

THE RIVER SIGER: A POLYGENETIC HOLOCENE PALAEOOTIDAL MEANDER AND CREEK SYSTEM IN THE SOMERSET LEVELS

A.G. BROWN¹ AND R. BRUNNING²



Brown, A.G. and Brunning, R. 2014. The River Siger: a polygenetic Holocene palaeotidal meander and creek system in the Somerset Levels. *Geoscience in South-West England*, **13**, 286-294.

A large palaeochannel known as the 'Siger' or 'Edithmead' meander is clearly visible on topographic maps and from field boundaries adjacent to the southern slopes of Brent Knoll in the Somerset Levels. Airborne laser altimetry (LiDAR) highlights the full extent of this large meander-arc and reveals a network of palaeotidal tributaries feeding into it. Coring within the channel has proved over 15 m of silty-clay, parts of which have been analysed using core-scanning XRF and palynology. Dating the core has proved difficult; however, one radiocarbon date is available from a thin palaeosol. This paper presents the results and discusses the formation of what is identified as a large palaeotidal meander and creek system which appears to have been initiated during the Early Holocene estuarine inundation of the Brue Valley and then re-activated as a tidal creek-system as part of the clay-lands of the Western Somerset Levels during the Late Holocene. It is argued that this history explains the composite form of a large-amplitude meander (implying a large discharge) with a typical salt-marsh creek system. The landform is thus polygenetic and this reflects the bipartite history of relative sea level along with the locally-high tidal range within the Severn Estuary. This study has implications for the Holocene history of the Somerset Levels, the Bristol Channel and also managed shoreline retreat.

¹ Palaeoenvironmental Laboratory University of Southampton (PLUS), Southampton, SO17 1BJ, U.K.

² Somerset Levels and Moors Officer, South West Heritage Trust, Taunton, U.K.

(E-mail: Tony.Brown@soton.ac.uk)

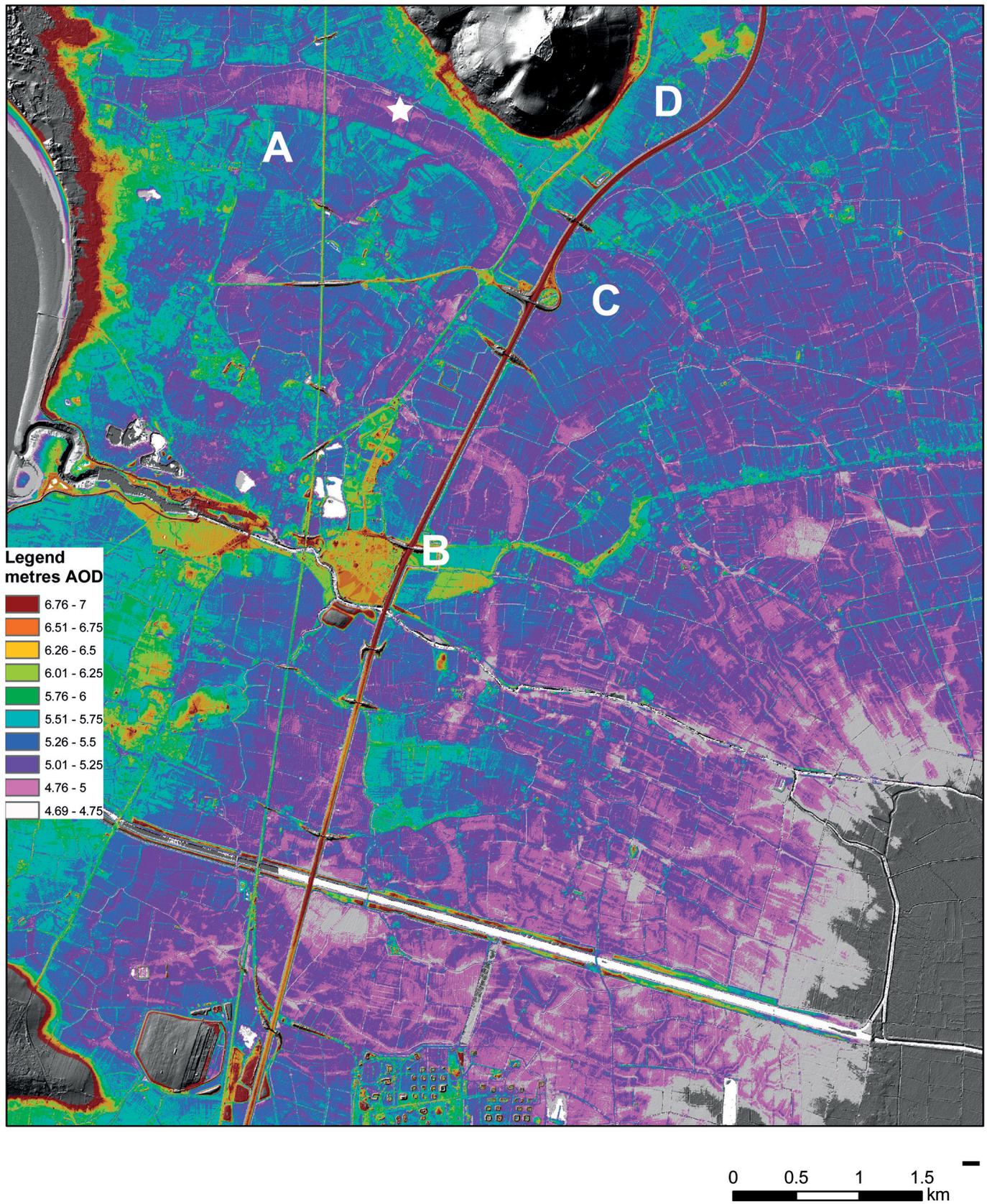
Keywords: coastal sedimentation, relative sea level rise, tidal palaeochannels, polygenetic landform.

INTRODUCTION, AIMS AND OBJECTIVES

The Somerset Levels, like other low-lying coastal basins, has a history of repeated marine transgressive and regressive phases linked to eustatic, isostatic and tectonic drivers. The relative sea level history of the Bristol Channel and the inherited topography of the Parrett, Brue and Axe river valleys has produced a 10-15 m deep belt of transgressive estuarine silts and clays interleaving inland with regressive high intertidal-terrestrial peats (Allen, 2000). Whilst the occurrence of such transgressive sequences dating to the Late Holocene is known from many coastal wetlands systems, including the East Anglian Fens, the Solway Firth and most notably the Dutch Delta (Allen 2005), the geomorphology of the facies is less well understood. This is particularly true of the Somerset Levels as whilst the overall Quaternary history of the basin(s) is well known (Kidson *et al.* 1974; Murray and Hawkins, 1976; Kidson and Heyworth, 1978; Heyworth and Kidson, 1982; Campbell *et al.*, 1998), the processes of transgressive and regressive marine inundation are not fully understood and as a result palaeogeography has to be generalised. This is particularly true of the Early Holocene (lower clay) and the Late Holocene inundations of the Somerset Levels broadly resulting from relative sea level rise coupled with secondary mechanisms including changes in storminess, tidal amplitude and sediment compaction. Geological and soil mapping has shown that the Somerset Levels can be divided into two areas. Along the coast are the silty-clay dominated 'Levels' with a superimposed coastal sand-dune system, with bedrock islands such as Brent Knoll and Pawlett. Inland are the 'moors', mainly

composed of later Holocene peat overlying Early Holocene lower estuarine clay, recognised by Godwin in the 1940s (Godwin, 1941, 1943, 1981). The beginning of the main peat formation has been very well dated in many places between c. 4,500-4,000 cal. BC. Within the moors are bedrock islands (outliers) and so-called 'burtle' islands composed of outliers of Burtle Formation sands which are known to be of Ipswichian (MIS 5e) age although some have argued for a pre-Ipswichian lower Member at Greylake (Hawkins and Kellaway, 1973; Kidson *et al.*, 1978; Andrews *et al.*, 1984; Campbell *et al.*, 1998).

Studies in the western area have shown the coastal clay to be up to 30 m thick and feather-out over peats inland (Druce, 1998). Sedimentological and palaeoecological studies of the foraminifera have shown it to have been marine in origin (Druce, 1998; Long *et al.*, 2001). Dates for this unit have only been obtainable from the thin interleaved peat bands within it. These exist between -21.3 m O.D. and c. -2 m O.D. (Long *et al.*, 2001), but only the upper deposits have been dated through work at Minehead (Jones *et al.*, 2005), Burnham-on-Sea (Druce, 1998) and Porlock (Jennings *et al.*, 1998). The dates available before 1998 were used as sea level index points to constrain Mean Sea Levels (MSL, Jones *et al.*, 2005). This suggested that the Highbridge cores represent a MSL of -25 to -26 m O.D. at c. 7,500 cal. BC (Jones *et al.*, 2005). By c. 6,200 to 5,900 cal. BC, MSL had risen rapidly to between c. -12.5 to -14 m O.D. and by c. 5,000 cal. BC, MSL was c. -8 m O.D. (Jennings *et al.*, 1998, table 1, p.166).



© Crown copyright and database rights 2012
Ordnance Survey 100024198
© Environment Agency copyright and/or
database rights 2012. All rights reserved.

Figure 1. LiDAR image of the Somerset coastal claylands. Map based on OS Landline Data and produced with their permission. Crown Copyright. Aerial imagery is Environment Agency copyright. The white star marks the location of the cores and the letters refer to network segments mentioned in the text.

From c. 5,000 cal. BC, the rate of sea level rise began to decrease from the previous very rapid rate of c. 5-6 mm yr⁻¹ to c. 2 mm yr⁻¹ between c. 5,000 and 3,000 cal. BC (Haslett *et al.*, 2000). This allowed organic sedimentation to outpace sea level rise leading to the development of peat dominated environments over virtually the whole Brue floodplain. In the latter half of the second millennium BC these peat environments are replaced by estuarine silts and clays along the whole coastal area, inland along the Axe Valley and through the Panborough Gap into the Brue Valley around Godney Moor (Haslett *et al.*, 1998; Haslett *et al.*, 2001; Hollinrake and Hollinrake, 2001; Godwin, 1955; Housley *et al.*, 2000).

In the Roman period most of the coastal marshes were reclaimed for agriculture and settlement, not just in Somerset but along most of the Severn Estuary. This is demonstrated by direct archaeological evidence for the whole of the Axe Valley and the area between Brean Down, Brent Knoll and Wedmore. Settlements and reclaimed land are also known from the area between Alstone and Pawlett and from recent work on the Steart peninsula. The only part of the Somerset coast that does not seem to have been reclaimed at this time is the area between Brent Knoll, Mark, Burtle and the Polden Hills. Here, a large palaeomeander recognised from maps and from field boundary patterns immediately to the south of Brent Knoll had been referred to as the River Siger or Edithmeade meander (Brunnering and Farr-Cox, 2005). The objectives of the research published here were to (a) date the meander and determine its facies context and (b) relate it to Holocene deposits and the sedimentary history in the western Somerset Levels.

METHODS

A definitive map of the palaeochannel system was published by Brunnering and Farr-Cox (2005) using LiDAR flown by the Environment Agency. The survey had a spatial resolution of one spot height every 2 m and a nominal ground height resolution of ±0.15 m and was transcribed from a hillshaded model created in ArcGIS. Initially hand gouge coring was attempted at Brent; however, this could only penetrate 7 m due to the dense and cohesive nature of the silty-clay. Two deeper boreholes were then made using a percussion coring system with a chamber width of 0.05 m. Even using this system the maximum depth recovered was 15 m. The core lithology was described using standard sedimentary logging procedures (Tucker, 1982) and 1 m-long cores transported to the University of Southampton. The geochemistry of the longest core (Figure 2) was investigated using an XRF core-scanning system (ITRAX) at the National Oceanography Centre at Southampton. ITRAX is an automated multi-function core scanning instrument that records optical, radiographic and elemental variations from sediment half cores up to 1.8 m long at a resolution as fine as 200 µm (Croudace *et al.*, 2006). Samples were taken for both pollen and diatoms at 0.2 m intervals and processed using standard procedures and protocols (Moore *et al.*, 1991; Battarbee, 1986). The pollen levels summarised here were counted to a total land pollen sum of 500 grains and identification was undertaken at the Palaeoenvironmental Laboratory University of Southampton (PLUS) utilizing its pollen reference collection. Radiocarbon dating was undertaken at Queens University Belfast and the nomenclature for the sub-division of the Holocene follows Walker *et al.* (2012).

RESULTS

The LiDAR survey clearly shows the composite nature of the network. The elements are: Edithmead meander (Figure 1, A) which has a width of 40-60 m and a meander radius of 3.13 km which would give an approximate wavelength of 6 km, two major tributary systems (Figure 1, B and C) and one minor tributary system (Figure 1, D). The two larger systems drain the southern side of the Brue Valley and the other the northern side

of the Brue Valley with the minor northerly tributary draining the gap between Brent Knoll and the Wedmore Ridge. All three systems have the characteristic dendritic form of tidal creek systems (French and Stoddart, 1992; Wallace *et al.*, 2005). However, it is also noticeable that the main branch of the southern network (Figure 1, B) runs along the junction of the clay-lands with the peat strongly suggesting it may have formed initially as a mire-lag channel. Also Brunnering and Farr-Cox (2005) have suggested the regular form of some of the minor tributaries in this area may be a product of linear peat cutting to supply fuel for the Roman salt industry.

The two boreholes (Figure 2) reveal 5 m of green-grey silty-clay overlying 10 m of olive green silty-clay with micaceous laminations (1-2 mm). Within this unit was a thin organic-rich band at approximately -2.5 m O.D. and a sandy-silt band at -7 m O.D. The organic-rich band contained no identifiable plant remains and so a bulk sample was submitted for AMS radiocarbon dating which returned a date of 4,728±36 BP (UBA-18118) which calibrates to 5,584-5,326 BP (3,634-3,376 BC) at the 2σ probability level. Since the date was considerably earlier than had been anticipated (see discussion) other corroborative dating evidence was sought. Although the silty-clays are not highly polleniferous, pollen was extracted in sufficient quantities to count from three levels. The results (Figure 3) clearly show major variations in the spectra with the basal sample (-0.9 m O.D.) reflecting oak-hazel and alder woodland, with pine in the region, saltmarsh and raised mire, but with no cereal-type pollen grains. The sample from -6 m O.D. revealed oak-hazel and alder woodland, with beech in the region, minor representation of saltmarsh and raised mire, but with cereal-type pollen grains present. The upper sample (-3 m O.D.) again showed oak-hazel and alder woodland, with beech in the region, a minor representation of saltmarsh and raised mire,

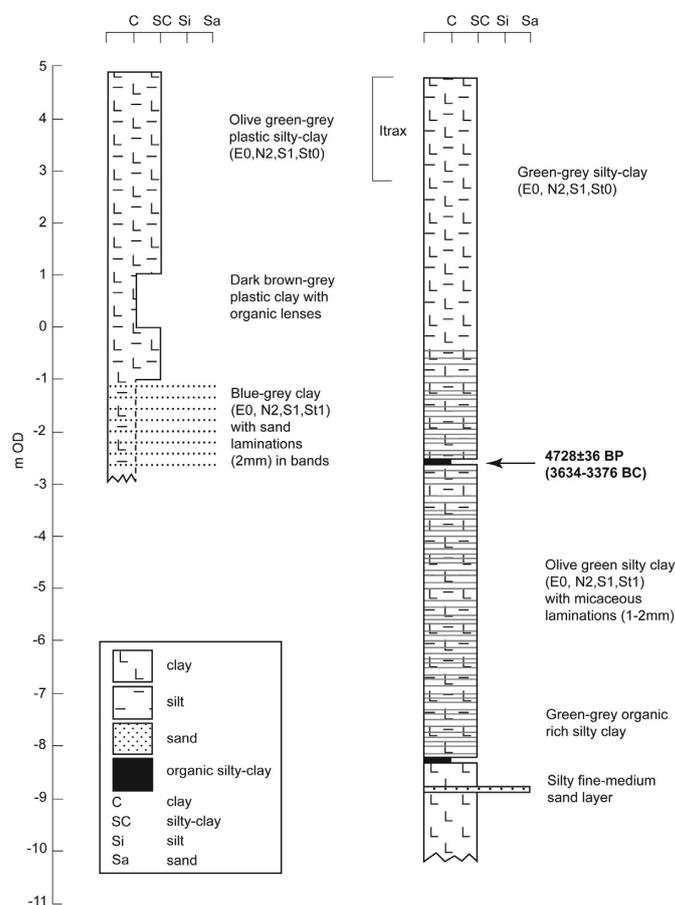


Figure 2. Stratigraphy of the 2000 (Sig1, left) and 2010 (Sig2, right) cores with radiocarbon dating and sediment description.

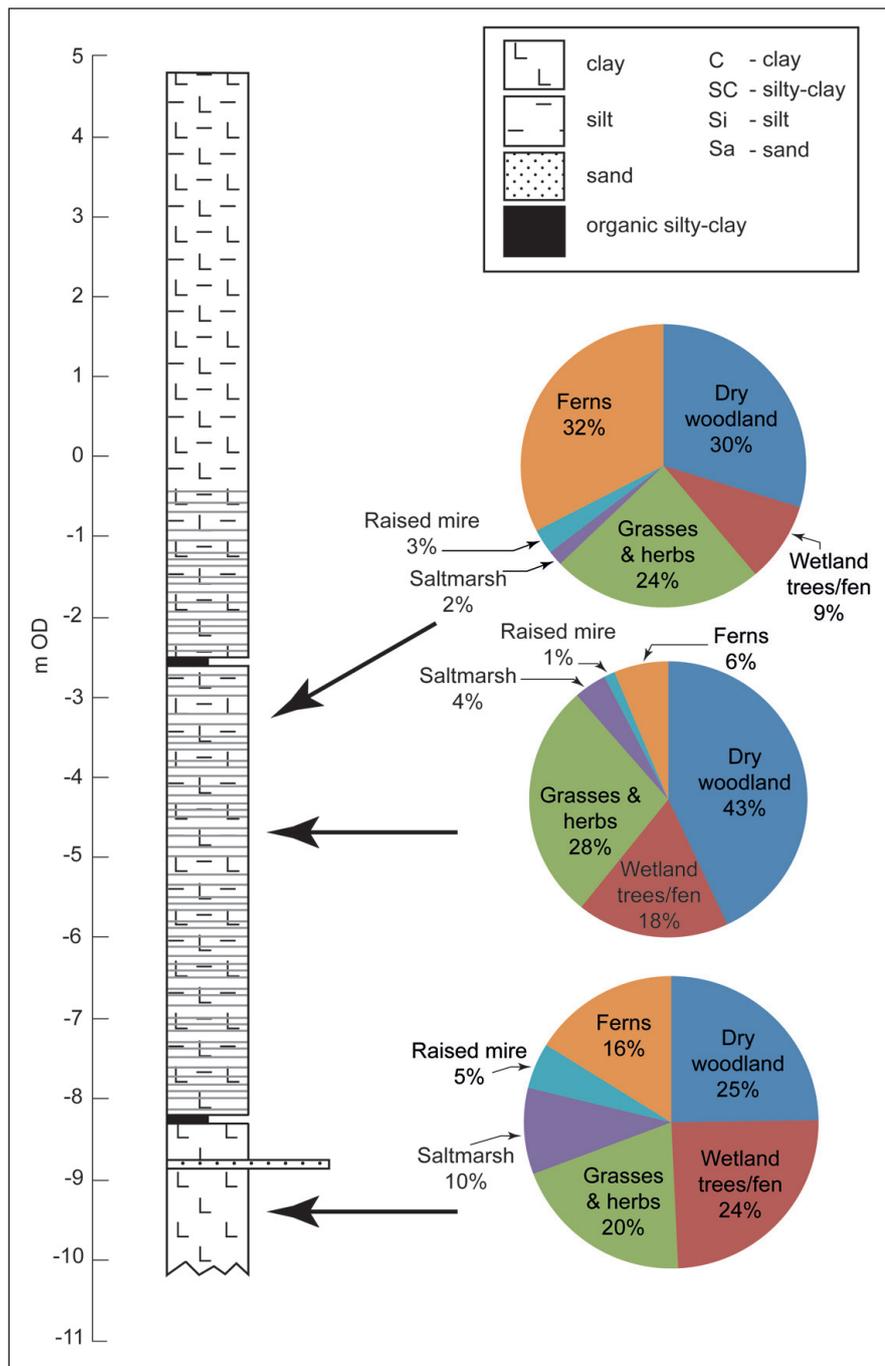


Figure 3. Summary pollen data from three levels taken from the 2010 (Sig2) core.

with cereal-type pollen grains present. This is conformable with the AMS date and suggests the initiation of the palaeochannel must pre-date the Bronze Age and is probably *c.* 8,500 BP in the Early Holocene *sensu* Walker *et al.* (2012). This is also consistent with the Bristol Channel RSL curve (Heyworth and Kidson, 1982; Haslett *et al.*, 1998; Jones *et al.*, 2005; Edwards, 2006; Sturt *et al.*, in press) suggesting that the palaeochannel was initiated during the Early Holocene inundation of the Levels.

Sediment geochemistry was utilised as a possible secondary method of confirming the radiocarbon and pollen dating as a characteristic Late Holocene sequence of heavy metal enhancement or chemostratigraphy is known from the Severn Estuary (Allen and Rae, 1987). More recently a prototype ITRAX was used for laminated sediment core sections from the Newport Deep (NPD7) in the Middle Severn Estuary which revealed increased levels of the anthropogenic pollutant elements Zn, Pb and Cu in the upper 0.275 m (Croudace *et al.*,

2006). Considerable problems were encountered due to the fragmentation of the core and also the difficulty of getting a smooth and level surface for the ITRAX beam; however, consistent results were achieved for the upper 2 m of the sequence. This showed a muted increase in heavy metals but high inter-count variability (Figure 4a, b). Although of a lower relative magnitude than the heavy metal counts from the Newport Deep core, there is no abrupt increase in heavy metals and so it is not possible to date the core using this approach. However, the relatively high Pb and As could reflect mining input from the mouth of the Axe to the north and ultimately mining on the Mendip Hills. What the ITRAX does show is: (a) high S at the base of the sequence which probably reflects the REDOX boundary and sulphate production, and (b) periodic variations in Cu, As and Pb at the mm to cm scale probably reflecting sedimentary laminations and a degree of density sorting.

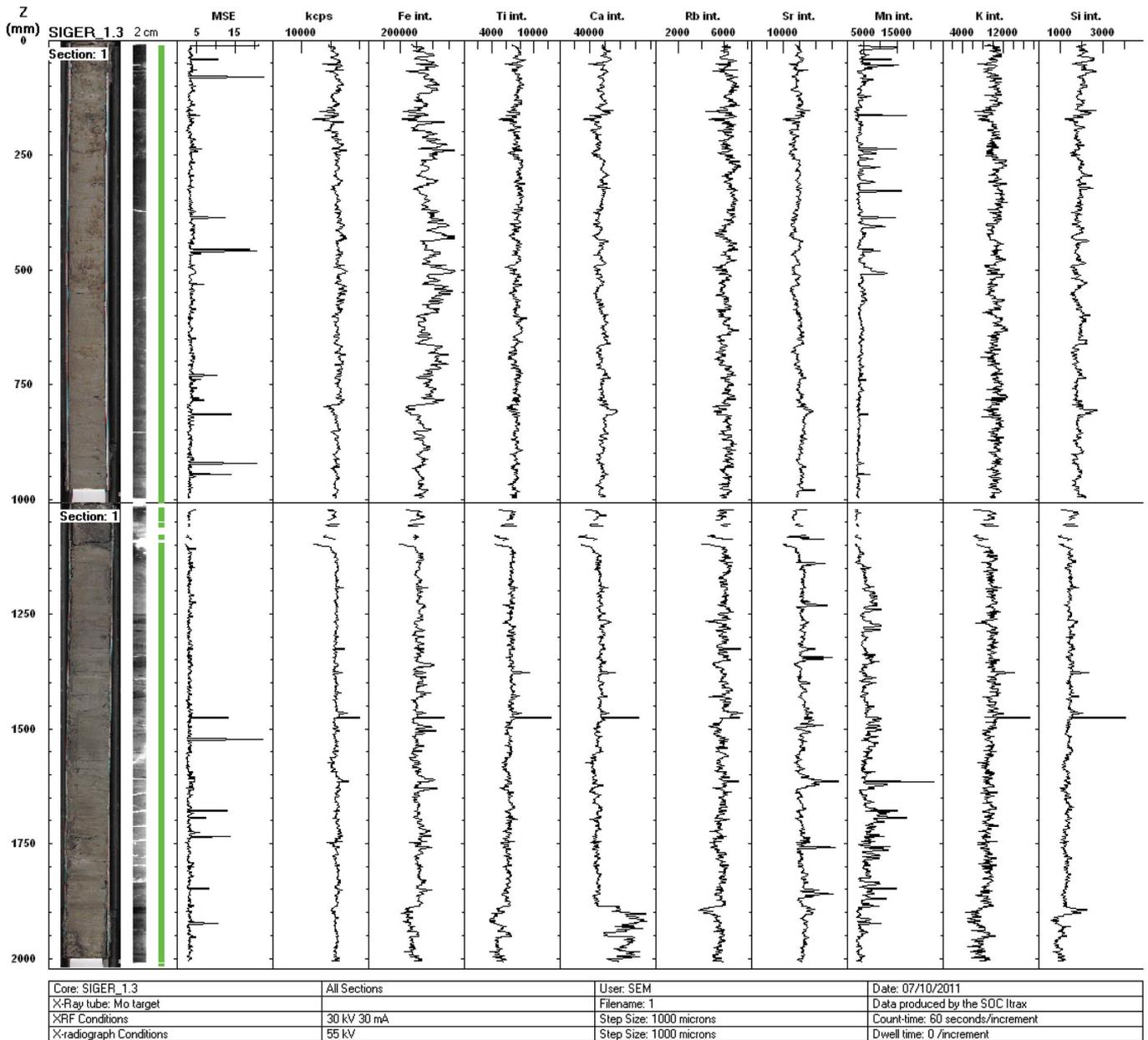


Figure 4. (a) ITRAX data from the upper 2m of the 2010 (Sig2) core.

GEOLOGICAL AND GEOMORPHOLOGICAL DISCUSSION

The planform of the Siger system shows a large amplitude meander draining three rectilinear dendritic systems. The form of these tributary systems is similar to many tidal creek systems in the Severn Estuary including those mapped from LiDAR in the Gwent levels on the Welsh side of the estuary (Cooke, 2010). However, the Edithmead Meander is atypical of these small palaeotidal systems but is similar to the large tidal meanders found on the Severn (Arlingham Meander), the Parrett (Pawlett Meander), the Wye and even the Usk. Similar large meanders in the tidal to peritidal reach of large rivers are known worldwide from the Thames (Greenwich Meander) to the Bynoe River in Australia. They are caused by the rapid increase in channel size (width and depth) that is a function of the addition of the tidal flux to the fluvial discharge below the tidal limit. As tidal flux increases exponentially down-estuary from the tidal limit so channel size increases exponentially as do meander amplitude and wavelength. It was first pointed out by Anhert (1960) that these tidal meanders tend to have a remarkably uniform outer curvature with narrowing at the point of maximum curvature – so-called double meanders. This is caused by a slight displacement of the flood and ebb tide

creating mid-channel bars (Solari *et al.*, 2002) so forming non-stationary meanders with a second harmonic that fluvial channels do not have (Marani *et al.*, 2002). Unfortunately not enough of the Siger is preserved to be able to detect such a double-form although it does have the remarkably uniform outer bank and an amplitude so large it can only reflect both a fluvial and tidal input. The fluvial input could have only been from the Brue Valley due to the Brent-Wedmore subsurface ridge to the north and the Pawlett-Polden Ridge to the south. The drainage networks B-D (Figure 1) are in planform typical of the many small tidal creeks, locally named ‘pills’, that drain the saltmarshes and mudflats of the present estuary and which have been found in archaeological excavations dating to the Roman and Medieval periods, and which occasionally contain the remains of fish traps (Allen and Bell, 1999).

The palaeochannel is filled with relatively uniform but in places laminated silty-clay of estuarine origin. The single radiocarbon date (5,584-5,326 cal. BP) and the pollen spectra recovered from the base of the sequence strongly suggest an Early Holocene date for its initiation. The later Holocene peat deposits exposed at Burnham-on-Sea have been dated between 5,440-5,080 cal. BC (Wk5298 6,340±70 BP) and 3,780-3,370 cal. BC (Wk5300 4,790±70 BP), with a positive sea level tendency

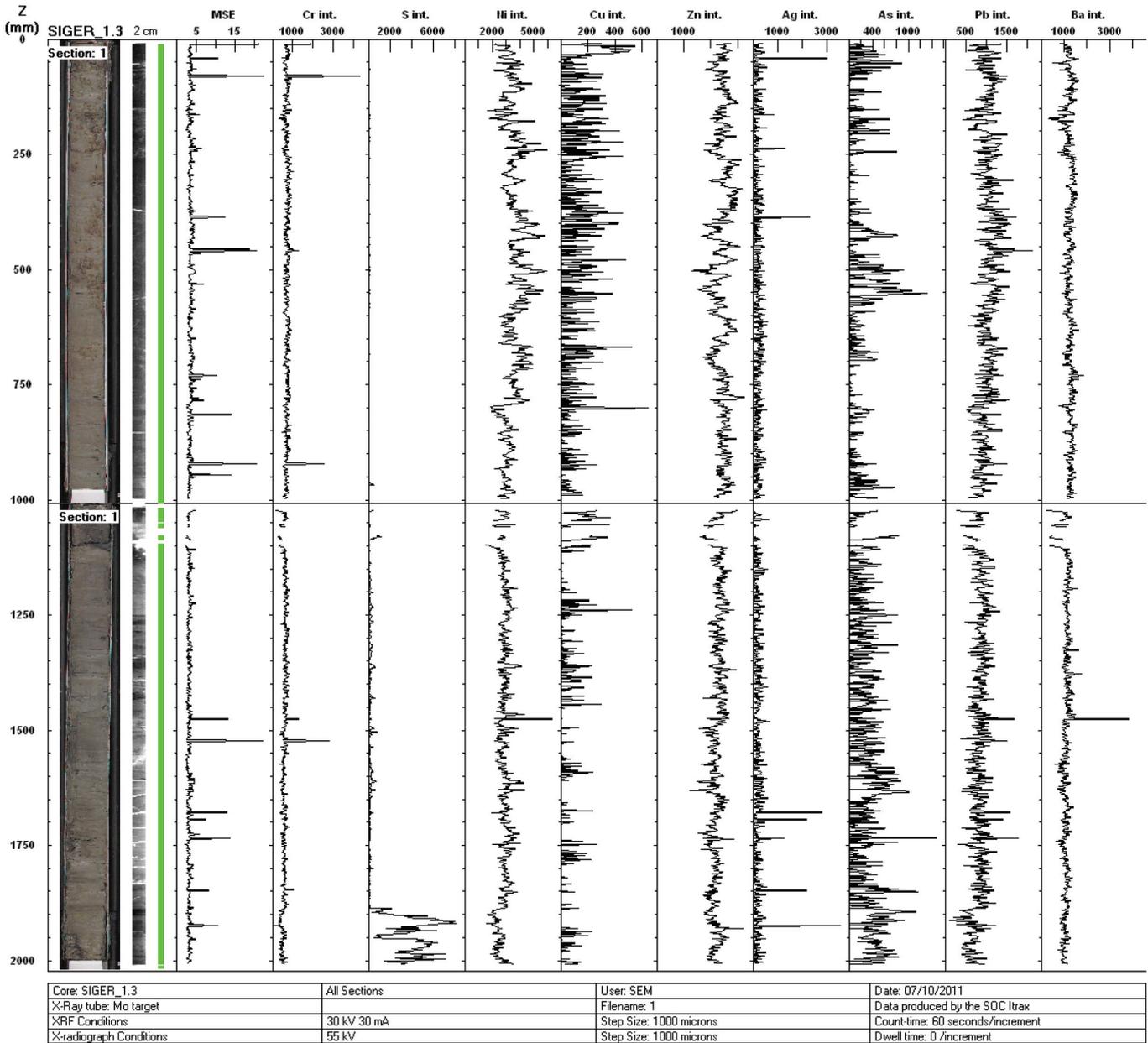


Figure 4. (b) ITRAX data from the upper 2m of the 2010 (Sig2) core continued.

identified at the top of the sequence and pollen evidence identifying the existence of nearby sand dunes (Druce, 1998). This suggests that the dated part of the column relates to a period when the channel was flowing through a freshwater reedswamp, which may have been protected by a sand dune barrier further to the west. This would appear to contradict suggestions made by Brunning and Farr-Cox (2005) that the initiation of the channel was of Roman or later age. However, this chronology was derived from the southern tributary system that is known to bisect peats with an upper surface date of c. 110 cal. BC to 130 cal. AD (Wk11546, Brunning and Farr-Cox, 2005). This apparent contradiction can be resolved in two possible ways. Firstly network B represents much later tidal creek extension into the claylands or secondly it represents re-activation and extension of the salt-marsh creek system from a re-activated channel system (A). Re-activation is implied by the similarity in the mid-Holocene history of the Brue, Parrett and Axe in that the decrease in the rate of sea level rise allowed the inter-tidal surface to elevate through the tidal frame with surfaces becoming drier and more vegetated and allowing supratidal peat growth (Haslett *et al.*, 2000). The persistence of the channel and its form is also a result of the high tidal range of the Severn Estuary (Lennon, 1963). Inland the high

groundwater level led to extensive peat formation which in the central Brue Valley became ombrotrophic and altered the river network (Aalbersberg, 1997, 2000; Brown, 2006). The form of the tributary network, relative altitude and its relationship to the coastal clay belt clearly indicates that the system was the principal tidal creek system that created the coastal clay belt and the upper clay both in the palaeochannel and across the coastal belt (Romano-British Clay *sensu* Godwin, 1941). This saltmarsh system is associated with a dense concentration of Roman salterns (Figure 5) and there may have been human modification of some of the tidal channels (Brunning and Farr-Cox, 2005). This transgression was caused by a relative rise in sea level, which was not eustatic but probably the result of sediment compaction combined with an increase in tidal range (Allen, 2005).

The question of when the Siger became inactive has been discussed by Brunning and Farr-Cox (2005) using evidence from field boundaries, later cross-cutting artificial channels, parish boundaries and Saxon charters. From the location and altitude of the borehole described here it is clear that the channel continues west under the coastal belt of sand dunes between Berrow and Burnham-on-Sea. Given the location and age of the parish church at Berrow this indicates the sand dunes

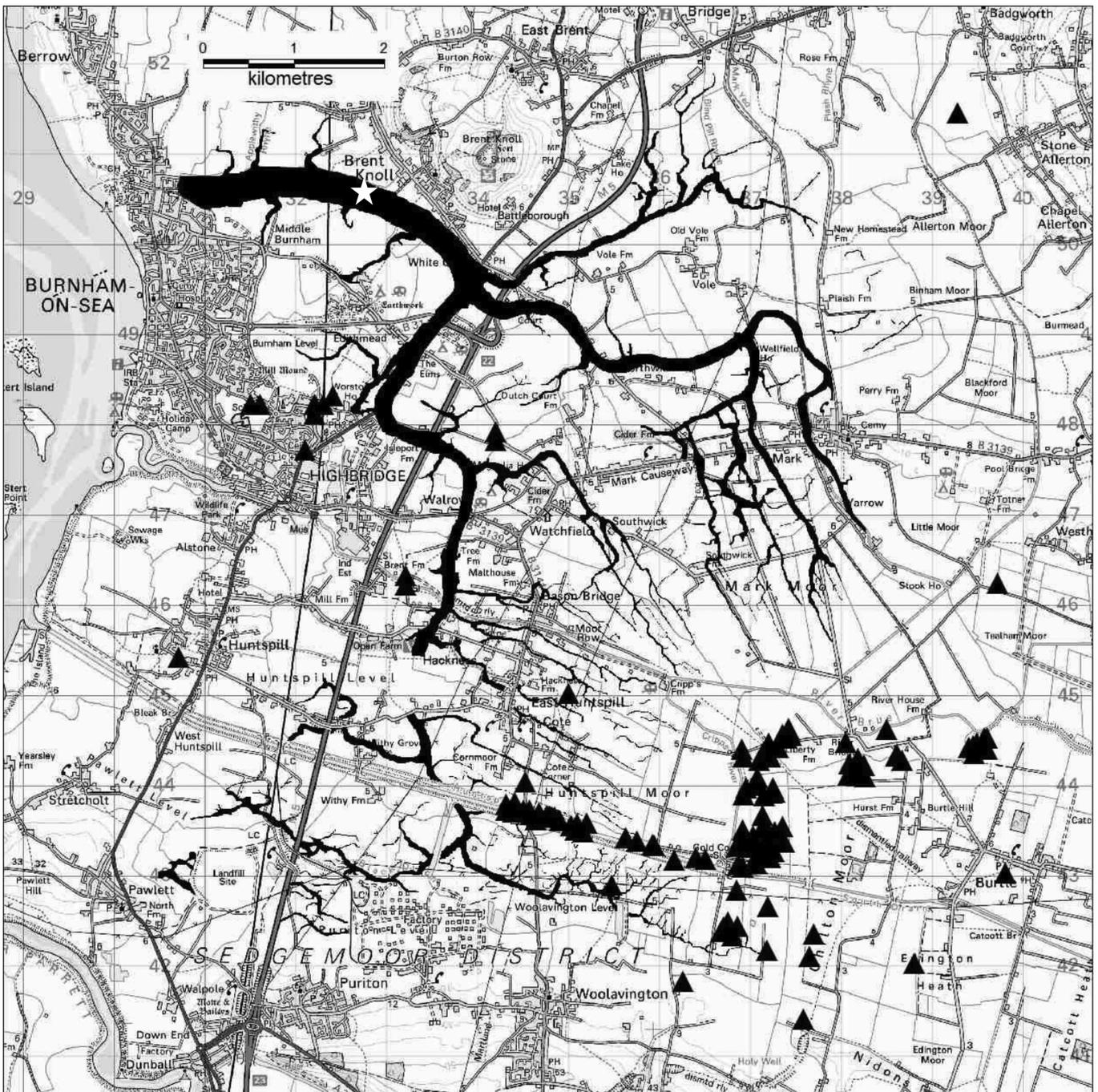


Figure 5. The relict Siger channel (in black), Roman salterns (black triangles) and core location (white star). Adapted from Brunning and Farr-Cox (2005).

must have existed prior to the 12th Century and probably considerably earlier. On the seaward side of the sand dunes the channel is covered by Gore Sands (McDonnell, 1993); however, laminated silty-clay sediments have been observed on these sands after erosional events although it is not easy to differentiate between the channel and adjacent deposits of the Wentlooge Formation without chronostratigraphic data. From these data it appears that the channel finally became completely inactive sometime in the early Medieval period, which fits with the evidence for the River Siger being named as an estate boundary in an early Saxon charter (Sawyer, 1968; Edwards, 1998). By this time it would have been high in the tidal frame and was probably only accommodating minimal estuarine flows due to siltation. Its demise may be related to the creation of a new or enhanced man-made channel through the dunes along the line of the present River Brue. This may also be linked to a sudden decrease in the flow of water from the Brue into the

River Axe, dated to cal. AD 691-989 (UtC 6098 1,170±60 BP) (Brown, 2006), which is a product of the extensive alteration of the natural drainage system in the mid to late Saxon period (Brunning, 2010).

CONCLUSIONS

From the dating of the deepest borehole and its basal depth (below -10 m O.D. and probably c. -17-30 m O.D.), the formation of the Siger channel is likely to be Early Holocene c. 10,000-8,000 BP initially with river flow from the Brue Valley then taking increasing tidal influx as sea level rose during the Early Holocene and being one of the conduits for net landward sediment influx over the last 9,000 years. The mid-Holocene relative reduction in sea level rise allowed peats to form in the inland Brue Valley and this displaced channels to the south and eventually to the north through the Panborough Gap

(Aalbersberg, 2000; Brown, 2006; Aalbersberg and Brown, 2011). So during the mid-Holocene and early Late Holocene the channel was probably inactive or only took local tidal flows and the channel partially infilled with estuarine sediments. For whatever cause, probably a combination of land subsidence through compaction and possibly increased tidal range and/or storminess (Allen, 2005), the channel was re-activated in the Late Holocene (c. 3,000 BP) as a salt-marsh creek at the same time as transgressive events are recorded in the Axe, Brue and Parrett Valleys. This creek produced continuous sedimentation in the area until sometime in the Late Holocene between the 8th Century AD and c. 1,100 AD, by which time it was buried by the sand-dunes that had formed the Berrow sand barrier system. Its demise may be linked to extensive modification of the river systems in the mid to late Saxon period.

Given the limited current dating of the channel's history and the variable dates for the start of sedimentation of the upper clay in the western Levels, this scenario must be viewed as hypothetical and provisional. However, if it is correct the Siger is an example of a fossilised enlarged tidal meander which was increasingly dominated over time by tidal flow due to inland changes in the Brue Valley hydrological network and relative land-sea level changes. The plan-form form of the network above the tidal meander is a model for 'natural' tidal creek systems that may be created by tidal inundation by managed coastal realignment, as is happening on the Stert peninsular presently. The Siger could also provide an accurate relative sea level record and tidal range estimate if improved dating of the sequence becomes possible.

ACKNOWLEDGEMENTS

This work was funded by a Leader+ European Commission Programme Project awarded to Somerset County Council ('The Lost Islands of Somerset' project). The authors must also thank Laura Basell of Geography, Archaeology and Palaeoecology, Queens University Belfast, Belfast, and Kevin Williams of Reading University for his assistance in the field. Lyn Ertle is thanked for cartographic assistance.

REFERENCES

AALBERSBERG, G. 1997. The Alluvial Fringes of the Somerset Level preliminary results. *Archaeology in the Severn Estuary*, **7**, 25-30.

AALBERSBERG, G. 2000. *The Alluvial Fringes of the Somerset Levels*. Unpublished PhD thesis, University of Exeter.

AALBERSBERG, G. and BROWN, A.G. 2011. The environment and character of the Glastonbury Lake Village: A re-assessment. *Journal of Wetland Archaeology*, **10**, 136-152.

ALLEN, J.R.L. 2000. Sea level, salt marsh and fen: shaping the Severn Estuary Levels in the later Quaternary (Ipswichian-Holocene). *Archaeology in the Severn Estuary*, **11**, 13-34.

ALLEN, J.R.L. 2005. Teleconnections and their archaeological implications, Severn Estuary Levels and the wider region: The 'fourth' and other mid-Holocene peats. *Archaeology in the Severn Estuary*, **16**, 17-65.

ALLEN, J.R.L. and BELL, M.G. 1999. A late Holocene tidal palaeochannel, Redwick, Gwent: late Roman activity and a possible early medieval fish trap. *Archaeology in the Severn Estuary*, **10**, 53-64.

ALLEN, J.R.L. and RAE, J.E. 1987. Late Flandrian shoreline oscillation in the Severn Estuary: a geomorphological and stratigraphical reconnaissance. *Philosophical Transactions of the Royal Society*, **B315**, 185-230.

ANDREWS, J., GILBERTSON, D. and HAWKINS, A. 1984. The Pleistocene succession of the Severn Estuary: a revised model based upon amino acid racemization studies. *Journal of the Geological Society*, **141**, 967-974.

ANHERT, F. 1960. Meanders in the Chesapeake Bay Area. *Geographical Review*, **50**, 390-401.

BATTARBEE, R.W. 1986. Diatom analysis. In: BERGLUND, B.E. (Ed.), *Handbook of Holocene Palaeoecology and Palaeohydrology*. Wiley, Chichester, 527-570.

BROWN, A.G. 2006. The Brue Valley and Glastonbury Lake Village. In: HUNT, C.O. and HASLETT, S.K. (Eds), *Quaternary of Somerset Field Guide*. Quaternary Research Association, London, 86-103.

BRUNNING, R. 2010. Taming the Floodplain: River Canalisation and Causeway Formation in the Middle Anglo-Saxon Period at Glastonbury, Somerset. *Medieval Archaeology*, **54**, 325-336.

BRUNNING, R. and FARR-COX, F. 2005. The river Siger rediscovered: LIDAR survey and relict landscape on the Somerset Claylands. *Archaeology in the Severn Estuary*, **16**, 7-15.

CAMPBELL, S., HUNT, C.O., SCOURSE, J.D., KEEN, D.H. and STEPHENS, N. 1998. *Quaternary of South-West England*. Joint Nature Conservancy Committee, Chapman & Hall, London.

COOKE, N. 2010. The new M4 project: sites identified on the Gwent Levels through the use of LiDAR data. *Archaeology in the Severn Estuary*, **21**, 29-45.

CROUDACE, I.W., RINDBY, A. and ROTHWELL, R.G. 2006. ITRAX: description and evaluation of a new multi-function X-ray core scanner. In: ROTHWELL, R.G. (Ed.), *New Techniques in Sediment Core Analysis*. Geological Society, London, Special Publications, 267, 51-63.

DRUCE, D. 1998. Late Mesolithic to early Neolithic environmental change in the central Somerset Levels; recent work at Burnham-on-Sea. *Archaeology in the Severn Estuary*, **9**, 17-29.

EDWARDS, H. 1998. *The charters of the Early West Saxon Kingdom*. Oxford, BAR British Series, 198.

EDWARDS, R.J. 2006. Mid-to late-Holocene relative sea level change in southwest Britain and the influence of sediment compaction. *The Holocene*, **16**, 575-587.

FRENCH, J.R., and STODDART, D.R. 1992. Hydrodynamics of salt marsh creek systems: Implications for marsh morphological development and exchange. *Earth Surface Processes and Landforms*, **17**, 235-252.

GODWIN, H. 1941. Studies in the post-glacial history of the British vegetation. VI. Correlation in the Somerset Levels. *New Phytologist*, **40**, 108-132.

GODWIN, H. 1943. Coastal peat beds of the British Isles and North Sea. *Journal of Ecology*, **31**, 199-247.

GODWIN, H. 1955. Studies of the post-glacial history of British vegetation XIII. The Meare Pool region of the Somerset Levels. *Philosophical Transactions of the Royal Society*, **B239**, 161-190.

GODWIN, H. 1981. *The Archives of the Peat Bogs*. Cambridge University Press, Cambridge.

HASLETT, S.K., DAVIES, P., CURR, R.H.F., DAVIES, C.F.C., KENNINGTON, K., KING, C.P. and MARGETTS, A.J. 1998. Evaluating late-Holocene relative sea-level change in the Somerset Levels, southwestern Britain. *The Holocene*, **8**, 197-207.

HASLETT, S.K., DAVIES, P., CURR, R.H.F., DAVIES, C.F.C., MARGETTS, A.J., SCOTNEY, K.H., THORPE, D.J. and WILLIAMS, H.O. 2000. The changing estuarine environment in relation to Holocene sea-level and the archaeological implications. *Archaeology in the Severn Estuary*, **11**, 35-53.

HASLETT, S.K., HOWARD, K.L., MARGETTS, A.J. and DAVIES, P. 2001. Holocene stratigraphy and evolution of the northern coastal plain of the Somerset Levels, UK. *Proceedings of the Cotteswold Naturalists' Field Club*, **42**, 78-88.

HAWKINS, A. and KELLAWAY, G. 1973. Burtle Clay of Somerset. *Nature*, **234**, 216-217.

HEYWORTH, A. and KIDSON, C. 1982. Sea-level changes in southwest England and Wales. *Proceedings of the Geologists' Association*, **93**, 91-111.

HOLLINRAKE, C. and HOLLINRAKE, N. 2001. Walpole landfill site, Somerset. *Archaeology in the Severn Estuary*, **12**, 119-125.

HOUSLEY, R.A., STRAKER, V. and COPE, D.W. 2000. The Holocene peat and alluvial stratigraphy of the Upper Brue valley in the Somerset Levels based on Soil Survey data of the 1980's. *Archaeology in the Severn Estuary*, **10**, 11-23.

JENNINGS, S., ORFORD, J.D., CANTI, M., DEVOY, R.J.N. and STRAKER, V. 1998. The role of relative sea-level rise and changing sediment supply on Holocene gravel barrier development: the example of Porlock, Somerset, UK. *The Holocene*, **8**, 165-181.

JONES, J., TINSLEY, H., MCDONNELL, R., CAMERON, N., HASLETT, S. and SMITH, D. 2005. Mid Holocene Coastal Environments from Minehead Beach, Somerset, UK. *Archaeology in the Severn Estuary*, **15**, 49-69.

KIDSON, C. and HEYWORTH, A. 1978. Holocene eustatic sea level change. *Nature*, **273**, 748-750.

KIDSON, C., HAYNES, J. and HEYWORTH, A. 1974. The Burtle Beds of Somerset-glacial or marine? *Nature*, **251**, 211-213.

KIDSON, C., GILBERTSON, D., HAYNES, J., HEYWORTH, A., HUGHES, C. and WHATLEY, R. 1978. Interglacial marine deposits of the Somerset Levels, South West England. *Boreas*, **7**, 215-228.

LENNON, G.W. 1963. A frequency investigation of abnormally high tidal levels at certain west coast ports. *Proceedings of the Institution of Civil Engineers*, **25**, 451-484.

- LONG, A.J., DIX, J.K., KIRBY, R., LLOYD JONES, D., ROBERTS, D.H., CROUDACE, I.W., CUNDY, A.B., ROBERTS, A. and SHENNAN, I. 2001. *The Holocene and recent evolution of Bridgwater Bay and the Somerset Levels*. University of Durham, Durham.
- MARANI, M., LANZONI, S. and ZANDOLIN, D. 2002. Tidal meanders. *Water Resources Research*, **38**, 7-1-7-14.
- MCDONELL, R. 1993. Preliminary archaeological assessment in Bridgwater bay: Gore Sands and Stert Flats. *Archaeology in the Severn Estuary*, **1993**, 41-46.
- MOORE, P.D., WEBB, J.A. and COLLINSON, M.E. 1991. *Pollen Analysis*. Blackwells, Oxford.
- MURRAY, J.W. and HAWKINS, A.B. 1976. Sediment transport in the Severn Estuary during the past 8000-9000 years. *Journal of the Geological Society of London*, **132**, 385-398.
- SAWYER, P.H. 1968. *Anglo-Saxon Charters*. Royal Historical Society, London.
- SOLARI, L., SEMINARA, G., LANZONI S., MARANI, M. and RINALDO, A. 2002. Sand bars in tidal channels Part 2. Tidal meanders. *Journal of Fluid Mechanics*, **451**, 203-238.
- STURT, F., DIX, J.K., SCAIFE, R.G., GRANT, M.J., BRAY, S., CAMERON, N., EDWARDS, R.J., GRIFFITHS, S., STEADMAN, S., THOMPSON, C.E.L. and JONES, J. In Press. Lost landscapes of the Mesolithic: Bristol Channel UK. *The Holocene*.
- TUCKER, M.E. 1982. *The Field Description of Sedimentary Rocks*. Geological Society of London Handbook, Geological Society, London.
- WALKER, M.J.C., BERKELHAMMER, M., BJÖRCK, S., CWYNAR, L.C., FISHER, D.A., LONG, A.J., LOWE, J.J., NEWNHAM, R.M., RASMUSSEN, S.O. and WEISS, H. 2012. Formal subdivision of the Holocene Series/Epoch: a Discussion Paper by a Working Group of INTIMATE (Integration of ice-core, marine and terrestrial records) and the Subcommittee on Quaternary Stratigraphy (International Commission on Stratigraphy). *Journal of Quaternary Science*, **27**, 649-659.
- WALLACE, K.J., CALLAWAY, J.C. and ZEDLER, J.B. 2005. Environment: A 5-year Experiment at Tijuana Estuary, California. *Estuaries*, **28**, 795-811.