the British Geological Survey east of the Lincoln Gap in eastern England. The fluvial deposits underlie the Southrey Terrace at Coronation Farm, Southrey and The Hermitage, Stainfield in the River Witham valley. Previously unpublished palynological analyses indicate that the temperate deposits compliment published pollen, mollusc and coleopteran assemblages from the same localities. The deposit at Southrey represents Ipswichian (=Eemian) substages Ip IIb and III, whilst that at Stainfield represents the Ip IIb Substage. The combined sequences are compared to those at neighbouring localities in the Witham and Bain-tributary valleys at Tattershall Castle and Tattershall Thorpe. The implications of the correlation of the interglacial deposits provide a re-evaluation of the River Trent-Witham terrace sequence, demonstrating that the Southrey Terrace deposits are not the equivalent of the Late Wolstonian (=Saalian) Balderton Member, but the Middle Devensian (=Weichselian) Substage Fulbeck Member, upstream of Lincoln. This implies that the River Trent was potentially aligned northwards towards the Humber before the Ipswichian Stage interglacial. The revised correlation indicates that glaciation of the region did not occur in the Middle Wolstonian (MIS 8) but during the Late Wolstonian (MIS 6) Substage.

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short title: Late Pleistocene deposits in Lincolnshire.

1. Introduction

The Middle to Late Pleistocene geology of the Lincolnshire river system of eastern England has been the subject of a number of recent investigations (Fig. 1). In particular the remapping of the area by the British Geological Survey (BGS) officers in the 1980s initiated a re-evaluation of the sequence of deposits associated with the River Trent and associated streams in the Lincolnshire region. The deposits are assigned to the Trent-Witham Subgroup (McMillan et al., 2011), those upstream of the Lincoln Gap to the Trent Valley Formation (Bowen, 1999; Brandon and Sumbler, unpublished report), those downstream of the city to the Witham Valley Formation (Berridge et al., 1999), and those in the Bain valley to the Bain Valley Formation (Brandon and Sumbler, unpublished report), individual terrace deposits being assigned member status (according to McMillan et al., 2011, and the BGS Lexicon of Named Rock Units: https://www.bgs.ac.uk/lexicon/home.html and references therein). Note that this scheme differs from that applied by Bridgland et al. (2014). This article presents the results of previously unpublished palynological investigations from two sites in the terrace deposits of the Witham Valley and their implications for the evolution of the Rivers Trent and Witham during the Late Pleistocene.

2. History of the Rivers Trent and Witham

The history of the River Trent and its associated streams is complicated, its Middle and Late Pleistocene history being related to glacial diversions and subsequent captures. The River Witham, represents a potential remnant of the Trent related to the river's course through the Lincoln Gap (Swinnerton, 1937; Straw, 1963, 1983, 2000, 2005; White et al., 2010; Bridgland et al., 2014; 2015). Crofts (1982) and Jackson (1982) demonstrated that a discontinuous spread of gravel and sand can be traced parallel to the present course of the River Witham. The modern Trent deviates from the Witham's course, before it passed through the gap at Lincoln. Instead it appears to have flowed northwards towards the Humber (e.g. Straw and Clayton, 1979; White et al., 2010; Bridgland et al., 2014, 2015). This course has been assumed to have been initiated following Late Pleistocene (Devensian Stage = Weichselian Stage) regional deglaciation during which substantial proglacial lake developed in the Vale of York and into which the Trent flowed potentially forming a delta. Previously the Trent appears to have passed through the gap at Lincoln, an interpretation based on the distribution of the Balderton Member, the substantial cold-climate fluvial accumulation that today forms the interfluve between the Trent and the Witham rivers (Figs 1 and 2). According to Brandon and Sumbler (1988) this unit is of Late Wolstonian (=Late Saalian) age, more specifically dating from the Pershore Stadial = Warthe Stadial (S. Gibson, 2019) following the deglaciation of the region (Gibbard et al., 2019) (Table 1).

More recently, White et al. (2010) and Bridgland et al. (2014, 2015) have undertaken a substantial re-examination of the River Trent system evolution, which has both relied upon and reinforced the interpretations presented by Brandon and Sumbler (1988). In particular, they accept the concept that the Fulbeck and Scarle terraces (of the Witham and Trent respectively), and therefore their underlying gravel and sand sequence, were aligned through the Lincoln Gap and continued downstream along the present valley of the River Witham (Table 1).

The course represented by the latest Trent Floodplain Member deposits was initiated by capture of the river during glaciolacustrine phase in the Vale of York, dammed by Devensian ice from the north. According to Brandon and Sumbler (1988), the Fulbeck Member was considered to be the Witham-equivalent of the Trent 'Floodplain' unit of Clayton (1953), Gozzard (1975) and Jackson (1977). These deposits are of Devensian age, according to Poznansky (1960), Brandon and Sumbler (1988), White et al. (2010) and Bridgland et al. (2014, 2015).

Of particular importance to these conclusions from the stratigraphical aspect were the finds of mammalian materials in the Fulbeck deposits in the Trent valley, upstream of Lincoln, east-southeast of Newark. These finds were reported by Brandon and Sumbler (1988) and include an assemblage with remains of *Hippopotamus amphibius* Linnaeus, 1758 and *Palaeoloxodon antiquus* (Falconer & Cutley, 1847), considered typical of the Ipswichian temperate Stage (=Eemian Stage, ~ Marine Isotope Substage (MIS) 5e) (Stuart, 1982).

According to Brandon and Sumbler (1988), these mammaliferous deposits comprise stratified sand and gravels that infill a shallow channel resting on Liassic (Jurassic) mudstone bedrock. These deposits underlie a terrace surface – the Fulbeck Member Terrace – that can be traced for some 20 km parallel to the River Witham from Hougham to Aubourn, upstream, south-west of Lincoln (Fig. 2). These deposits range from *c*.1.5 – 3 m in thickness and grade downstream 1.1.km^{-1}. They were interpreted by Brandon and Sumbler (1988, p.127) as "a forerunner of the Witham". These authors note that the fossil remains were all derived from the basal gravels from four localities, Stubton Gorse Pond (National Grid Reference (NGR): SK 889 496), Stubton Moor Farm (NGR: SK 885 487), Fulbeck Airfield (NGR: SK 891 508) and Little Skye (NGR: SK 896 538) (Fig. 1). Additional localities in this unit including organic material are mentioned by White et al. (2010) and Bridgland et al. (2014, 2015), in particular that at Norton Bottoms (NGR: SK 863 588) (Table 1).

Downstream of the Lincoln Gap the discovery of fossiliferous, organic clay and silt deposits underlying gravel and sand, was first reported from two boreholes by Jackson (1982) during the BGS survey. Brandon and Sumbler (1988) state that the gravel and sand unit (underlying the terrace surface) overlies the Wragby Till Member in the immediate area, although the organic silty clays rest on Jurassic bedrock in the boreholes; the glacial diamicton being regarded as of Wolstonian age both by these and other authors (e.g. Straw, 1963, 1983, 2000, 2005; White et al., 2010, 2017; Bridgland et al., 2014, 2015). The Wragby Till Member (Table 1) was equated by Straw (1983, 2000, 2010); Bridgland et al. (2014); White et al. (2016) to ~MIS 8 (i.e. the Middle Wolstonian Substage), but correlated by Gibbard et al. (2018 and references therein) to Late Wolstonian Substage (MIS 6). At the request of the BGS, samples from the two boreholes in the Southrey Terrace, TF 16 NE 19 at Coronation Farm, Southrey and TF 17 SW 34 at The Hermitage, Stainfield, were investigated by one of the authors (SMP) for their palynological assemblages in 1980, subsequent to initial analyses by Dr A. Bonny (AB, *cf*. below).

The deposits underlying the Southrey Terrace (Southrey Member: mapped as 'Terrace 2' by BGS) have been repeatedly referred to in publications on the fluvial history of the region (e.g. Brandon and Sumbler, 1988; White et al., 2010; Bridgland et al., 2014, 2015), yet despite these authors discussing the presumed Late Wolstonian (MIS 7) age of these sequences (Table 1), none of these reports have presented full details of the palaeontological evidence available. Analyses from Coronation Farm and The Hermitage sites were undertaken over 30 years ago, the samples and the potential results of the analyses of other fossil groups (Coleoptera, Mollusca, pollen) were previously published (Bridgland et al., 2014). Further palynological analyses and their biostratigraphical implications are presented here, together with summarises of related evidence and their wider implications.

3. Palaeontology

3.1. Palynology

The samples supplied to SMP by Drs A. Brandon and I. Jackson (BGS) were prepared throughout using the standard technique used in the Subdepartment of Quaternary Research, University of Cambridge (West, 1968), including the use of sodium pyrophosphate (Bates, Coxon and Gibbard, 1978). The results of the analyses are presented in the pollen percentage diagrams (Figs 3 and 4) using the program TILIA (Grimm, 2004), the calculation sum being total determinable land pollen and spores. Taxa with <1% are shown as pluses on the diagrams. Pollen identification conventions follow Andrew (1970) together with some types listed in Birks (1973).

3.1.1. Coronation Farm, Southrey

Previous palynological analyses at this site were initially carried out by AB from what is stated to be a neighbouring borehole TF 16 NE 22B: NGR: TF 1535 6682 (according to Bridgland et al., 2014, p. 214) where the sequence was 400 cm thick (the ground surface is at 4.8 m OD). However, the borehole they quote is not sited at Southrey, but at Poolham Ings (NGR TF1977 6687) 4.32 km from the former locality (according to the BGS website: http://mapapps.bgs.ac.uk/geologyofbritain/home.html). At the latter, the borehole records only 0.9 m of gravel and sand resting on Ancholme Clay bedrock (the ground surface is at 6.2 m OD). This reference to the latter borehole is incorrect and it is therefore difficult to locate the sequence analysed by AB (unpublished report 1981, personal communication; reproduced in Bridgland et al., 2014, fig. 3.10). This is unfortunate since the sequence was thicker in borehole TF 16 NE 22B (*c*. 4.0 m). However, this confused location justifies the investigation of the accurately sited sequence investigated by SMP, reported here.

The lithology of the Coronation Farm, Campney Lane, Southrey BGS borehole (TF 16 NE19: NGR: TF 1535 6682) is as follows:

Ground surface : 5.7 m OD
0 - 4.6 Yellow brown pebbly sand and gravel.
4.6 - 5.0 Olive grey mottled brown clay with occasional pebbles.
5.0 - 6.8 Olive grey clay and silt containing abundant plant fragments; becoming silty and then sandy towards the base.
6.8 - 7.0 Very sandy and pebbly clay with some organic debris.
Bedrock (Jurassic Ancholme Clay)

The sequence appears to represent a broadly fining upwards profile and potentially includes an hiatus at *c*. 5.0 m, based on the sediment description and lack of pollen preserved in these possibly partially oxidised sediments (cf. below). The overlying upper 4.6 m rest on the clays beneath with a sharp, unconformable junction.

Eleven samples collected by Dr I. Jackson at 20 cm intervals were analysed by SMP in 1980 from the olive grey silty clay and overlying pebbly clay (BGS reference nos MPA 8845-8855). Pollen was not abundant in the sediment, so that 150-200 grains per sample could be counted. The pollen and spores were generally poorly preserved in all the samples. Samples 480 cm (from the pebbly clay), 500 cm and 600 cm contained few palynomorphs and were therefore not counted.

The occurrence of temperate tree taxa demonstrate that this sequence represents interglacial temperate environmental conditions. On the basis of the high frequencies of *Carpinus* pollen, the absence of *Abies*, and the record of low frequencies of *Picea* pollen, the deposit is attributed to the Ipswichian temperate Stage (cf. Phillips, 1974; West, 1980), as reported by Brandon and Sumbler (1988), but see below.

The pollen diagram can be divided into two pollen assemblage biozones (Fig. 3):

(1) Samples 520-580 cm with high frequencies of *Carpinus*, and lower values of *Corylus* and Cyperceae pollen.
(2) Samples 620-680 cm with high values of *Corylus*, Cyperaceae and *Quercus* pollen.
The boundary is drawn at 600 cm where the values of *Carpinus* first exceed and remain higher than those of *Quercus*. This definition is that of the boundary between substages Ip IIb and III as defined by West (1977, 1980).

The pollen assemblages are indicative of mixed-oak forest with the *Quercus* percentage being exceeded by that of *Carpinus*. However, as well as the forest, the high frequencies of *Corylus* pollen (particularly in Substage III) suggest the presence of hazel scrubs (Sparks and West, 1970). The high values for land pollen and spores show that there were large areas of open vegetation with grasses, *Rumex*, Asteraceae (Lactuceae), *Plantago*, *Artemisia* and other herbs potentially colonising the drier areas of a river floodplain. Such conditions are also found at Ipswichian sites elsewhere, e.g. Chatteris (West et al., 1995), Aveley (West, 1969) and Histon Road (Sparks and West, 1959). Around the site wetter-ground vegetation is indicated by the presence of aquatic plants, such as *Sparganium*-type, *Sagittaria* and *Alisma*, and taxa of fen and fen carr as *Salix*, Cyperaceae, *Equisetum*, *Filipendula* and *Thelypteris palustris*. Reworked palynomorphs, an index of local sediment recycling, occur throughout the sequence, as indicated by the curve for pre-Quaternary types. These results compare favourably with those obtained by AB in her initial investigation (*cf.* Bridgland et al., 2014).

3.1.2. The Hermitage, Stainfield

Nine samples were analysed from the BGS borehole TF 17 SW 34 (NGR: TF 1063 7191) at The Hermitage, Stainfield.

Ground surface: 5.3 m OD
0 – 5.2 Pebbly sand and coarse gravel.
5.2 – 6.8 Olive grey silty clay with carbonaceous lenses with flint pebbles at the base.
6.8 – 11.1 Bluish grey clay with olive brown patches, sandy at the base.
11.1 – 12.20 Olive grey clayey silt, passing into silt at 8.0 m with gastropod shells, wood fragments and plant debris.
Bedrock (Jurassic Ancholme Clay).

The sequence recorded in this borehole represents a generally fining upwards profile, again including a sharp break at 6.8 m. Unconformably overlying the silty clay are 5.2 m of coarse gravels and sand.

Nine samples from this locality were analysed by SMP in 1980 from the olive grey silty clayey silts and overlying silty clay (Fig. 4). Of the samples examined countable pollen and spores were only recovered from 7.60 - 9.48 m, the counts ranging from 453 to 172 per slide. The palynomorphs were generally poorly preserved throughout.

The pollen diagram (Fig. 4) represents a single pollen assemblage biozone. The analyses from this borehole are dominated throughout by mixed-oak forest tree taxa, again confirming that the sequence accumulated during a temperate, interglacial period. The occurrence of *Pinus*, *Quercus* and *Alnus* pollen, together with that of other temperate tree pollen, including particularly *Acer*, *Fraxinus*, *Ulmus*, *Tilia* and

Corylus pollen confirm the occurrence of diverse temperate woodland in the immediate vicinity of the site. Accompanying these are low frequencies of coniferous *Picea* and *Taxus* pollen, but *Carpinus* is notably absent. The temperate nature of the local climate is supported by the pollen of frost-sensitive taxa *Hedera* and *Ilex*. The remaining taxa, including Poaceae, Cyperceae and herb taxa indicate the occurrence of local open grassland areas on partially disturbed ground. The overall sequence can be interpreted as a channel-like depression filling in a river floodplain setting, as at the Coronation Farm locality. The record of potentially pre-Quaternary type coniferous (e.g. *Abies*, *Picea* type) pollen suggests the reworking of older pollen types into the host sediments.

Taking the assemblage from these sediments as a whole, indicates once again that the unit accumulated during the Ipswichian temperate Stage (cf. Phillips, 1974; West, 1980), during Substage Ip IIb (as reported to Brandon and Sumbler, 1988, p. 132, by SMP in 1980), based on the representation and characteristic proportions of the tree pollen taxa. Commenting on this conclusion, Brandon and Sumbler (1988, p. 132) state "since it underlies pre-lpswichian gravels, the most likely possibility is that it is of intra-Wolstonian date, possibly oxygen isotope stage [Marine Isotope Stage] 7". They continue that the exploratory pollen analyses from this sequence undertaken by AB (unpublished 1981, personal communication; reproduced in Bridgland et al., 2014, fig. 3.11), who stated that they "indicate Zone II of the Hoxnian or (less probably) of the lpswichian Stage", the spectra closely matching those presented here. This statement is presented without further justification and it is unclear on what biostratigraphical evidence this Hoxnian attribution is based, other than the assumed age of the overlying gravel and sand unit, unless it is the occurrence of the potentially reworked conifer pollen. However, in view of the more detailed analyses presented here, a pre-Ipswichian correlation is considered unjustified, as also supported by the stratigraphy.

3.2. Insects and mollusc assemblages

The insect and mollusc assemblages from Coronation Farm, Southrey are reported in Bridgland et al. (2014). The former determined by G.R. Coope comprise a fully temperate fauna similar to those today in the area, dominated by *Quercus* woodland. The Mollusca (identified by R.C. Preece) comprise mainly fragmented shells of predominantly aquatic taxa, which includes (in his words) *Mercuria confusa (i.e. Mercuria simili*s Draparnaud, 1805) a taxon which is restricted to emergent vegetation in nearly freshwater in river estuaries, and was abundant in the Tattershall Castle interglacial deposits (cf. below). The only terrestrial mollusc was *Vertigo antivertigo* (Draparnaud, 1801) a wetland species that favours marshes and fens. Fragmentary material of *Bithynia tentaculata* (Linnaeus, 1758) provided material from which an amino-acid racemisation analysis gave a ratio suggesting a MIS 7 (i.e. Late Wolstonian age: Penkman, 2007) attribution, a date that conflicts with the remaining evidence from the Southrey locality (*cf*. above). The Mollusca recovered from a single sample from the Stainsfield sequence (9.5 m) are richer in terrestrial taxa, the assemblage indicating a moist, grassland habitat. In neither case are the faunal assemblages stratigraphically significant.

4. Implications for the Witham/Trent rivers' sequence

The results from the Stainsfield and Southrey borehole sequences, presented here, indicate that the deposits underlying the Southrey Terrace ('Terrace 2': Brandon and

Sumbler, 1988) represent an interglacial temperate accumulation in a slow-flowing river channel. They are unconformably overlain by coarse gravels and sands, the latter almost certainly of cold-climate origin, and that potentially accumulated in a braided, or wandering river regime (cf. Gibbard and Lewin, 2002). The two units are separated at both sites by an hiatus of unknown duration. It appears that the two interglacial units represent parts of the same event, i.e. the Late Pleistocene Ipswichian Stage. The overlying predominantly cold-climate deposits must therefore post-date that event. According to Brandon and Sumbler (1988, p. 132) the Southrey interglacial deposits yielded an infinite radiocarbon date (i.e. greater than 48 ka). Amino-acid racemisation analysis of molluscan shells from the Southrey deposit by Penkman (2007) gave a ratio that suggests an age of possibly *c*. 200 ka (~Marine Isotope Stage 7), but determinations by this method frequently conflict with other stratigraphical evidence and therefore must be regarded with caution (cf. Gibbard et al., 2019). Overall therefore the weight of evidence from the palynology of the interglacial deposits suggests that they accumulated during the Ipswichian Stage (Eemian Stage, ~ Marine Isotope Substage [MIS] 5e).

4.1 Comparison with other potentially equivalent sequences in the Witham and Bain catchments: sites at Tattershall Castle and Tattershall Thorpe

Other potentially equivalent interglacial sequences occur in the area of the confluence of the Witham and Bain valleys, downstream of Lincoln at Tattershall Castle and Tattershall Thorpe (also called Kirkby-on-Bain) (Tables 1 and 2). At these localities organic temperate climate channel-fill sediments underlie gravel and sand sediment units (cf. Bridgland et al., 2014; Holyoak and Preece, 1985), the overlying terrace surface, mapped by BGS as 'Terrace 1' at Tattershall Castle, but Terrace 2 at Tattershall Thorpe. Comparison of the palynological sequence from Tattershall Castle demonstrates that it represents the same event as that at Stainsfield and Southrey, i.e. the Ipswichian Stage, this date proposed by Holyoak and Preece (1985) for the Tattershall Castle organic sediments. The Tattershall Castle sequence representing Ip IIb, being dominated by a diverse temperate woodland assemblage, in particular *Quercus*, *Corylus* and *Alnus*, the latter indicating wet woodland, the former presumably colonising drier ground areas, whilst herb pollen and spores were relatively minor constituents of the assemblages suggesting that open ground was relatively rare locally. This compares closely with the sequence at Stainfield. Lastly at Tattershall Castle, a latest Wolstonian open-ground environment, is indicated by deposits underlying the interglacial sediments, according to J. Evans (in Girling, 1974).

Correlation based solely on the palynology with the Tattershall Thorpe channel-fill in the Bain valley sequence is less certain (Fig. 5). Here again tree pollen was dominant with *Quercus*, *Alnus* and *Pinus* the most frequent tree taxa, together with lower frequencies of *Corylus*, *Betula*, *Ulmus* and *Fraxinus*. Holyoak and Preece (1985) correctly concluded that this implied deposition during the early temperate substage (zone II) of an interglacial temperate event (*cf*. Turner and West, 1968; West, 1980). Holyoak and Preece (1985) go on to highlight some differences from the Tattershall Castle spectra, in particular the greater representation of *Pinus*, *Betula*, *Ulmus* and *Fraxinus* pollen, the lower representation of *Corylus*, and the absence of *Taxus* and *Tilia* pollen. Whilst Holyoak and Preece (1985) suggested that the differences could be interpreted to imply a different age from the most likely correlation with Ipswichian Substage IIb, the differences could equally well reflect local, rather than regional vegetational variations, or differences in representation of taxa resulting from differing taphonomic or sedimentary micro-facies conditions. Although the assemblages were thought not to provide sufficient support to either confirm or refute biostratigraphical correlation in isolation with the Ipswichian Stage. Nevertheless there can be little doubt that they are of this age.

Additional pollen spectra from a rhinoceros bone and a clay bed at Tattershall Castle were counted by Dr Linda Phillips (reported by Holyoak and Preece, 1985). They yielded a tree pollen assemblage similar to those in the main sequence, although with a higher frequency of *Carpinus* pollen. The latter suggests this spectrum might represent an interval late in the Ip IIb Substage. Increased *Carpinus* pollen frequencies are characteristic of Ip III of the Ipswichian Stage interglacial, this assemblage comparing favourably with that from the upper biozone at Southrey. Three additional spectra collected from fine-grained sediments overlying the main channel fill contained spectra dominated by *Pinus*, with lower frequencies of *Betula*, *Corylus*, *Alnus*, Poaceae and a few grains of *Picea* and *Carpinus* pollen. These spectra can be correlated with Ipswichian Substage Ip IV. The Mollusca from Tattershall Castle indicate that the sediments were deposited in a slow-flowing stream, which supported plentiful aquatic plants. There is evidence of changes in the rate of flow, but no evidence for rapid flow. Taxa characteristic of fast-flowing rivers are absent (for example, *Corbicula fluminalis* (Müller, 1774)). Holyoak and Preece (1985) recorded *Pseudamnicola confusa* (i.e. *Mercuria similis* Draparnaud, 1805) and *Hydrobia ventrosa* (*Ecrobia ventrosa* Montagu, 1803) taxa indicates mildly brackish conditions, as discussed below.

At Tattershall Castle, although marsh species are well represented throughout much of the sequence, land shells actually outnumber those of freshwater species. The terrestrial Mollusca are derived from a wide variety of habitats including marshes and woodland; species of open country are uncommon, are represented only by *Pupilla muscorum* (Linnæus, 1758) and *Vallonia costata* (O.F. Müller, 1774) (although the latter can live in closed woodland). However, as described above the basal parts of the sequence have faunas characteristic of dry open habitats. The composition of the terrestrial faunas does not differ appreciably in those levels interpreted as being deposited when stream flow was quicker and it appears that the faunas reflect regional conditions or facies changes within the river catchment.

At Tattershall Thorpe, upstream in the Bain valley, the molluscan assemblages upstream differ in several respects from those at Tattershall Castle. Most of the aquatic species reflect a quieter environment than at the latter. Species indicative of large streams are scarce and the brackish indicators, e.g *Pseudamnicola confusa* and *Hydrobia ventrosa* agg. were absent. The terrestrial fauna also differs. Marsh species dominate, and several shade-demanding species are present, *Clausilia pumila* Pfeiffer, 1828, a central European forest species, was unambiguously present and so also was *Trichia* cf. *plebeia (Trochulus plebeius* (Draparnaud, 1805), neither of these having been recorded at Tattershall Castle.

The absence of several species occurring at Tattershall Castle, and the presence at Tattershall Thorpe of others not present at Tattershall Castle is of uncertain importance. However, many species are common to both sites, including some that are not of general occurrence in British Pleistocene interglacial deposits (e.g. *Belgrandia marginata* (Michaud, 1831), *Cochlicopa nitens* (Gallenstein, 1848). The differences between the two sites may reflect local habitat variation or sedimentary facies, although the two sequences do represent different substages within the temperate event and therefore could also reflect environmental change through the interval; the Tattershall Castle sequence being Ip IIb, whilst that at Tattershall

Thorpe is Ip III. A small unstratified sediment sample from the interglacial beds yielded the following Mollusca were obtained from this sample: The presence of *Valvata piscinalis* (Müller, 1774), *Bithynia tentaculata* (Linnaeus, 1758), *Corbicula fluminalis* (Müller, 1774), *Pisidium amnicum* (Müller, 1774), *P. subtruncatum* (Malm, 1855) and *P. henslowanum* (Sheppard, 1823) suggests this deposit represents a different facies, of a substantial body of flowing water, in contrast to the predominance of stagnant-water molluscs in the samples from in the main sequence samples. There is no strong biostratigraphical justification therefore to consider that the two sequences represent different temperate events, i.e. different interglacials.

Therefore whilst the molluscan assemblages in the Tattershall Thorpe interglacial deposits differ in some respects from those from Tattershall Castle, all the pollen spectra can nonetheless be correlated with the Ipswichian Stage. The differences between these two sites may reasonably be attributed to local environmental heterogeneity rather than to a substantial difference in age (Holyoak and Preece, 1985). Moreover, the correlation of the Tattershall interglacial deposits with the Ipswichian (i.e. Eemian) Stage is supported by both Uranium-Series disequilibrium (75-115 ka B.P.), thermoluminescence (114±16 ka B.P.) and amino-acid geochronology, reported by Holyoak and Preece (1985). An additional thermoluminescence age of 148,000+34,000 years BP was obtained by Perkins and Rhodes (1994) from the Tattershall Thorpe temperate deposits. Correlation was not clarified by subsequent amino-acid racemisation analysis which suggested comparison with an MIS 7 temperate event (Penkman, 2007), but since this appears to conflict with the bio- and lithostratigraphy, this dating should be regarded as questionable (see below for further discussion of this correlation).

Evidence of brackish water conditions was apparent in the sections that lie above — 1.8 m OD. The evidence mainly derives from the presence of *Mercuria confusa*, *Hydrobia ventrosa* was present throughout, according to Holyoak and Preece (1985). As these authors note, *M. confusa* is very local in Britain today, being found in places were only slight saline influence, such as at Oulton Broad in Suffolk. At many sites *M. confusa* lives on mud under waterside vegetation that is inundated by fresh or slightly brackish water ponded back by all except low neap tides (Holyoak, 1983). It would appear that the deposits between — 1.8 and — 0.2 m O.D. at Tattershall Castle accumulated in a similar environment, a little above the main brackish influence of spring tides (Fig. 5).

4.2 Upstream of the Lincoln Gap

Upstream of Lincoln, temperate faunal remains, including *Hippopotamus amphibius* and *Palaeoloxodon antiquus*, considered characteristic of the Ipswichian temperate Stage by Brandon and Sumbler (1988) (cf. Stuart, 1982), occur within stratified sand and gravels that infill a shallow channel incised into bedrock. These finds, from the basal sands and gravel of the Fulbeck Member, have been taken to confirm an Ipswichian age of the gravels. This attribution was unquestioned by White et al. (2010) and Bridgland et al. (2014, 2015) in their re-evaluation of the Trent system sequence (Table 1). However, the occurrence of large vertebrate remains, occasionally together with stone tools, in the basal strata of gravel and sand aggradations, often occurring as a 'lag', are known to occur widely throughout southern Britain (Gibbard and Lewin, 2002; Lewin and Gibbard, 2010).

The intermixing of temperate and cold-faunal elements confirms that deposits in this situation cannot be assumed to represent a simple interglacial accumulation, as interpreted by Bridgland et al. (2014, 2015), a similar problem being encountered in the Balderton unit deposits (cf. discussion in Keen, 2001, p. 1658). This interpretation is reinforced by the fact that only large faunal material was recovered. Moreover, it is unlikely that coarse gravel and sand deposits would occur during an interglacial temperate event when fine-grained sedimentation overwhelmingly dominates fluvial deposition in the region (Gibbard and Lewin, 2002). Therefore, by analogy with similar finds from other river systems throughout lowland eastern and southern England, it is probable that the Fulbeck Member gravel and sand is potentially the upstream equivalent of the cold-climate Southrey gravels and sands that overlie the Southrey and Stainfield temperate deposits, rather than the Balderton unit (Fig. 5; Table 2). Moreover, given the occurrence of Ipswichian Interglacial material underlying the cold-climate Southrey gravels and sands, the latter probably accumulated during the Devensian Stage.

More precisely, it is likely that the gravels and sands date from the Early or Middle Devensian substages, which was a major period of gravel and sand accumulation in river valleys throughout lowland England (cf. Gibbard, 1985; van Huissteden et al., 2001; Gibbard and Lewin, 2002; see below). This interpretation contrasts with the apparently older age suggested by Brandon and Sumbler (1988) and restated by Bridgland et al. (2014, 2015).

If the interpretation presented here is correct, then it appears that the River Trent ceased to flow through the Lincoln Gap before the Middle Devensian Substage, indeed it appears that it did not adopt this route even during the post-Late Wolstonian. This is because there is no concrete evidence of deposits equivalent to the Balderton unit downstream of Lincoln; the implication being that the modern course of the Trent might indeed date from the Late Wolstonian, contrary to the views of Bridgland et al. (2014, 2015) and Buckland et al. (2019). This conclusion should be further tested by geochronological investigation, when an opportunity arises.

This Southrey Terrace and its underlying deposits were originally correlated by Brandon and Sumbler (1988) with their Balderton Terrace/Member unit, upstream of the Lincoln Gap, which they concluded dated from the Late Wolstonian, the latter based on the fact that it rested on the Wolstonian-age Wragby Till (Straw and Clayton, 1979) and represented a pre-Ipswichian-Stage event equated to MIS 6 (*contra* Straw 2018; *cf.* discussion in Gibbard et al. 2009). This correlation was accepted by White et al. (2007, 2017), Bridgland et al. (2014, 2015) and unquestioned by Penkman (2007). It is interesting to note that interglacial deposits at the base of the Balderton Member have been reported from Norton Bottoms, near Newark (White et al., 2007; Penkman et al., 2011, 2013; Bridgland et al., 2014, 2015, p. 477), stated as being clearly "of ... MIS 7 age" (further justification of the assumed age of this discovery has not been presented). However, White et al. (2010) and Bridgland et al. (2014, 2015), recognised that the Balderton Member is demonstrably older than the next younger Witham Valley Fulbeck Member (Fig. 5; Table 1), the latter including potentially reworked Ipswichian fossil material, as stated above. Assuming this to be correct, it appears likely that the Southrey gravels and sands should be the downstream equivalent of the Fulbeck Member gravels, based upon their relationships to Ipswichian-age deposits, rather than those of the Balderton Member unit. This indicates that the River Trent was not aligned through the Lincoln Gap into the lower Witham valley by this time, unless the lower part of the higher, Martin Member is the equivalent of the Balderton unit in the lower Witham valley (Straw, 1963; Brandon & Sumbler, in Bowen, 1999). From this it follows that the fossiliferous deposits at Norton Bottom cannot be the same age as those at Southrey and Stainsfield and therefore potentially do represent material dating from a pre-Ipswichian-Stage event, during the Wolstonian Stage, i.e. part of the Late Wolstonian-equivalent MIS 7 interval (the Waverley Wood Temperate Event of Gibbard and West, 2020) or possibly earlier (Table 2).

If this correlation is correct, these results confirm earlier workers' conclusion that the River Witham was aligned through the Lincoln Gap during the Ipswichian Stage, and potentially also immediately before in the latest Wolstonian Substage, when the basal incision and gravel phase would have occurred (Table 2). This alignment would have continued into the Early Devensian Substage, based on the same reasoning as above. The implication for the Trent is that the river might have adopted its northwards course towards the Humber before rather than during the Middle or Late Devensian substages (the latter being the conclusion reached by Straw and Clayton, 1979; Bridgland et al., 2014, 2015). Whilst in the latter case the diversion could have been associated with the development of a substantial glacial lake in the Vale of York formed during the Devensian (e.g. Straw and Clayton, 1979; Murton, 2018; cf. Buckland et al., 2019). However, the fact that the Trent Balderton Member is not represented downstream of the Lincoln Gap implies that the river was aligned towards the Humber already at this time (cf. below; Table 2). The adoption of this north-easterly course by the Trent would presumably reflect events during the Wolstonian deglaciation, such as blockage of the Lincoln Gap by glacial ice. However this hypothesis cannot be tested on the basis of the currently available evidence.

4.3 Downstream of the Lincoln Gap

Downstream correlation of the Southrey Terrace demonstrates that the Tattershall Castle and the Tattershall Thorpe sequence (the latter in the tributary Bain valley), underlie an apparently lower terrace surface, mapped as Terrace 1 by the BGS 1-2 m lower than the Southrey surface (Fig. 5). This occurred intermediate between the Southrey and the modern Floodplain surfaces and is termed the Tattershall Terrace by Bridgland et al. (2014, 2015). This surface has a fan-like surface form and occurs only at the Bain valley confluence with the Witham (Straw and Clayton, 1979). It is underlain by gravels and sands that, in turn, unconformably overlie the interglacial deposits at the Tattershall Castle quarry (Holyoak and Preece, 1985; Bridgland et al. 2014, 2015; Straw, 2018). If the correlations above are correct, the gravel and sand sequence underlying Terrace 1 would be intermediate in age between the Southrey and Floodplain gravel and sand units (underlying the modern floodplain). The latter of Late Devensian age are interpreted by Straw (2018) as relating to outwash from the Late Devensian ice sheet in eastern Lincolnshire. However, plotting the borehole (source: BGS archive) and exposure evidence from the lower Witham and Bain valley spreads, it is clear that the differentiation of Terrace surfaces 1 and 2 is not supported by the underlying geology (Fig. 5). Rather this indicates that the Southrey Gravels and the Tattershall Gravels are the same unit. Moreover, the gravels overlying the Tattershall Castle interglacial sediments are the lateral equivalent of those overlying the Tattershall Thorpe interglacial unit, an observation contrary to that stated by Bridgland et al. (2014). The implication therefore is that there is no discrete gravel and sand member intermediate between the Southrey/Tattershall Members and that underlying the modern floodplains of the Witham system.

Numerical age dating of cold-climate and interstadial silt channel-fill sequences within the Tattershall Gravel Member, overlying the Bain valley interglacial deposits, by Girling (1974, 1977) (C14: 42,000 yr BP: Birm-260) and Holyoak and Preece (1985) (C14: 28-46.3 ka BP) give Middle Devensian ages (~MIS 4-3). Whilst some of these radiocarbon ages, especially those greater than c. 30 ka, might be considered somewhat unreliable, a comparable result was obtained by the thermoluminescence technique of 21,000+8500 yr BP from one sample by Perkins and Rhodes (1994) confirming the view that the Southrey/Tattershall unit is that age, as concluded above. However, dates from the gravels overlying the interglacial deposits at Tattershall Thorpe reported by the latter authors (140 000 and 148 000±34 000 BP) conflict with the geology. Indeed more recent optically stimulated luminescence dates ranging from 156-96 ka (mean age: 122.6 ka) from the underlying interglacial deposits at the same site (Schwenninger et al. 2014) indicate that the older ages reported by Perkins and Rhodes (1994) for the overlying unit are giving a false indication of both the gravels' depositional age. Notably, these recently determined ages confirm the Ipswichian correlation of the temperate sequence. In contrast, the gravels and sands underlying the modern Witham and Bain floodplains are separated by an incisional phase and are therefore of Late Devensian age, potentially, in part, originating as outwash from the local Devensian ice sheet in eastern Lincolnshire, as Straw (2018) concluded (Table 2).

Whilst the interglacial sediments at Southrey and Stainsfield were deposited in a slow flowing, freshwater river-channel environment, minor saline water incursion was indicated at *c*. 0-1 m O.D., at Tattershall Castle at the confluence of the Witham and Bain valleys, as in the Fenland beyond, at Somersham (-3.7 to -0.5 m O.D.), Block Fen (-6.3 to -5.8 m O.D.) and March (-2.5 to 2.4 m O.D.) (West et al., 1994, 1995; Gibbard et al., 2019). The recognition of saline incursion close to present sea-level at these localities further reinforces their correlation with the Ipswichian Stage (~MI Substage 5e), since it is well established that global relative sea-level failed to reach above -15 m O.D. throughout the preceding MIS 7 temperate event, according to Dutton et al. (2009) (cf. Gibbard and West, 2020). The absence of saline indicators at Tattershall Thorpe, Southrey and Stainsfield implies that the brackish-water incursion failed to reach these localities, most likely as a consequence of their greater altitude.

4.4 Glaciation and comparison with the near Continent

The glaciation of Fenland and adjacent regions (Gibbard et al., 2018), which includes the Wragby Till Member and its equivalents (i.e. Late Wolstonian, ~MIS 6, Morton or Tottenhill Stadial [cf. Gibson, 2019], cannot be Middle Wolstonian, ~MIS 8, as previously thought by other authors as discussed above. This implies that the later, slightly revised evolution of the Trent-Witham system in Lincolnshire must post-date this event.

This conclusion also adds further support to the findings that glaciation during the Middle Saalian and equivalents (i.e. *c*. 300 - 245 ka) throughout the NW European region was limited in extent (cf. Hughes et al. 2020). The few deposits that have been attributed to this interval have been based on isolated numerical age determinations, mainly optically stimulated luminescence or amino-acid racemisation analyses of abutting sediments or their contained fossils. The most frequently quoted record is that reported by Beets et al. (2005) who suggested that Middle Saalian-age (i.e. MIS 8) till occurs in the Dutch sector of the North Sea, based on geophysical, micropalaeontological and amino-acid analyses. Whilst a till unit unquestionably occurs at the site (Laban & van der Meer 2004), today Dutch workers question its' correlation to MIS 8, instead attributing the deposit to the Late Saalian (i.e. Late Wolstonian, MIS 6; Cohen 2017 personal communication). Despite similar isolated reports from other circum-North Sea localities, their correlation also remains equivocal. The lack of a regional till sheet and consistent biostratigraphy supports the conclusion that glacial ice failed to extend into the central western European area (Litt et al. 2007, 2008) and the adjacent central and southern North Sea basin (Huuse, personal communication 2017) during this time (Hughes et al. 2020).

5. Conclusions

The results of palynological analyses from two boreholes put down in the 1980s by the British Geological Survey in the River Witham Valley, downstream of Lincoln, Lincolnshire are presented. Both the palynological sequences represent temperate conditions dominated by mixed oak forest trees, accompanied by open herb-dominated areas, confirming an earlier exploratory analysis. The biostratigraphy of the sequences implies that they represent parts of the last, Ipswichian Stage interglacial. This is contrary to an older age (? MIS 7, i.e. Late Wolstonian) assumed by previous investigators and unquestioned more recently. These deposits underlie the Southrey Terrace.

The gravel and sand unit upon which the Southrey Terrace surface is developed can be traced both south-west and east to south-east of the Lincoln Gap (Fig. 5; Table 2). Although previously correlated upstream with Balderton Member Sands and Gravels (Balderton Terrace), this is shown to be incorrect. The correlation of the Southrey and Stainsfield temperate-climate units to the Ipswichian Stage implies that the overlying gravel and sand at these sites, and therefore the overlying terrace surface must be post-Ipswichian in age. It therefore dates broadly to the Middle Devensian Substage, by analogy with sequences elsewhere in southern Britain (Table 2). It is demonstrated herein firstly that the Witham Southrey Member deposits must be equivalent upstream to a unit younger than the Balderton Sands and Gravels, most likely the Fulbeck Member deposits. Secondly, this indicates that the River Trent was not aligned through the Lincoln Gap into the lower Witham valley by this time. This implies that the lower part of the higher, Martin Member potentially represents the youngest Trent unit aligned via the lower Witham valley. The results confirm Bridgland et al's. (2014, 2015) conclusion that the alignment of the lower River Trent into northern Lincolnshire towards the Humber Estuary occurred before the Middle Devensian Substage, and potentially in the Late Wolstonian (Table 2). The adoption of this course is likely to result from events that occurred during or immediately following the Late Wolstonian deglaciation of the Lincoln district.

The correlations above further demonstrate that the Southrey and Stainsfield units cannot be the temporal equivalent of those within the basal part of the Balderton Member Sand and Gravel upstream in the Trent system at Norton Bottoms and elsewhere. Once again these results throw into question the validity of the age determinations obtained for the sites discussed by amino-acid racemisation analyses where the dating results conflict with the litho-, morpho- and biostratigraphy of the localities.

The Southrey Member gravels and sands are demonstrably equivalent of those at the Tattershall sites overlying the temperate deposits and are therefore also of Middle Devensian age. The Tattershall Terrace surface (Terrace 1 of the BGS), mapped as separate entity from their Terrace 2 (Southrey Terrace), is not supported by the underlying depositional sequences which indicate that the gravel and sands are lateral equivalents. The interpretation of this member as the downstream equivalent of the Witham Fulbeck Terrace gravels (upstream of Lincoln) is supported by their stratigraphical position. Their age is confirmed as Middle Devensian by the numerical dates obtained from silt-filled channels in the gravels at Tattershall Castle and Tattershall Thorpe quarries. The discrete gravel and sand units underlying the modern Witham and Bain rivers' floodplain therefore accumulated broadly during the Late Devensian Substage (Table 2).

There can be no doubt that the glaciation of Fenland and adjacent regions, represented by the Wragby Till Member and its equivalents, cannot be of Middle Wolstonian-age (MIS 8; i.e. *c.* 300 - 245 ka) but dates from the Late Wolstonian (=Late Saalian, MIS 6) Substage. This is further supported by the markedly limited evidence for glaciation during this interval (Middle Saalian and equivalents) throughout the NW European region, as noted above. Indeed it appears that glacial ice failed to extend into lowland western Europe, including the adjacent central and southern North Sea basin, during MIS 8. This throws into question the few isolated reports of glaciation referred to this phase from the North Sea region. Their correlation should be critically re-examined in the light of this knowledge.

Comparison of the sequences to equivalent units lower in the Witham catchment implies that the valleys, like the Fenland beyond into which the river discharges, were invaded by saline water during the high sea-level phase of the Ipswichian interglacial. The absence of brackish-water ingression at upstream sites, especially Tattershall Thorpe, where the temperate deposits occur at 5-6 m O.D., indicates that the incursion did not reach this height in the Witham valley.

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Figure captions

Figure 1. Location map showing the location of the sites discussed in the text. The National Grid reference co-ordinates system is shown on the map margins.

Figure 2. Map showing the distribution of terrace deposits in the Lincoln Witham, Bain and Trent valleys (modified from Bridgland et al., 2014). Borehole record source: BGS archive (http://mapapps.bgs.ac.uk/geologyofbritain/home.html) and localities mentioned in the text.

Figure 3. Pollen diagram from Coronation Farm borehole, Southrey (TF 16 NE19). For further explanation, see text.

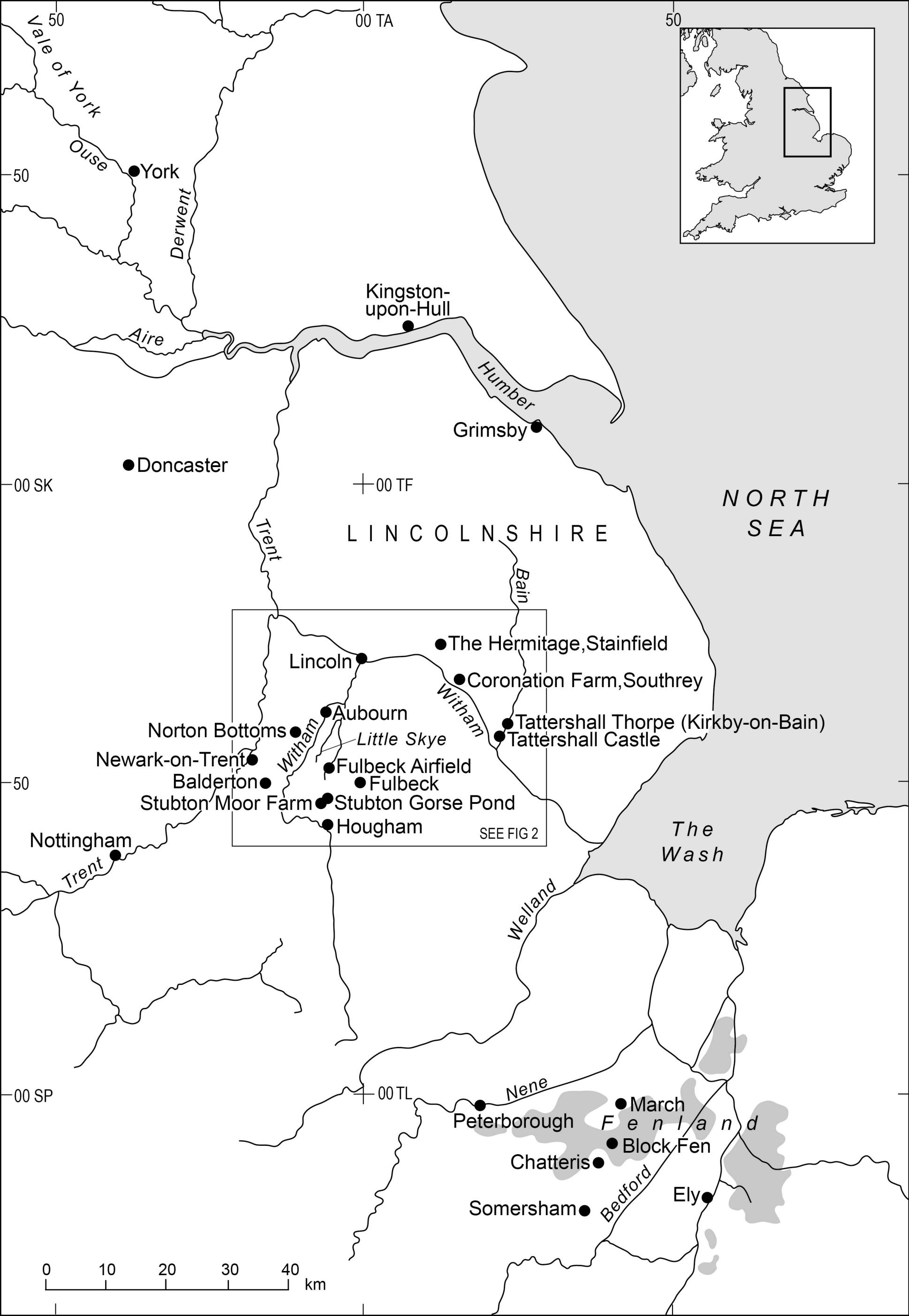
Figure 4. Pollen diagram from The Hermitage borehole, Stainfield (TF 17 SW 34). For further explanation, see text.

Figure 5. Fluvial deposits in the Trent, Witham and Bain (tributary) valleys showing the lower terrace units discussed in the text. Borehole record source: BGS archive (http://mapapps.bgs.ac.uk/geologyofbritain/home.html) and localities mentioned in the text.

Table caption

Table 1. Chronological scheme for the fluvial terrace and related deposits in the Trent, Witham and Bain valleys, according to White et al. (2010) and Bridgland et al. (2014; 2015).

Table 2. Revised geological timetable of the fluvial and related deposits and events in the Lincolnshire region and their correlation to the near Continent during the Middle to Late Pleistocene subseries (modified from Gibbard et al., 2013) showing the conclusions presented in this article. The NW European chronostratigraphy/climatostratigraphy is based on Litt et al. (2007, 2008).



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The Hermitage,Stainfield
Lincoln
Coronation Farm,Southrey
Witham
Aubourn
Tattershall Thorpe (Kirkby-on-Bain)
Norton Bottoms
Little Skye
Tattershall Castle
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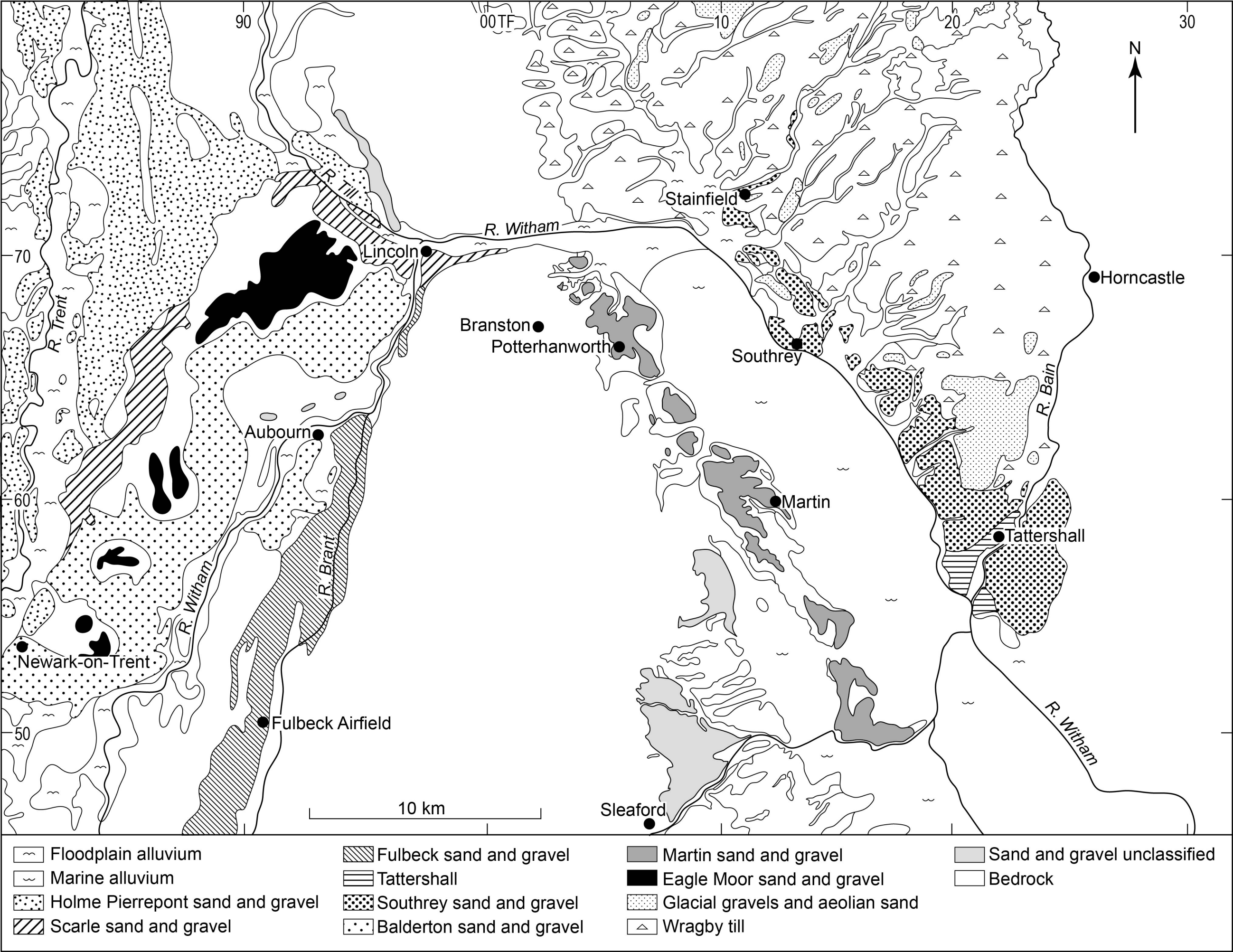
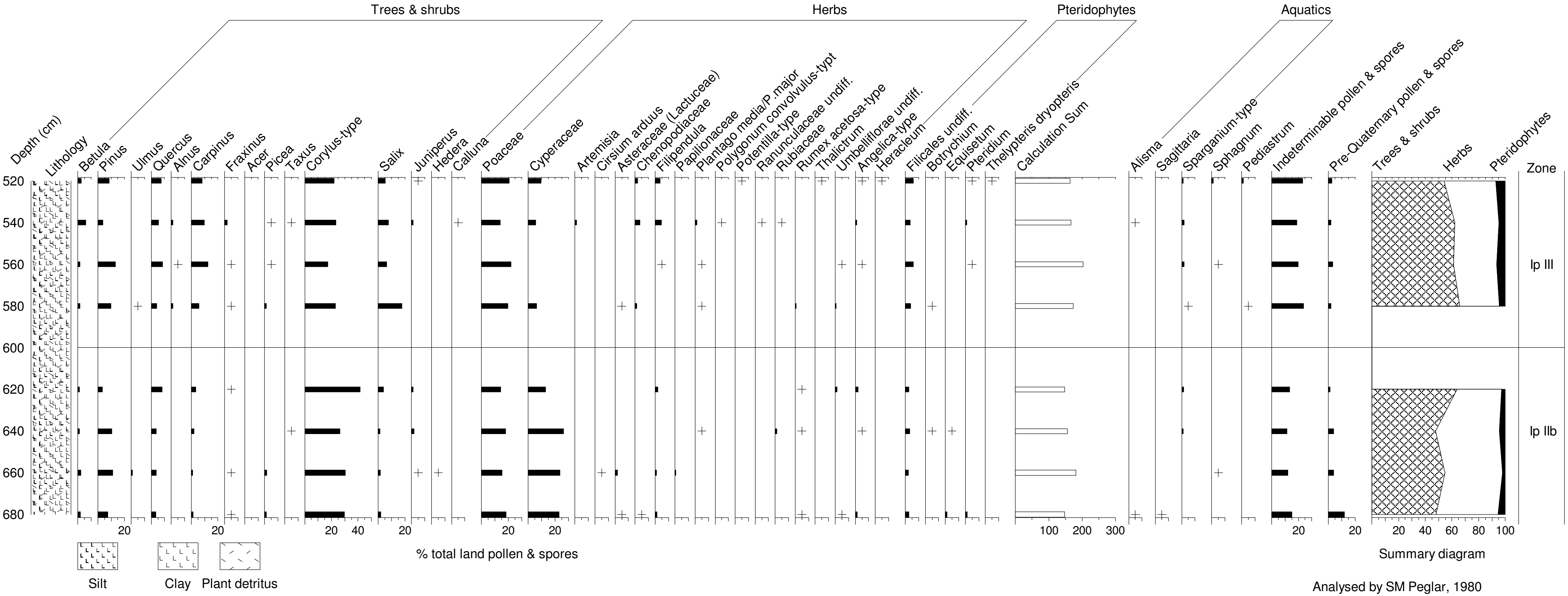

90
00TF
10
20
30
N
70
60
50
R. Till
R. Witham
Lincoln
Stainfield
Horncastle
R. Trent
Branston
Potterhanworth
Southrey
R. Bain
Aubourn
Martin
Tattershall
R. Brant
R. Witham
Newark-on-Trent
Fulbeck Airfield
10 km
Sleaford
R. Witham
Floodplain alluvium
Marine alluvium
Holme Pierrepont sand and gravel
Scarle sand and gravel
Fulbeck sand and gravel
Tattershall
Southrey sand and gravel
Balderton sand and gravel
Martin sand and gravel
Eagle Moor sand and gravel
Glacial gravels and aeolian sand
Wragby till
Sand and gravel unclassified
Bedrock

CORONATION FARM

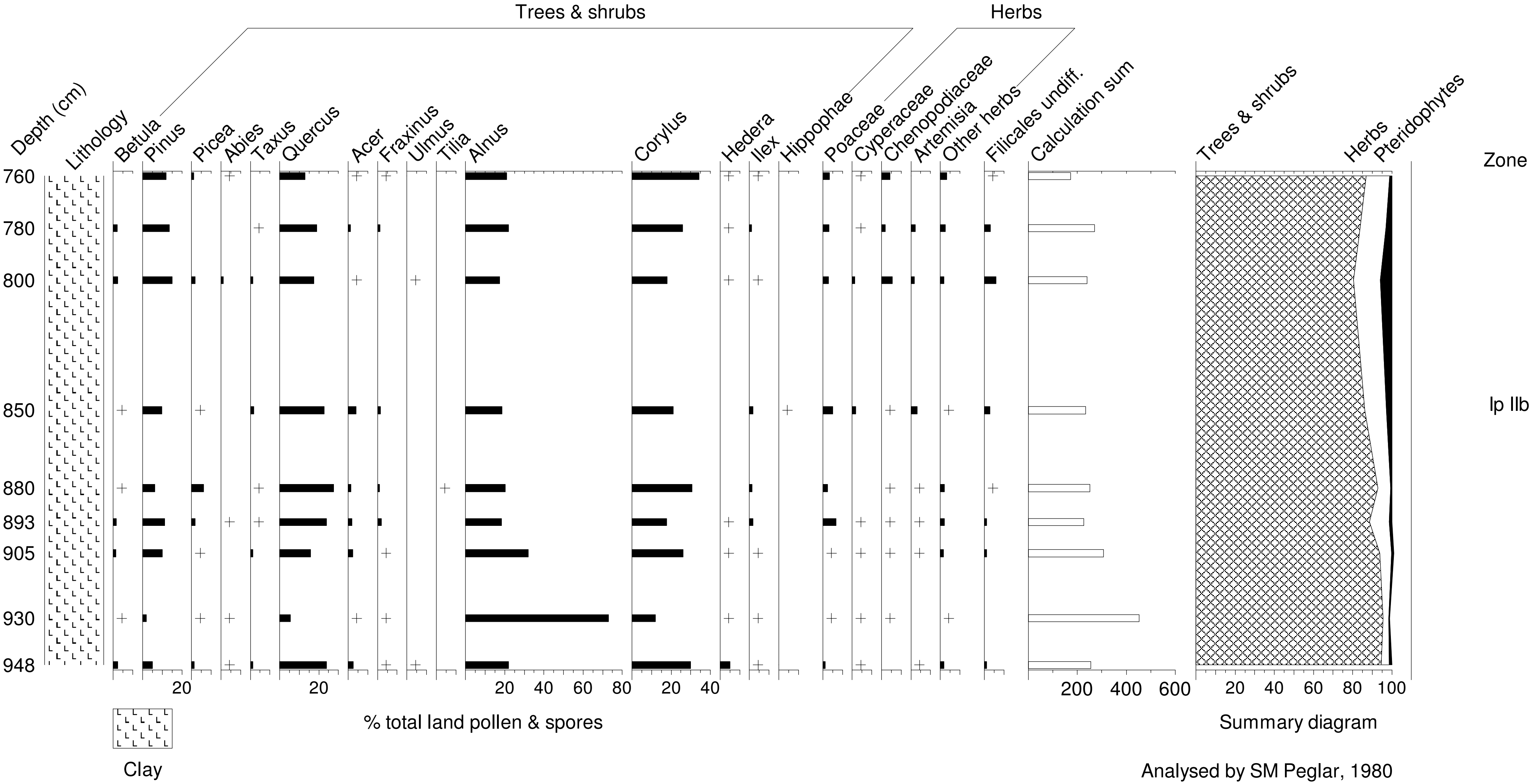
Southrey, Lincolnshire



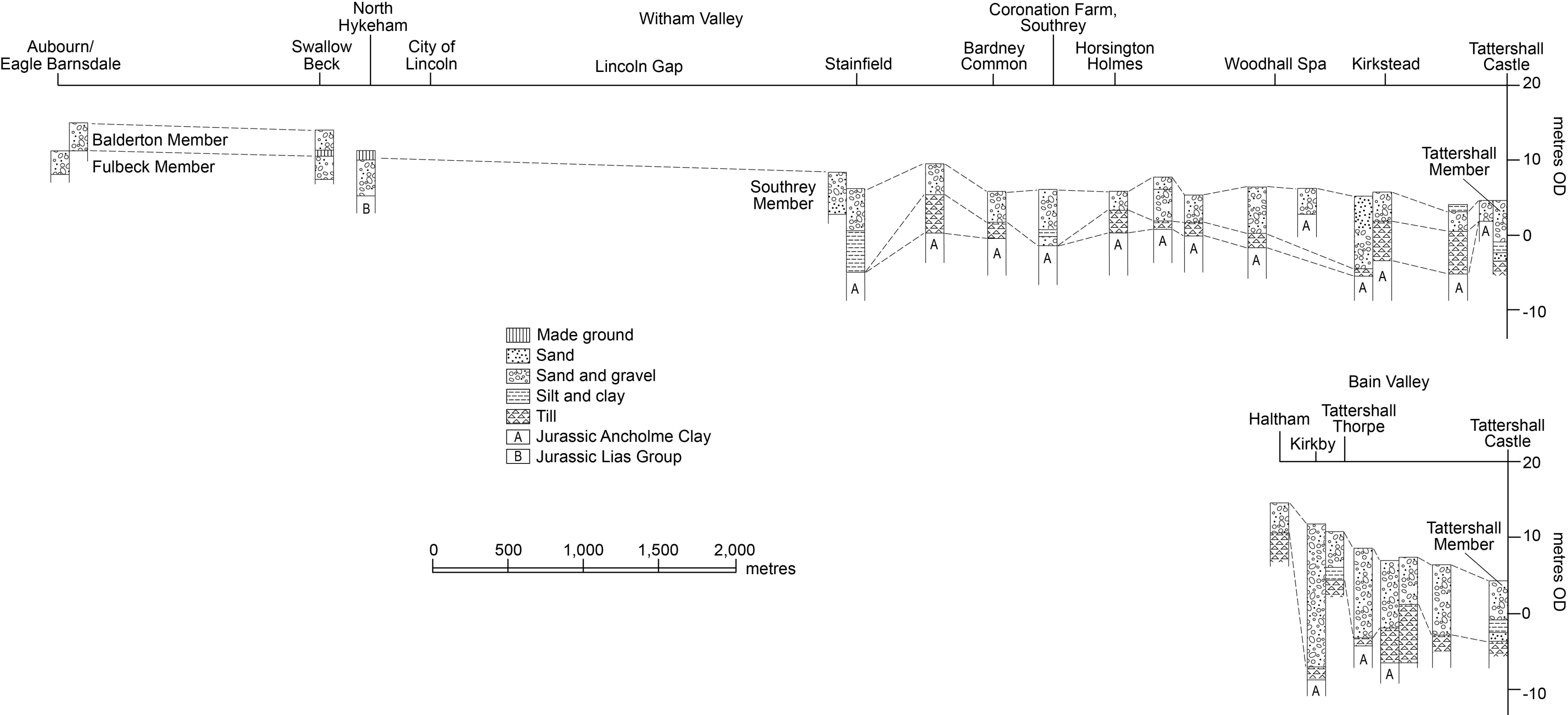
Analysed by SM Peglar, 1980

THE HERMITAGE

Stainfield,Lincolnshire



Analysed by SM Peglar, 1980



Witham Valley
Aubourn/ Eagle Barnsdale
Swallow Beck
North Hykeham
City of Lincoln
Lincoln Gap
Stainfield
Bardney Common
Coronation Farm, Southrey
Horsington Holmes
Woodhall Spa
Kirkstead
Tattershall Castle
Balderton Member
Fulbeck Member
Southrey Member
Tattershall Member
metres OD
20
10
0
-10
A
B
Made ground
Sand
Sand and gravel
Silt and clay
Till
Jurassic Ancholme Clay
Jurassic Lias Group
0
500
1,000
1,500
2,000
metres
Bain Valley
Haltham
Kirkby
Tattershall Thorpe
Tattershall Castle
Tattershall Member
metres OD

<table>
<tr><td colspan="2" rowspan="2">British chronostratigraphy</td><td colspan="3">Fluvial sequences</td><td rowspan="2">Glaciation</td><td rowspan="2">Marine Isotope (Sub-) Stage (MIS)</td></tr>
<tr><td>Trent Valley</td><td>Witham Valley</td><td>Bain Valley</td></tr>
<tr><td rowspan="2">Devensian</td><td>Late</td><td>Holme Pierrepont gravel and sand (Terrace)</td><td>Buried, i.e. Floodplain Gravel</td><td>Buried, i.e. Floodplain Gravel</td><td>Vale of York glaciation and outwash</td><td>~1-2</td></tr>
<tr><td>Middle</td><td>Scarle gravel and sand (Terrace)</td><td>Southrey gravel and sand (Terrace)</td><td>Tattershall Castle gravel and sand (Terrace)</td><td></td><td>?5d-2</td></tr>
<tr><td colspan="2">Ipswichian</td><td>Fulbeck sand and gravel</td><td>?Fulbeck sand and gravel</td><td>Tattershall Castle</td><td></td><td>~5e</td></tr>
<tr><td rowspan="4">Wolstonian</td><td rowspan="2">Late</td><td>Balderton sand and gravel (Terrace)</td><td>Southrey sand and gravel</td><td>Tattershall Thorpe sand and gravel</td><td></td><td>6</td></tr>
<tr><td>Norton Bottoms (Terrace)</td><td>Coronation Farm, Southrey</td><td>Tattershall Thorpe</td><td></td><td>~7a-c, ?7e</td></tr>
<tr><td rowspan="2">Middle</td><td>Eagle Moor sand and gravel (Terrace)</td><td>Martin-lower facet sand and gravel (Terrace)</td><td></td><td></td><td rowspan="2">8</td></tr>
<tr><td>Wragby Till</td><td></td><td></td><td>glaciation</td></tr>
</table>

British chronostratigraphy / climatostratigraphy		Fluvial events	Glacial events	Climate/ environment	Human occupation	Continental chronostratigraphy / climatostratigraphy			Approximate Marine Isotope (Sub-) Stage (MIS)
Devensian	Late	Aggradation of gravel and sand in river valleys (Holme Pierrepont Member, Trent Valley Formation, Witham Valley Floodplain Gravel, etc.)	Vale of York glaciation and outwash	Periglacial/ glacial	?	Weichselian		Late	~1-2
		Non-deposition/erosion		Periglacial					
	Middle	Aggradation of gravel and sand in river valleys (Fulbeck Member, Scarle Member Trent Valley Formation, Southrey gravel and sand, Tattershall gravel and sand, etc.) ?Trent diverted to Humber		Periglacial	?			Middle	?4-3
		Non-deposition/erosion							
Ipswichian		Aggradation of temperate floodplain and channel sediments, Southrey, Stainfield, Tattershall Castle, Tattershall Thorpe		Temperate		Eemian			~5e
Wolstonian	Late	Downcutting and aggradation of gravel and sand in river valleys, ?Trent diverted to Humber		Periglacial		Warthe Stadial	Saalian	Late	6
		Non-deposition/erosion							
		Aggradation of gravel and sand in river valleys (Balderton Member - Trent Valley Formation, etc.)							
			Wolstonian glaciation *s.s.* lacustrine ponding of river valleys.	Periglacial / glacial	?	Drenthe Stadial			
		? Deposition of Norton Bottoms and associated deposits. Complex ‘temperate’ channel fills.		Boreal / temperate	*	?Schöningen Interstadial/ Interglacial			~7a-c, ?7e