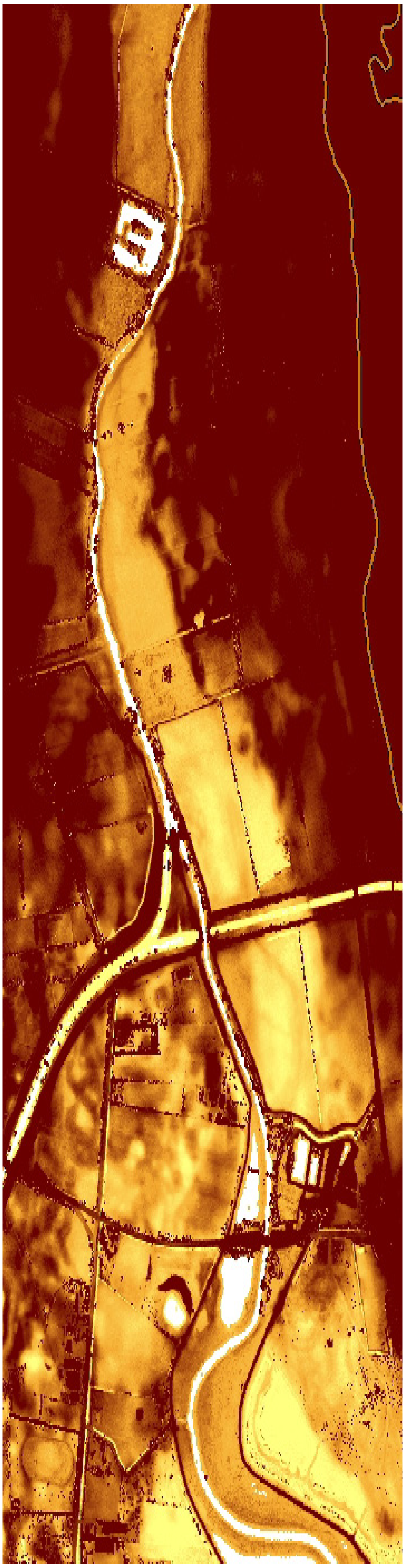

THE SUFFOLK RIVER VALLEYS PROJECT, PHASE 2: An assessment of the potential and character of the palaeoenvironmental and geoarchaeological resource of Suffolk river valleys affected by aggregate extraction

Funded by Aggregates Levy Sustainability Fund
Administered by English Heritage

Tom Hill, William Fletcher, Ben Gearey & Andy Howard

http://www.suffolk.gov.uk/Environment/Archaeology/MineralsAndArchaeology/SuffolkRiverValleysProject.htm

PN 4772/ANL

THE SUFFOLK RIVER VALLEYS PROJECT, PHASE 2: AN ASSESSMENT OF THE POTENTIAL AND CHARACTER OF THE PALAEOENVIRONMENTAL AND GEOARCHAEOLOGICAL RESOURCE OF SUFFOLK RIVER VALLEYS AFFECTED BY AGGREGATE EXTRACTION

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March 2008

cover plate: LiDAR image of the River Little Ouse, located c. 0.75km northwest of Fornham All Saints, Suffolk (TL 583424 268323; LiDAR data © Environment Agency)

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1 INTRODUCTION

This report documents the results of Phase 2 of the Suffolk River Valleys Project. During Phase 1 of the project, the rivers Waveney, Little Ouse, Lark, Gipping and Black Bourn were all identified as systems with significant archaeological potential lacking supporting palaeoenvironmental and to some extent, cultural evidence. Generic models of alluvial development of such low gradient fluvial systems suggests that the build up of fine-grained sediment through overbank sedimentation has probably resulted in the burial of significant archaeological remains within such valley floor environments (Howard and Macklin, 1999). The study of these valleys in particular was considered important because of the direct impact of past, present and future aggregate extraction on the landscape and cultural heritage of Suffolk. Current research through the Aggregates Levy Sustainability Fund (ALSF) in Suffolk is addressing the issues regarding the identification and quantification of the archaeological record in the minerals resource areas (*The Aggregate Landscape of Suffolk: The Archaeological Resource*. PNUM 3987; Plouviez *et al*., 2007), but no provision had been made within the project for the characterisation and investigation of the palaeoenvironmental and geoarchaeological resource. The Suffolk River Valleys Project (PNUM 4772) subsequently developed through the identification of this major gap in our knowledge. The project was therefore originally designed to:

- Assess and characterise the geoarchaeological and palaeoenvironmental resource of the major river valleys of Suffolk affected by mineral extraction

- Investigate how the evolution of different river catchments relates to the preservation and character of archaeological sequences in these areas

- Assess the potential for investigating the role that factors such as human activity and climate change have played in the evolution of the different river valleys

- Use the information to create a research agenda for Cultural Resource Management for the Suffolk river valleys and thus aid in the design and development of future prospection and mitigation strategies in areas susceptible to or affected by aggregate extraction

- Enhance the Historic Environmental Record (SMR/HER) held by Suffolk County Council to inform future cultural resource management

- Disseminate the results of the research to the stakeholders, including the general public

This project report (draft submitted March 2007, revised full document submitted March 2008) demonstrates that the county has a rich and diverse archaeological record, but that considerably less information relating to the associated palaeoenvironmental record was available (Hill *et al*., 2008a), especially in the case of landscape changes over the last *c*. 10,000 yrs (i.e. the post-glacial or Holocene period). It also demonstrated that deposits of high palaeoenvironmental potential (pollen, coleopteran etc) were present in river valleys across the county. Moreover, it was considered that targeted research would assist in devising suitable planning strategies in areas affected by aggregate extraction.

However, although there was no clear evidence within the pollen sequences collected during the fieldwork phase to suggest significant disturbances or sediment reworking, the radiocarbon dating program produced highly anomalous results for each site. Samples from Beccles, Hengrave and Ixworth all produced inverted dates, in addition to occasional modern ages being encountered within the stratigraphic sequences (Hill et al., 2008b). It was considered beyond the scope of the original project to assess the precise reasons for these anomalies in detail. A subsequent meeting with the English Heritage scientific dating team (Mr Derek Hamilton, Dr Peter Marshall) established that sampling protocols during both fieldwork and laboratory analysis did not appear to be responsible for the erroneous radiocarbon results and it was therefore regarded as essential to investigate in further detail the reasons for such inconsistencies. From the curatorial perspective of Suffolk County Council, it was important to assess whether there were generic problems associated with radiocarbon dating of valley floor deposits in the East Anglian region. Phase 1 of the Suffolk River Valleys Project had highlighted the abundance of valuable palaeoenvironmental records within valley lowlands susceptible to aggregate extraction. A clear understanding of the causes of this dating problem was therefore necessary to assist subsequent palaeoenvironmental work within the region and to inform the management of deposits of palaeoenvironmental potential at risk through aggregate extraction.

The objective of the Suffolk River Valleys Phase 2 project proposal was to explore the potential causes of problems encountered during radiocarbon dating in Suffolk. Working in close collaboration with the English Heritage scientific dating team, who advised on the project design, the principle aim's of the second phase of study were to:

- Revisit the three sites investigated during Phase 1 of the Suffolk River Valleys Project (Beccles, Hengrave and Ixworth) which had produced promising palaeoenvironmental sequences but anomalous radiocarbon dates.

- To apply a rigorous sampling and radiocarbon dating methodology to samples recovered from these sites and hence investigate the factors behind the initial set of radiocarbon results.

As well as addressing issues specifically related to stratigraphy and chronology of these river valley sediments, **value-added** dimensions of this research included:

- Drafting of the outline of a methodological research paper in collaboration with the English Heritage scientific dating team and other academics working in floodplain environments using ASLF funding, to compare palaeoenvironmental data sets for which radiocarbon dating has produced inconsistent results.

- The development of a methodology for Suffolk County Council (and the wider East Anglian region) for assisting in the formulation of mitigation strategies for cases of floodplain development and aggregate extraction with specific reference to radiocarbon dating.

2 BACKGROUND TO SUFFOLK RIVER VALLEYS PROJECT PHASE 2

2.1 PREVIOUS RESEARCH IN THE SUFFOLK RIVER VALLEYS

An extensive literature survey was undertaken as part of Phase 1 of the Suffolk River Valleys Project and identified the significant lack of previous palaeoenvironmental work undertaken within the county (Hill *et al.*, 2008a). Previous studies had primarily focused on Pleistocene deposits due to the importance of East Anglia in the identification of a number of key stratigraphic type sites for Quaternary climatic stages (e.g. Cromerian, Anglian, Hoxnian, Ipswichian; Wymer, 1999). This was further accentuated by the rich Palaeolithic record relating to these periods, with the earliest known phase of human occupation in mainland UK being identified at Pakenham (Parfitt *et al.*, 2005). Much of the deposits relating to the pre-Holocene periods have also received considerable attention due to their value as a source of aggregates. The study of these sequences in particular was considered important because of the direct impact of past, present and future aggregate extraction on the landscape and cultural heritage of Suffolk. Such fundamentally important Palaeolithic and aggregate discoveries are hence partly responsible for having deflected palaeoenvironmental research away from the more abundant archives dating to the Holocene period. The Suffolk River Valleys Project was subsequently commissioned through the identification of this major gap in knowledge. The project was therefore designed to:

- Provide baseline data to characterise the geomorphological character of selected Suffolk valley floors and the potential of the landforms and sediments recorded within them for palaeoenvironmental reconstruction of the surrounding archaeological landscape.

- Provide an assessment of the potential for the preservation of archaeological remains within Suffolk valleys through an understanding of their geomorphological history.

- Review and collate both the grey and published palaeoenvironmental and archaeological literature into a single volume, chronologically ordered review.

The Phase 1 literature review (Hill *et al.*, 2008a) discovered that the majority of valuable geoarchaeological and palaeoenvironmental evidence relating to the Holocene period was derived from grey literature in the form of small-scale archaeological interventions such as site evaluations (e.g. Hall, 2006) or as specialist input within larger projects (e.g. Wiltshire, 1990). The potential for the survival and preservation of river valley deposits suitable for palaeoenvironmental assessment in Suffolk has been shown to be considerable through excavations at Scole in the Waveney Valley (Ashwin and Tester, *in prep*), at Brandon (Carr *et al*, 1988) and along the River Gipping (Rose *et al.*, 1980) for example. As a result, palaeoenvironmental work has subsequently become part of commercially funded (PPG 16) investigations in the area.

The results of the literature review enabled the identification of a number of regions within Suffolk where an abundance of archaeological discoveries were concentrated but in which a significant lack of supporting palaeoenvironmental research was present. In addition, the study of these areas in particular was considered important because of the potential impact of aggregate extraction on the landscape and cultural heritage of Suffolk (see Figure 1).

Phase 1 of the Suffolk River Valleys Project therefore concentrated on identifying and assessing the palaeoenvironmental and geoarchaeological potential of five regions within the Suffolk lowlands; the areas in and around Beccles, Brandon, Hengrave, Hoxne and Ixworth (Hill *et al*., 2008b). Upon identification of these five regions, it was necessary to locate specific study areas within each region suitable for fieldwork and subsequent palaeoenvironmental analysis. Due to the proven success of palaeoenvironmental reconstructions from waterlogged organic deposits, combined with their typical chronological integrity, the identification of potential sites was based on locating stratigraphic sequences such as those commonly encountered within either relict channels (palaeochannels) or organic-rich floodplain settings. This was achieved through the utilisation of a number of resources available through the University of Birmingham, Suffolk County Council Archaeological Service (SCCAS) and project partners the Environment Agency. A full breakdown of each resource, combined with the justification for the subsequent identification of each site location is provided in Hill *et al.* (2008b). A brief summary of each is provided here:

- **Aggregates History** - As part of the commitment to the core ALSF objectives, the areas were selected based on the close proximity of extraction sites. The type of aggregates and extractive industries in the region are varied, and more recently this has included larger scale aggregates quarries, focusing on chalk, as well as sand and gravel. Using information provided by the Aggregates Landscape of Suffolk Project (PNUM 3987) (See figure 1) current permissions and active quarries were plotted alongside sites previously targeted for extraction. Targets were identified close to these areas, however not so close so that palaeoenvironmental deposits could have become disturbed or adversely affected by water table fluctuation and draw down.

- **Historic Environment Record (HER) Data** - Suffolk County Council Sites and Monuments Records (SMR) was provided as MapInfo MIF files and incorporated into a Suffolk River Valleys Project GIS. The SMR provided information relating to the spatial distribution of archaeological finds throughout Suffolk. The SMR data includes fully recorded sites and excavations, in addition to isolated spot finds. In addition, the SCCAS provided a number of GIS 'layers' including surface soil, bedrock geology and parish boundary data.

- **Aerial Photograph Acquisition and Analysis** - Aerial photographs were used to identify visual topographic features that may suggest the preservation of organic deposits. The aerial photographs were supplied by SCCAS and included vertical photographs taken from two separate periods (from the 1940’s as well as photographs taken in 1999). Comparisons were made between aerial photographs taken in the 1940's and in 1999 to identify palaeochannels and other significant landscape features that were not visible

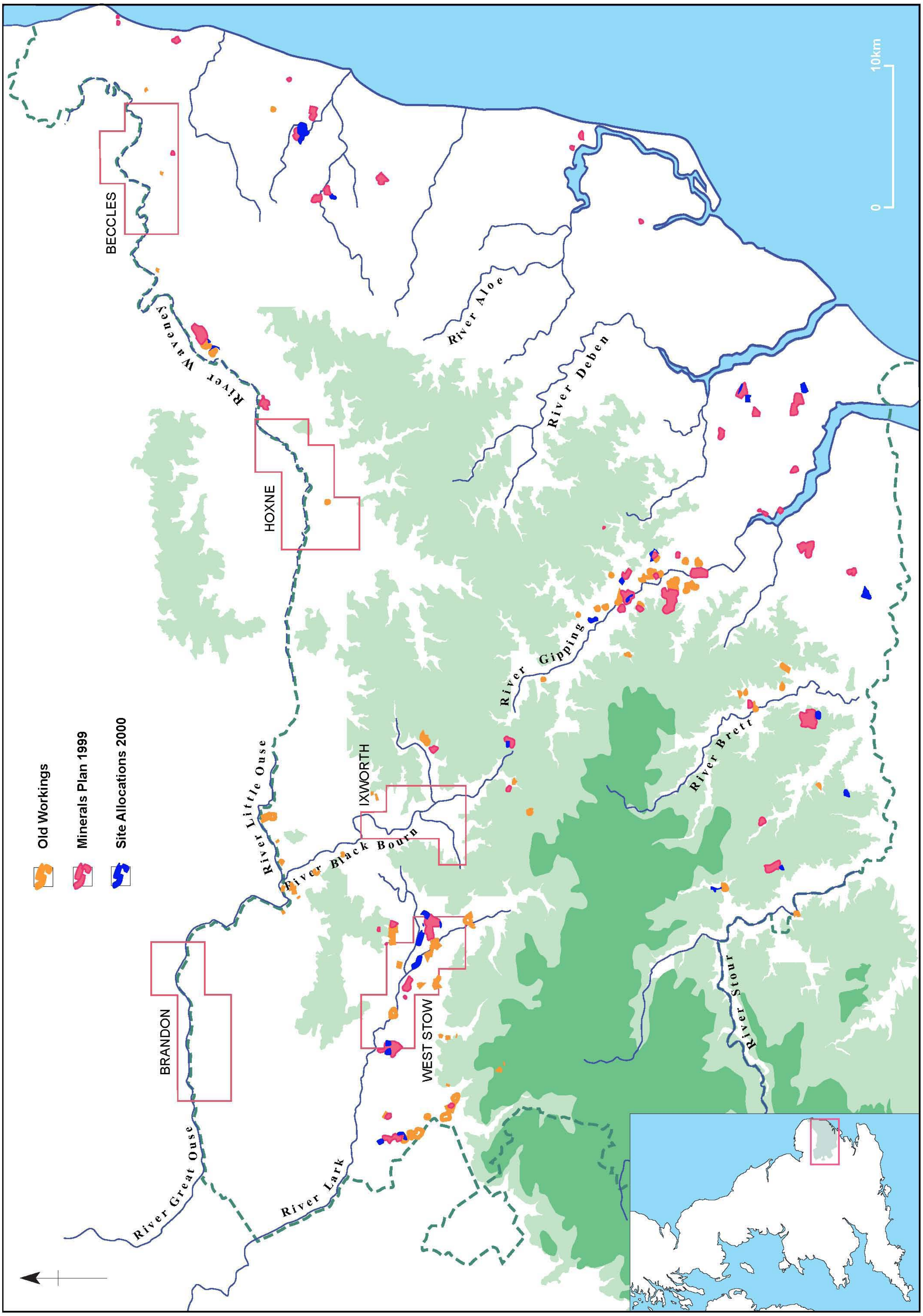


Figure 1: Map of Suffolk identifying the primary water courses, site locations chosen for assessment and the distribution of past and present aggregate sites within the county.

on the later prints because they had had been destroyed by ploughing, gravel extraction or other forms of development.

- **LiDAR Acquisition and Analysis** - A request for airborne laser altimetry (LiDAR) data was granted by the Environment Agency. The topographic information obtained through LiDAR can be analysed and interpreted to identify site locations with potential organic-rich deposits, such as those encountered on waterlogged floodplains or relict channels. A LiDAR Digital Surface Model (DSM) was created for each study area, which was examined to identify significant landscape features, such as palaeochannels and terraces. LiDAR data was subsequently made available for all five study areas previously identified as having significant geoarchaeological potential.

2.2 RESULTS FROM SUFFOLK RIVER VALLEYS PROJECT PHASE 1

The utilisation of the above resources enabled the identification of five study sites suitable for palaeoenvironmental investigation. Access permission was granted for each of the chosen sites in the areas of Beccles, Brandon, Hengrave, Hoxne and Ixworth (see Figure 1). The first phase of fieldwork took place in July and August 2006, during which coring surveys at each site were carried out to investigate the nature of the stratigraphic archives present. The coring strategy for each field area was site specific to ensure the palaeoenvironmental potential previously identified during the desk-based assessment (e.g. the potential location of palaeochannels, waterlogged peatlands etc) was fully understood.

Upon completion of coring at each site, an assessment of each stratigraphic archive was undertaken in order to identify whether deposits of palaeoenvironmental potential were present. Of the five sites, two were found to be of low potential. The desk-based assessments for the chosen sites at Brandon and Hoxne had suggested potential palaeochannel features. However, fieldwork had indicated that the LiDAR and GIS-based interpretations were incorrect. A full summary of these site assessments and subsequent palaeoenvironmental interpretations relating to the sites not deemed suitable for further study can be found in Hill *et al*. (2008b). However, at Beccles, Hengrave and Ixworth, sedimentary sequences rich in organic material had been encountered, from which sample cores were extracted. A single sample core was taken from Hengrave, where a palaeochannel feature, originally identified during an assessment of parish boundary data, was encountered. At Ixworth, coring had identified a sequence of organic-rich deposits within Mickle Mere Nature Reserve interpreted as evidence for *in-situ* organic accumulation within a floodplain setting. A sample core was extracted from this location for palaeoenvironmental assessment. However, at Beccles, two sample cores were taken due to the considerable spatial variation in stratigraphy. A full break down of the site specific fieldwork results is provided in Hill *et al.* (2008b).

Multi-proxy palaeoenvironmental assessments were undertaken on the cores taken from the three sites. A suite of assessments were applied, dependent on the type of deposits encountered, and included pollen, beetle and diatom analyses. In addition, each core assessment was supported through a radiocarbon dating programme to provide chronological control. The programme strategy was developed through collaboration with the English Heritage scientific dating team, with dating concentrated on stratigraphic boundaries within each core sequence. Single AMS radiocarbon measurements were undertaken on plant macrofossil remains taken from the selected sedimentary horizons.

Phase 1 of the project thus successfully identified the presence of organic-rich deposits within the lowlands of Suffolk. The multi-proxy assessments undertaken on the four sample cores indicated that, in general, the preservation of pollen and beetles was good. Each of the proxy techniques commonly provided abundant and interpretable assemblages which contributed to the reconstruction of palaeolandscape conditions responsible for the development of individual sedimentary sequences. In addition, the high-resolution sampling strategies undertaken during pollen and diatom assessments provided apparently biostratigraphically conformable results. However, radiocarbon dating of all four sequences produced anomalous results. Six of the 36 samples submitted provided insufficient carbon. Those samples that yielded sufficient carbon for dating, displayed inversions and modern ages deep within some of the sequences. Whilst sampling of Beccles Core 2 using a gouge corer may have been a contributing factor to some of the anomalous results, a subsequent meeting with an English Heritage dating specialist (Dr Peter Marshall) established that sampling protocols applied during both fieldwork and laboratory analyses did not appear to be responsible for providing all the erroneous radiocarbon results. A number of potential explanations were considered including the potential impact of vertical mixing and disturbance of the organic deposits through human and/or pastoral activity (trampling and poaching), as well as the potential for invasive plant species growing down into the deposits (*Phragmites* roots and stems were found to have penetrated Iron Age oak posts encountered at Beccles for example).

It was beyond the scope of the original Suffolk River Valleys Project to consider the precise reasons for the anomalous radiocarbon results in detail. English Heritage thus commissioned a second phase to the Suffolk River Valleys Project (Fletcher *et al.*, 2007) to investigate the sedimentary sequences from Beccles, Hengrave and Ixworth further. Suffolk River Valleys Phase 2 (PNUM 4772/ANL) was therefore designed through collaboration between the University of Birmingham, SCCAS and the scientific dating team at English Heritage to assess the chronostratigraphic integrity of the deposits at these locations.

3 SUFFOLK RIVER VALLEYS PROJECT PHASE 2

3.1 RESEARCH METHODOLOGY

Fieldwork for Phase 2 was undertaken in July and August 2007. Each site in question was revisited in order to take new cores for radiocarbon dating. To enable close comparisons between the radiocarbon dating results of Phases 1 and 2, the new sample cores were taken from close proximity to those locations used in the original phase of fieldwork. Due to the suggestion that potential dating anomalies (at the Beccles site at least) may have resulted from disturbance to the upper layers of peat, it was proposed that trial trenching of the locations be undertaken to allow detailed inspection of the stratigraphy of these uppermost deposits. Monolith tins were then used to subsample the open trench faces. Core extraction using a Russian Corer was then undertaken to sample the remaining stratigraphic sequence to depth.

As the primary focus of Phase 2 of the project was to assess the issues raised regarding the chronostratigraphic integrity of each of the sedimentary archives, a framework for radiocarbon dating was developed for each core sequence. In collaboration with the English Heritage scientific dating team, it was proposed that initial radiocarbon dating should be undertaken on samples from the top, middle and bottom of each core. Similar stratigraphic units and comparable depths to those sampled during Phase 1 were targeted to assist in a re-evaluation of the original results. At each radiocarbon sample depth, individual plant macrofossil samples were collected in addition to bulk samples. It was also agreed that this initial phase of dating must be undertaken prior to any palaeoenvironmental assessments (pollen, beetle analyses etc) to ensure that a reliable sedimentary sequence was present at each site. If a chronostratigraphically reliable archive was present, it was proposed that high-resolution radiocarbon dating would then be undertaken throughout each core profile, complemented with a suite of palaeoenvironmental assessments. However, timetabling problems resulted in the completion of only the first stage of radiocarbon dating within the timeframe allowed by the current ALSF programme (2007-2008). As a consequence of rescheduling, the additional high-resolution radiocarbon dating supported by palaeoenvironmental assessments could not be undertaken.

3.2 SITE LOCATIONS AND FIELDWORK RESULTS

A full discussion of each site location can be found in Hill *et al.* (2008b) and this section provides a summary of the fieldwork undertaken during Phase 2 of the project. In addition, specific fieldwork techniques designed to reduce the potential for sample contamination are also discussed. A full breakdown of the stratigraphy of each sample core using the Troels-Smith (1955) classification scheme is provided in Appendix I.

3.2.1 Beccles

Sedimentary coring was undertaken as part of Phase 1 of the Suffolk River Valleys Project in addition to field investigations taking place during an archaeological excavation on Beccles Marshes (Chapman *et al.*, 2007) (TM 642355 291900). The results indicated that the organic deposits varied in depth from *c*. 2.50 m to *c*. 6.50 m across the site and a *c*. 6 m peat sequence was extracted for palaeoenvironmental assessment as part of Phase 1 (Beccles 2007 Core 1). A second core was also sampled to the north where the stratigraphy included estuarine clays and silts overlying the floodplain peat unit (Beccles 2007 Core 2). Palaeoenvironmental assessments indicated a biostratigraphically reliable sequence from both cores despite low pollen concentrations. Radiocarbon dating results included inverted dates as well as occasional modern ages deep within Beccles Core 2. Two further cores were taken from the site as part of Phase 2, the core locations relative to the fieldwork undertaken during Phase 1 are shown in Figure 2. It was concluded that no further palaeoenvironmental assessments were deemed necessary relating to the estuarine sedimentary sequence. The overall absence of suitable plant macrofossils preserved within the estuarine deposits encountered during Phase 1 (accounting for four of the six failed AMS radiocarbon dates) was regarded as restricting potential for further radiocarbon dating.

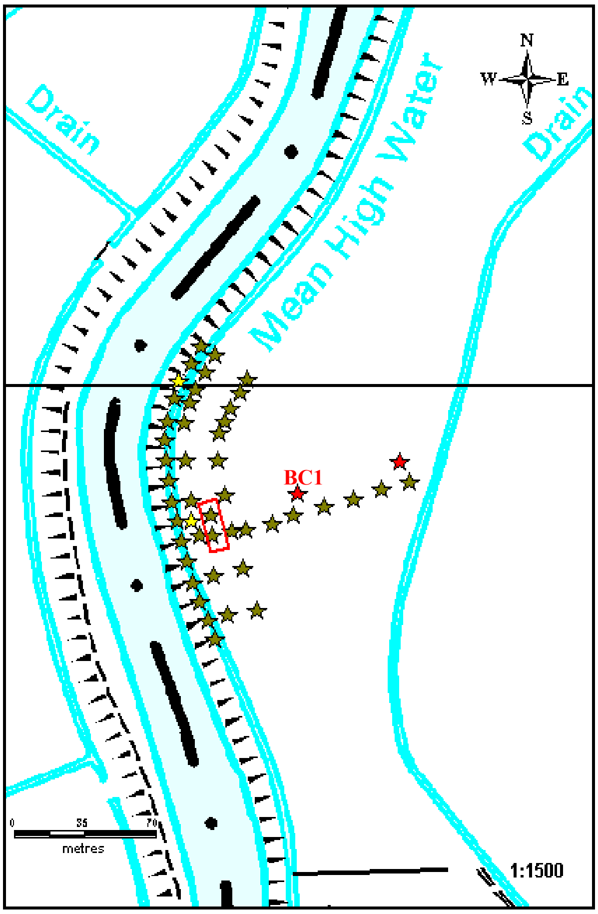


Figure 2: Location of Phase 2 sample cores (Beccles 2008 Cores 1 and 2, highlighted in red) in relation to fieldwork undertaken during Phase 1.

The cores were located at a distance of *c*. 50 m (Beccles 2008 Core 1) and *c*. 100 m (Beccles 2008 Core 2) along a transect trending eastwards of the original Beccles Core 1. This was undertaken so that factors such as the potential for disturbance resulting from human activity at the archaeological site could be reduced, whilst maintaining a strong stratigraphic relationship to the original core location. In order to further prevent the potential for sample contamination from within the peat sequence, machine trenching was undertaken prior to sedimentary coring. This was undertaken to ensure the stratigraphic integrity at the sample location (i.e. ensure the upper sedimentary sequence has not been affected by post-depositional agricultural disturbance, dumping, peat cutting etc). Sampling using monolith tins was then undertaken commencing from where the stratigraphy was deemed *in-situ* down to the base of the trench (Figure 3). Below this depth to the base of the gravels, samples were extracted using a Russian Corer with a 0.05 m chamber diameter. The surface elevations of Beccles 2008 Core 1 and 2 were levelled to 0.028m O.D. and 0.017 m O.D. respectively. Core samples were taken in 0.50 m sections and stored in plastic guttering, labelled and wrapped for transport back to the laboratory at the University of Birmingham.

<u>Figure 3:</u> Trial trenching and monolith sampling of trench face undertaken for Beccles (2008) Core 1, Suffolk

3.2.2 Hengrave

A palaeochannel feature was identified at Hengrave during the desk-based assessment of Phase 1 and a core sequence subsequently recovered (TL 829505 691752). This site was revisited as part of Phase 2, and a core was taken *c.* 2 m east of the Phase 1 sample core location. The surface of the sample core location was levelled to 20.509m O.D. The core location relative to the fieldwork undertaken during Phase 1 is shown in Figure 4. Due to access restrictions however, machine trenching could not be undertaken to assess the stratigraphic integrity of the site prior to coring. A hand-dug trench was therefore excavated to a depth of *c.* 0.65 m. Deposits indicative of potential ground disturbance (brick fragments etc) were encountered to a depth of *c.* 0.38 m, below which an undisturbed well humified peat was identified. Monolith tins were used to sample to the base of the hand-dug trench (see Figure 5) below which coring was undertaken using a Russian corer down to basal gravels (at *c.* 3.65 m depth).

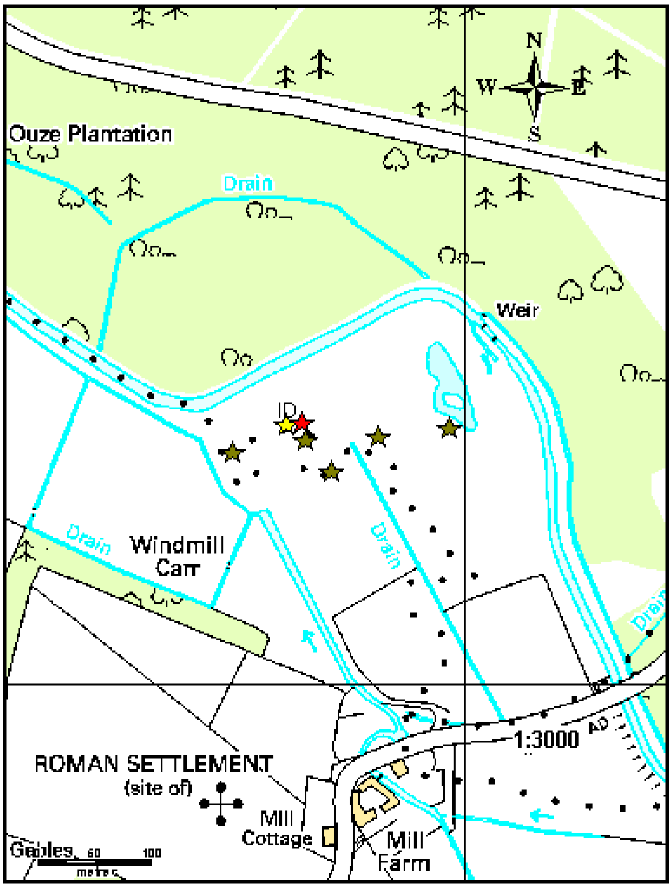


Figure 4: Location of Phase 2 sample core (highlighted in red) in relation to fieldwork undertaken during Phase 1.

Figure 5: Monolith sampling of hand-dug trench at Hengrave during fieldwork for Suffolk River Valleys Phase 2

3.2.3 Ixworth

A sequence of interbedded floodplain peat deposits had been identified and sampled on the floodplain of the River Black Bourn immediately south of Ixworth within Mickle Mere Nature Reserve (TL 593767 269749) during Phase 1 and was revisited as part of Phase 2. Access permission to the Mere was granted through Suffolk Wildlife Trust. Although the reserve had been partially re-flooded since 2006, it was possible to return to the approximate core location (Figure 6). As the site was located within a nature reserve, trenching was not permitted. As a consequence, the complete stratigraphic sequence was retrieved using a Russian corer, although a small slot was excavated to a depth of 0.50 m due to the highly compact and minerogenic nature of the upper floodplain deposits. The surface of the sampled core location was surveyed to 27.213m O.D.

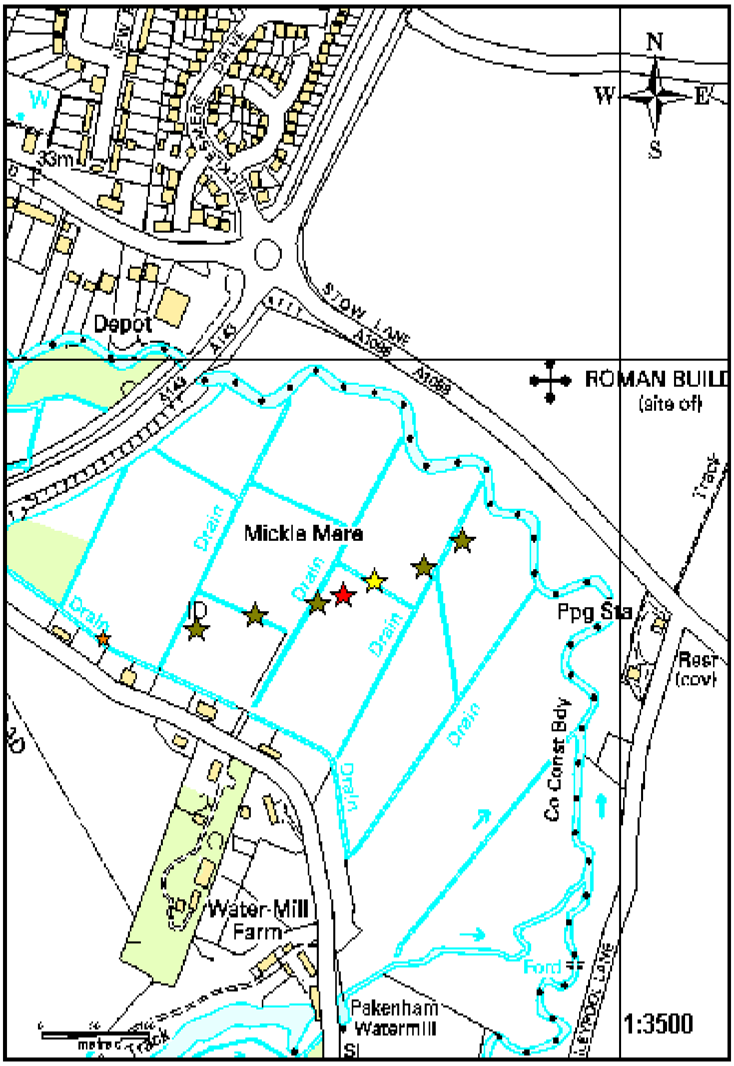


Figure 6: Location of Phase 2 sample core (highlighted in red) in relation to fieldwork undertaken during Phase 1.

4 RESULTS

Each sample core taken as part of Suffolk River Valleys Phase 2 was transported to the environmental laboratory at the University of Birmingham where the sediments and associated stratigraphy was described using Troels-Smith (1955). Due to the radiocarbon dating issues raised during Phase 1 of the project, detailed stratigraphic logging was undertaken to identify the variation in abundance and diversity of plant macrofossil remains. Sedimentary horizons with high levels of detrital material were noted, in addition to the stratigraphic relationship between each horizon and those being dated as part of Phase 2. A summary of core stratigraphy is provided in Appendix I. Each core was found to have good stratigraphic agreement with those taken during Phase 1.

4.1 RADIOCARBON PREPARATION

Prior to radiocarbon sample submission, samples were taken from each horizon and assessed for their pH and overall organic content (determined by loss on ignition (LOI) measurements). These were required to assess the potential for carbon contamination of the sedimentary sequences through the influence of hard water and/or in wash of allochthonous material. The results of the pH and LOI measurements are provided in Table 1. Twelve individual plant macrofossil samples and 12 bulk sediment samples were subsequently submitted to English Heritage in September 2007.

Sample No.	Sample Name	Organic content % *	Carbonate content % *	pH **
1	Hengrave 0.47 m	43.98	2.76	6.04
2	Hengrave 1.61 m	59.22	2.68	6.43
3	Hengrave 2.76 m	46.60	2.91	5.65
4	Ixworth 0.71 m	54.88	2.56	5.64
5	Ixworth 1.24 m	14.75	1.34	6.95
6	Ixworth 2.39 m	52.79	3.35	5.82
7	Beccles 2008 Core 1 : 0.84 m	79.12	2.98	3.85
8	Beccles 2008 Core 1 : 3.30 m	78.25	2.73	6.15
9	Beccles 2008 Core 1 : 4.60 m	71.77	3.61	4.83
10	Beccles 2008 Core 2 : 1.37 m	76.71	3.45	5.61
11	Beccles 2008 Core 2 : 3.59 m	70.25	1.74	5.98
12	Beccles 2008 Core 2 : 4.30 m	31.35	1.36	4.29

* For LOI, samples were oven dried at 105 degrees for 12hrs, organic content was then fired at 550 degrees for 4 hours carbonate content was fired at 950 degrees for 2 hours.

** Measurements for pH were achieved following the procedure of Catt (1980).

Table 1: Summary of LOI and pH measurements of the 12 sedimentary sampled for radiocarbon dating.

4.2 RADIOCARBON DATING METHODOLOGY

Radiocarbon age determinations were obtained on samples extracted from four cores:

- Beccles (2008) core 1;
- Beccles (2008) core 2;
- Hengrave (2008);
- Ixworth (2008)

The results reported below were intended to form an initial assessment of the radiocarbon dating potential of the three sites (Beccles, Hengrave and Ixworth), with it was hoped a more comprehensive programme of dating to follow. Unfortunately due to timetabling problems the first stage was only completed within the timeframe allowed by ALSF 2007-2008.

Fourteen macrofossil samples were submitted to the Scottish Universities Environmental Research Centre (SUERC), East Kilbride. These included the dating of a number of duplicate macrofossil fragments from the same sample depth for radiocarbon comparison (notably in Beccles 2008 Core 1 and 2). Samples were pre-treated by the acid-base-acid protocol (Stenhouse and Baxter 1983) and CO_2 obtained by combustion in pre-cleaned sealed quartz tubes (Vandeputte *et al* 1996). The purified CO_2 was converted to graphite (Slota *et al* 1987) for subsequent AMS analysis. The sample $^{14}C/^{13}C$ ratios were measured on the SUERC AMS, as described by Xu *et al* (2004).

Twelve bulk peat samples (weighing 72-103g) were submitted to the Centre for Isotope Studies, University of Groningen, The Netherlands (GrN). The samples were pre-treated using the acid/alkali/acid method (Mook and Waterbolk 1985) and measured using gas proportional counting (Mook and Steurman 1983). In all cases the acid insoluble/alkali soluble ('humic acid') and alkali/acid insoluble ('humin') fractions of the samples were separated after pre-treatment, combusted and measured. Each separation was carried out in a quantitative manner thus the total budget of carbon in the peat sample was conserved within the component fractions recovered for gas proportional counting. Both laboratories maintain continual programmes of quality assurance procedures, in addition to participation in international inter-comparisons (Scott 2003). These tests indicate no laboratory offsets and demonstrate the validity of the precision quoted.

4.3 RADIOCARBON RESULTS

The results, relating the radiocarbon measurements directly to calendar dates, are given in Tables 2-5 and in Figures 7, 10, 13, and 16 and are quoted in accordance with the international standard known as the Trondheim convention (Stuiver and Kra 1986). They are conventional radiocarbon ages (Stuiver and Polach 1977) and have been calibrated using the curves of Reimer *et al* (2004) and the computer program OxCal (4.0.5) (Bronk Ramsey 1995; 1998, 2001; 2008). The calibrated date ranges cited in the text and tables are those for 95% confidence. They are quoted in the form recommended by Mook (1986), with the end points rounded outwards to 10 years. The ranges in Tables 2-5 have been calculated according to the maximum intercept method (Stuiver and Reimer 1986). Unless otherwise stated, the red plots of the radiocarbon diagrams relate to alder (*Alnus glutinosa*) macrofossil fragments, the light blue plots relate to humic acid results, whilst the dark blue relate to the humin results and the black plots relate to the combined humic acid and humin results (see Figures 7, 10, 13 and 16). Additional results from the radiocarbon dating program can be found in Appendix II.

4.3.1 Beccles (2008) Core 1

Figure 7 provides a summary of the radiocarbon dating results for Beccles (2008) Core 1. Table 2 provides a full breakdown of the radiocarbon results obtained for each sample. All bulk and plant macrofossil samples submitted for radiocarbon consideration provided sufficient carbon for successful dating. All submitted plant macrofossil samples were *Alnus* remains (twig/wood fragments). Duplicate radiocarbon dating of separate macrofossil samples was undertaken at both 0.84 m and 3.30 m depths.

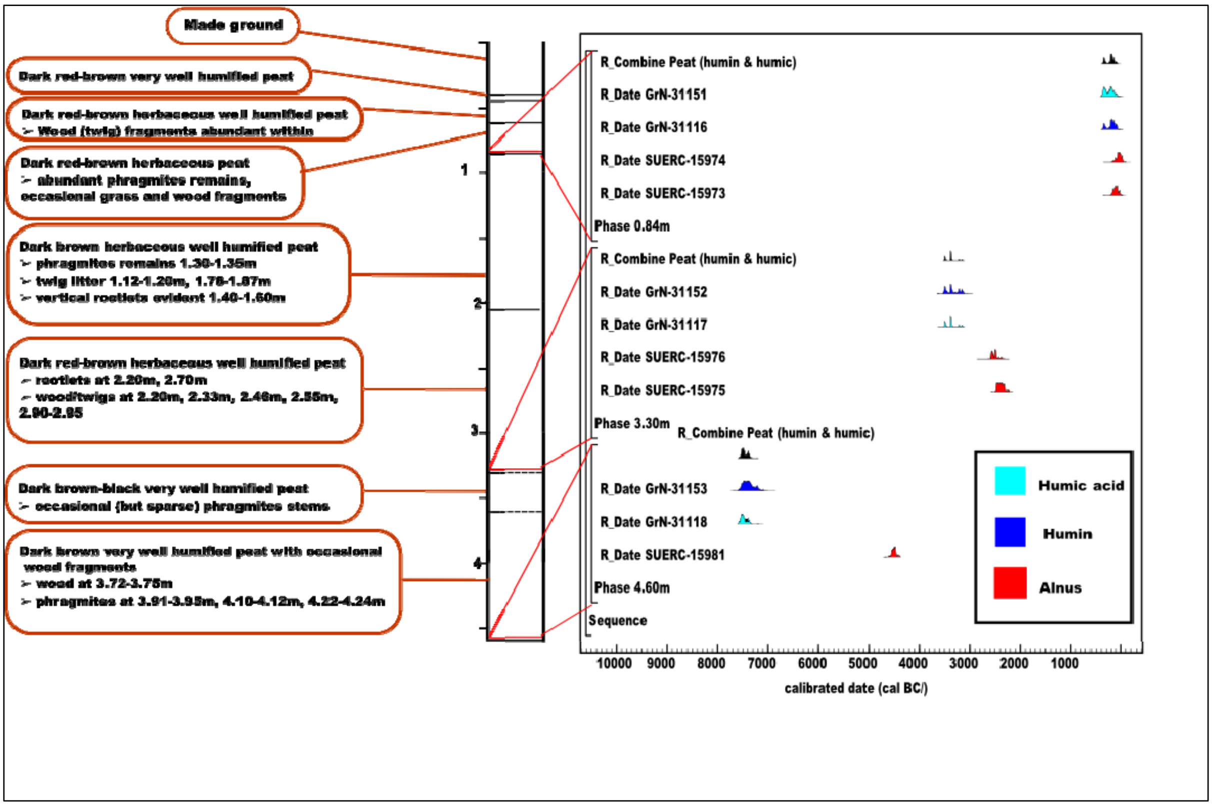


Figure 7: Probability distributions of dates from Beccles (2008) Core 1. Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993).

0.84 m

All four results from this level are deemed statistically consistent (T'=6.9; ν=3; T'(5%)=7.8; Ward and Wilson 1978) and the material may therefore be of the same actual age.

3.30 m

The four measurements from this level are not statistically consistent (T'= 347.155; ν=3;T'(5%)=7.8; Ward and Wilson 1978) and thus represent material of different ages. Although both the humin/humic acid fractions (T'=0.0; ν=1; T'(5%)= 3.8) and two *Alnus* fragments (T'=2.9; ν=1; T'(5%)= 3.8) are statistically consistent.

4.60 m

The three measurements from this level are not statistically consistent (T'=2576.412; ν=2; T'(5%)= 6.0; Ward and Wilson 1978) and it therefore contains material of different ages.

Lab code	Sample ID	Material	Organic Content	pH	δ13C (‰)	Radiocarbon age (BP)	Weighted mean	Calibrated date (95% confidence)
GrN-31116	I–0.84 m	Peat (Humin)	79%	3.9	-28.9	2130 ±40	2142±32 BP (T'=0.2; ν=1; T'(5%)= 3.8)	360-50 cal BC
GrN-31151	I–0.84 m	Peat (Humic acid)			-28.9	2160 ±50		
SUERC-15973	I–0.84 m A	Plant macrofossil: *Alnus* twig, (R Gale)			-29.5	2065 ±35		190–10 cal BC
SUERC-15974	I–0.84 m B	Plant macrofossil: *Alnus* twig (R Gale)			-28.1	2015 ±40		160–70 cal BC
GrN-31117	I–3.30 m	Peat (Humin)	78%	6.2	-28.0	4590 ±30	4590 ±26 BP (T'=0.0; ν=1; T'(5%)= 3.8)	3500–3340 cal BC
GrN-31152	I–3.30 m	Peat (Humic acid)			-28.7	4590 ±50		
SUERC-15975	I–3.30 m A	Plant macrofossil: *Alnus* wood (R Gale)			-30.8	3885 ±35		2480–2210 cal BC
SUERC-15976	I–3.30 m B	Plant macrofossil: *Alnus* wood (R Gale)			-30.7	3970 ±35		2580–2350 cal BC
GrN-31118	I–4.60 m	Peat (Humin)	72%	4.8	-28.4	8460 ±50	8427 ±43 BP (T'=1.6; ν=1; T'(5%)= 3.8)	7580–7370 cal BC
GrN-31153	I–4.60 m	Peat (Humic acid)			-28.0	8340 ±80		
SUERC-15981	I–4.60 m	Plant macrofossil: cf. *Alnus* twig (R Gale)			-28.4	5660 ±35		4560–4400 cal BC

Table 2: Results of radiocarbon dating from Beccles (2008) Core 1

Figures 8 and 9 show the organic fractions encountered in the radiocarbon samples from Beccles (2008) Core 1. In all three samples, the humin acid contains most of the carbon and therefore has the greatest influence on a combined age. This contradicts Shore *et al*. (1995) who found that the humic acid contained most of the carbon in peat samples from Lanshaw Moss and White Moss. The difference might be explained by the very different environmental settings of these two sites, with a soligenuous mire and raised mire complex being compared with the floodplain environment at Beccles.

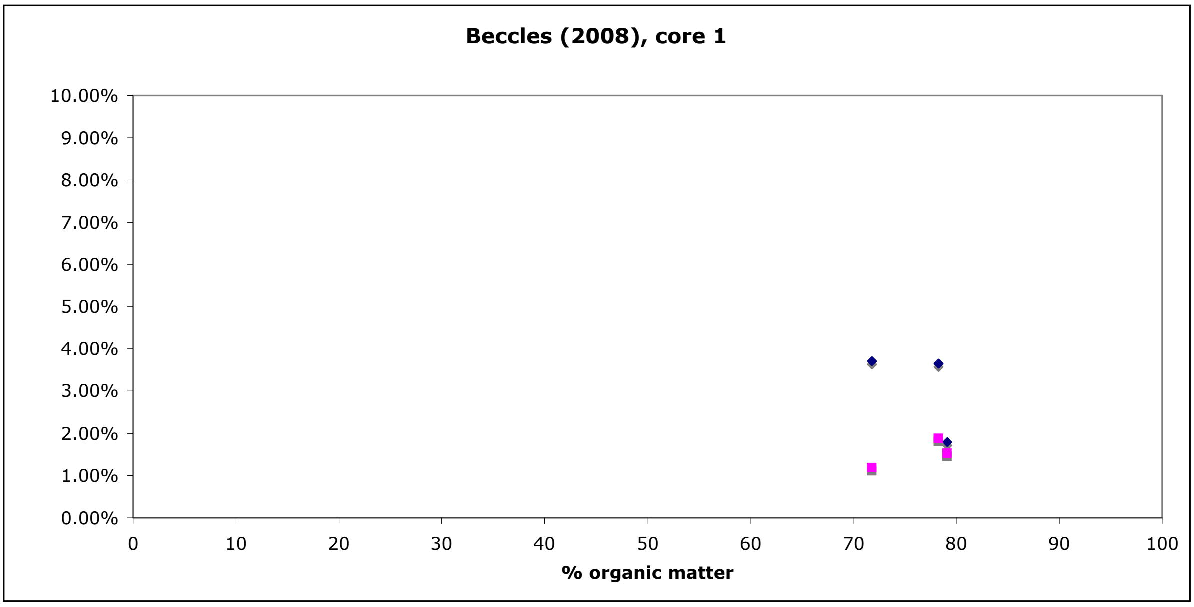


Figure 8: Beccles (2008) Core 1, % carbon content by weight of total sample weight and % organic content. [**pink = humic acid**, **blue = humin**]

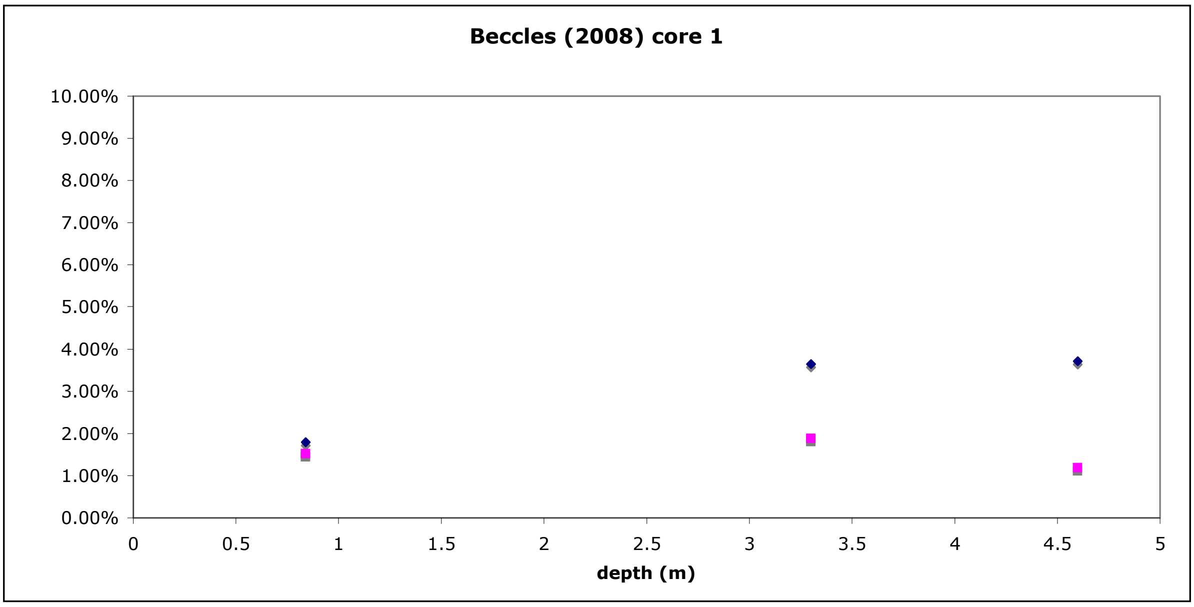


Figure 9: Beccles (2008) core 1, % carbon content by weight of total sample weight and depth of sample. [**pink = humic acid**, **blue = humin**]

4.3.2 Beccles 2008 Core 2

Figure 10 provides a summary of the radiocarbon dating results for Beccles (2008) Core 2. Table 3 provides a full breakdown of the radiocarbon results obtained for each sample. Except for the plant macrofossil sample from 4.30 m depth, all submitted bulk and macrofossil samples yielded sufficient carbon for radiocarbon dating to be successful. Duplicate radiocarbon dating of separate macrofossil samples was undertaken at 1.37 m depth.

1.37 m

The four measurements are not statistically consistent (T'=84.1; ν=3; T'(5%)=7.8; Ward and Wilson 1978). The peat fractions are not statistically consistent (T'=63.1; ν=1; T'(5%)=3.8; Ward and Wilson 1978), whilst the two twigs are: (T'= 1.5; ν=1; T'(5%)= 3.8; Ward and Wilson 1978). With the humic acid faction removed, the three remaining measurements from 137cm are statistically consistent (T'=1.6; ν=2; T'(5%)=6; Ward and Wilson 1978).

3.59 m

The three measurements are not statistically consistent (T'=47.663; n=2; T'(5%)= 6.0; Ward and Wilson 1978), although the humin and humic acid fractions of the peat sample are statistically consistent (T'=0.0; ν=1; T'(5%) 3.8: Ward and Wilson 1978).

4.30 m

The humin and humic acid fractions are statistically consistent (T'=0.1; ν=1; T'(5%)= 3.8; Ward and Wilson 1978).

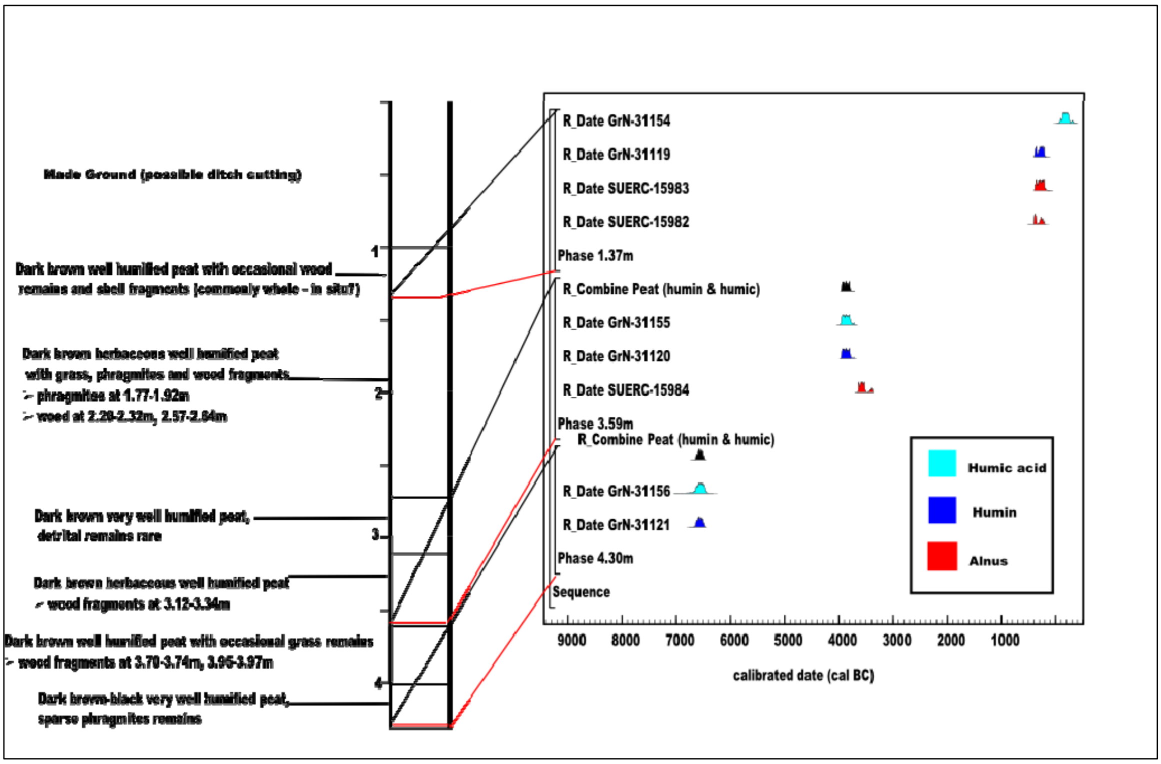


Figure 10: Probability distributions of dates from Beccles (2008) Core 2. Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993).

Lab Code	Sample ID	Material Dated	Organic Content	pH	δ13C (‰)	Radiocarbon age (BP)	Weighted mean	Calibrated date (95% confidence)
GrN-31119	2–1.37m	Peat (Humin)	76%	5.6	-28.7	2230 ±30		390–200 cal BC
GrN-31154	2–1.37m	Peat (Humic acid)			-28.6	1830 ±40		cal AD 70–320
SUERC-15982	2–1.37m A	Plant macrofossil: *Alnus* twig, 1 growth ring (R Gale)			-28.7	2275 ±35		400–210 cal BC
SUERC-15983	2–1.37m B	Plant macrofossil: *Alnus* twig, 1 growth ring (R Gale)			-28.4	2215 ±35		390–180 cal BC
GrN-31120	2–3.59m	Peat (Humin)	70%	6	-28.6	5060 ±30	5060 ±24 BP (T'=0.0; ν=1; T'(5%)= 3.8)	3960-3785 cal BC
GrN-31155	2–3.59m	Peat (Humic acid)			-28.0	5060 ±40		
SUERC-15984	2–3.59m	Plant macrofossil: *Alnus* roundwood, c. 8 growth rings (R Gale)			-29.0	4765 ±35		3650–3380 cal BC
GrN-31121	2–4.30m	Peat (Humin)	31%	4.3	-27.6	7740 ±40	7735 ±35 BP (T'=0.1; ν=1; T'(5%)= 3.8)	6640–6480 cal BC
GrN-31156	2–4.30m	Peat (Humic acid)			-27.7	7720 ±70		
GU-6796	2–4.30m	Plant macrofossil: *Alnus* twig, *c.* 1 growth ring (R Gale)				Sample failed		

Table 3: Results of radiocarbon dating from Beccles (2008) Core 2

Figures 11 and 12 show the organic fractions of the peat samples encountered in Beccles (2008) Core 2. In all three samples the humin contains most of the carbon and therefore has the greatest influence on a combined age, this contradicts Shore *et a*l (1995) who found that humic acid contained most of the carbon (see above). The % carbon content of the humic fraction shows very small increases with % organic matter, a similar pattern to Beccles (2008) Core 1 (See Figure 8).

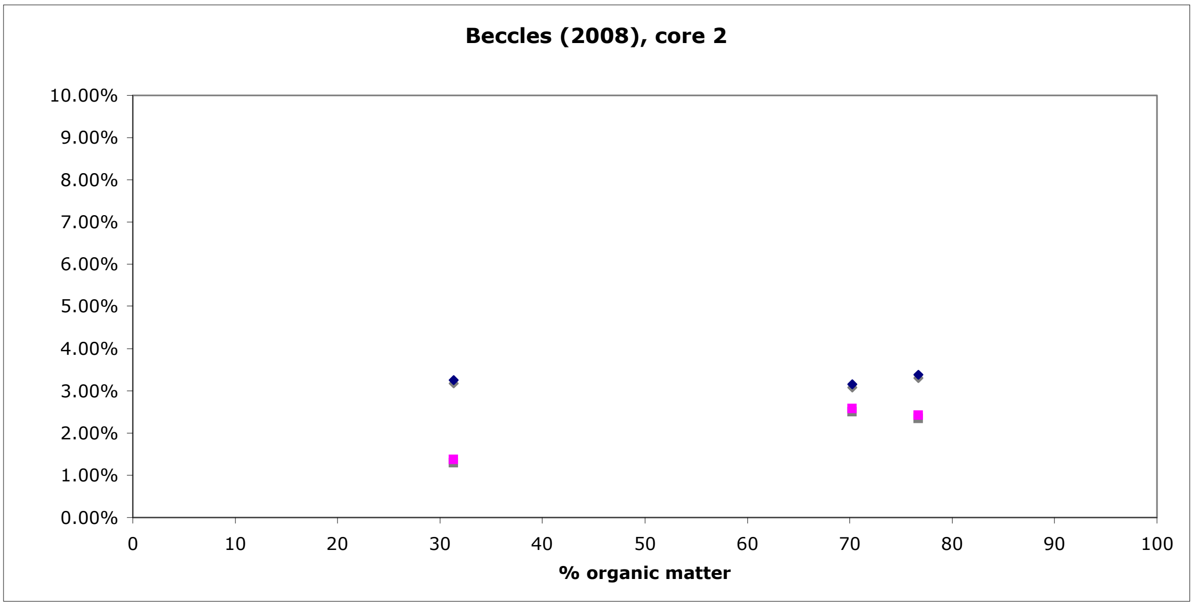


Figure 11: Beccles (2008) core 2, % carbon content by weight of total sample weight and % organic content. [**pink = humic acid**, **blue = humin**]

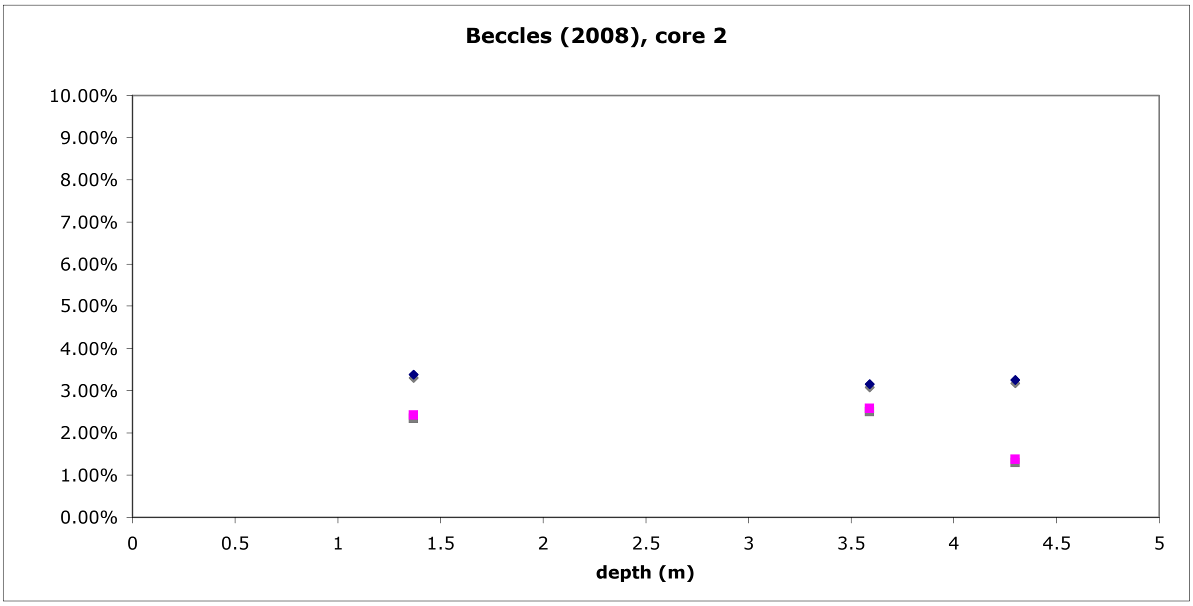


Figure 12: Beccles (2008) core 2, % carbon content by weight of total sample weight and depth of sample. [**pink = humic acid**, **blue = humin**]

4.3.3 Hengrave (2008)

Figure 13 provides a summary of the radiocarbon dating results for Hengrave (2008). Table 4 provides a full breakdown of the radiocarbon results obtained for each sample. All bulk and plant macrofossil samples yielded sufficient carbon to enable successful radiocarbon dating, except the plant macrofossil sample from 1.61 m depth.

0.47 m

The three measurements are not statistically consistent (T'=12.198; ν=2; T'(5%)= 6.0; Ward and Wilson 1978), although the plant macrofossil and humin fraction are statistically consistent (T'=1.4; ν=1; T'(5%)= 3.8; Ward and Wilson 1978).

1.61m

The humin and humic acid fractions are statistically consistent (T'=0.2; ν=1; T'(5%)= 3.8; Ward and Wilson 1978).

2.76m

The three measurements are not statistically consistent (T'=21.697; ν=2; T'(5%)= 6.0; Ward and Wilson 1978), although the humin and humic acid fractions are statistically consistent (T'=0.2; ν=1; (5% 3.8).

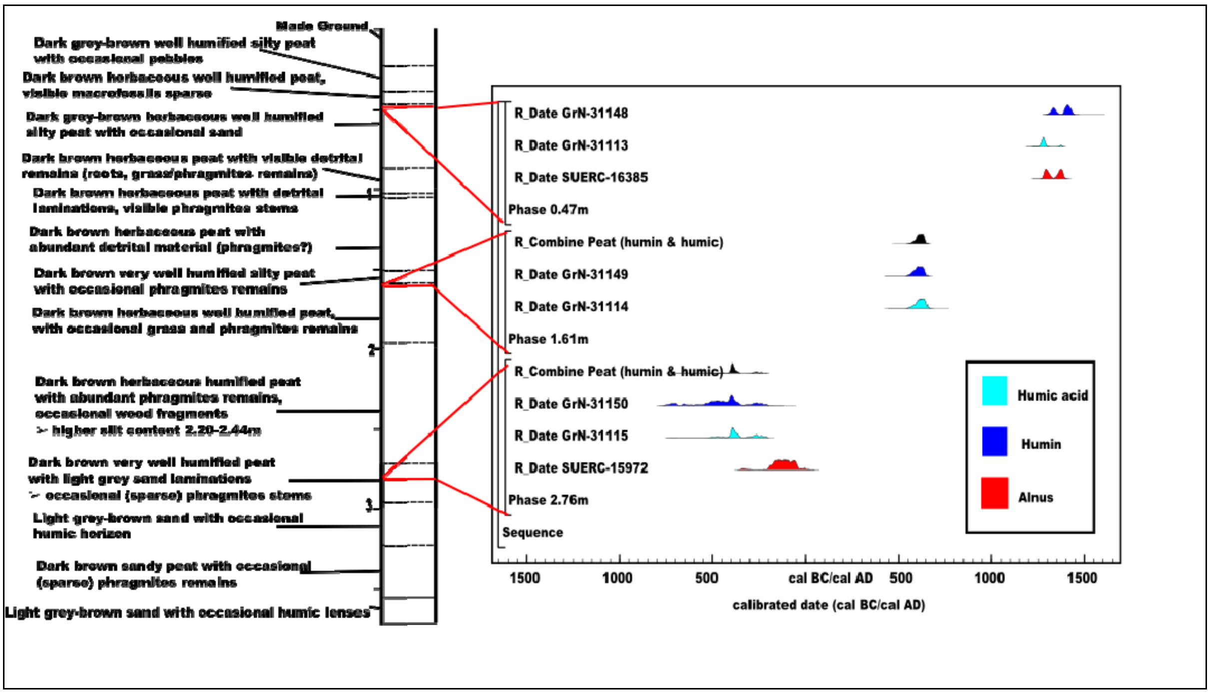


Figure 13: Probability distributions of dates from Hengrave (2008). Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993).

Lab Code	Sample ID	Material Dated	Organic Content	pH	δ13C (‰)	Radiocarbon age (BP)	Weighted mean	Calibrated date (95% confidence)
GrN-31113	0.47m	Peat (Humin)	44%	6.0	-29.1	715 ±30		cal AD 1260–1380
GrN-31148	0.47m	Peat (Humic acid)			-29.7	540 ±40		cal AD 1300–1450
SUERC-16385	0.47m	Plant macrofossil: stem fragment (D Robinson)			-25.1	660 ±35		cal AD 1270–1400
GrN-31114	1.61m	Peat (Humin)	60%	6.4	-28.9	1430 ±35	1442 ±23 BP (T'=0.2; ν=1; T'(5%)= 3.8)	cal AD 570–655
GrN-31149	1.61m	Peat (Humic acid)			-28.5	1450 ±30		
GU-6786	1.61m	Plant macrofossil: herbaceous stem (R Gale)				Sample failed		
GrN-31115	2.76m	Peat (Humin)	47%	5.7	-29.8	2310 ±40	2319 ±34 BP (T'=0.2; ν=1; T'(5%)= 3.8)	410–360 cal BC
GrN-31150	2.76m	Peat (Humic acid)			-30.5	2340 ±60		
SUERC-15972	2.76m	Plant macrofossil: monocot culm (R Gale)			-27.5	2095 ±35		210–1 cal BC

Table 4: Results of radiocarbon dating from Hengrave (2008)

Figures 14 and 15 show the organic fractions of the peat samples encountered in sample core Hengrave (2008). Two of the samples show the humin fraction contains most of the carbon and therefore has the greatest influence on a combined age.

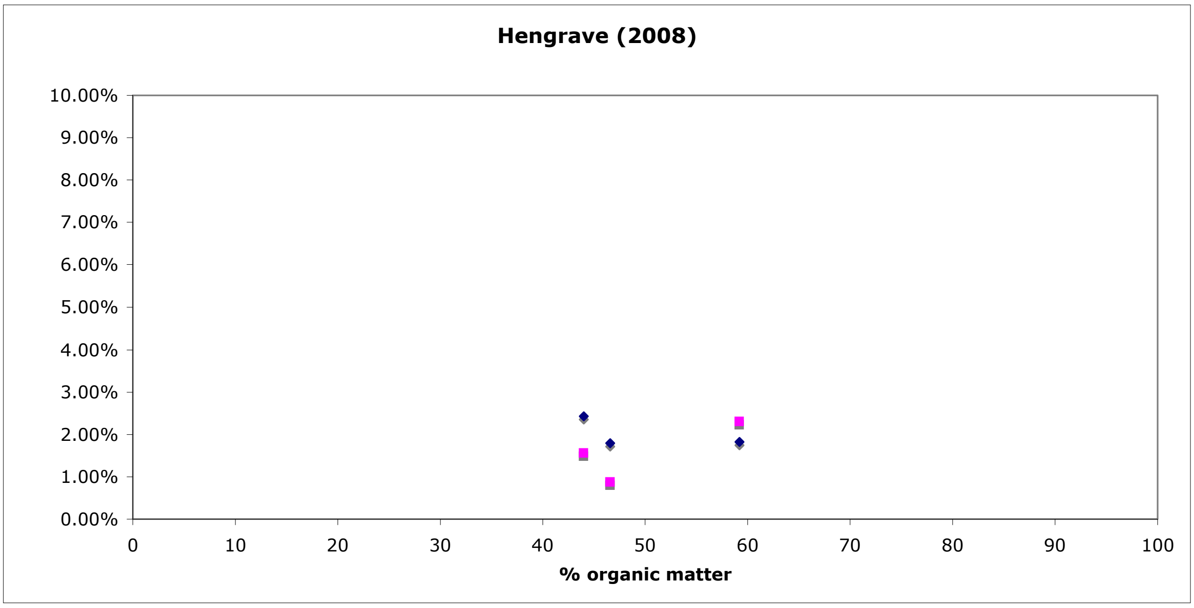


Figure 14: Hengrave (2008) % carbon content by weight of total sample weight and % organic content. [**pink = humic acid**, **blue = humin**]

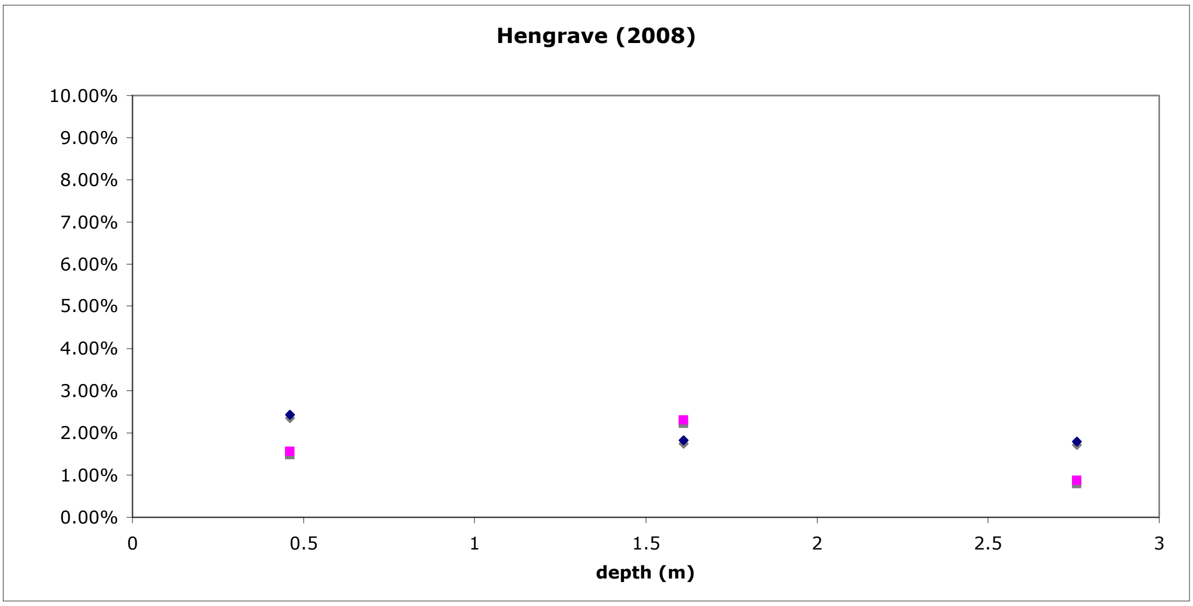


Figure 15: Hengrave (2008) % carbon content by weight of total sample weight and depth of sample. [**pink = humic acid**, **blue = humin**]

4.3.4 Ixworth (2008)

Figure 16 provides a summary of the radiocarbon dating results for Ixworth (2008). Table 5 provides a full breakdown of the radiocarbon results obtained for each sample. Due to the high level of humification present within the organic deposits encountered at Ixworth, an overall absence of plant macrofossil remains restricted successful radiocarbon dating to just the humic and humin acid fractions extracted from the bulk peat samples. A fragment of alder was initially identified from within the basal sample (2.39 m depth), but the low carbon yield of this fragment prevented successful dating of it.

0.71m

The humin and humic acid fractions are statistically consistent (T'=2.9; ν=1; T'(5%)= 3.8; Ward and Wilson 1978).

1.24m

The humin and humic acid fractions are statistically consistent (T'=1.5; ν=1; T'(5%)=3.8; Ward and Wilson 1978).

2.39m

The humin and humic acid fractions are statistically consistent (T'=0.1; ν=1; T'(5%)=3.8; Ward and Wilson 1978).

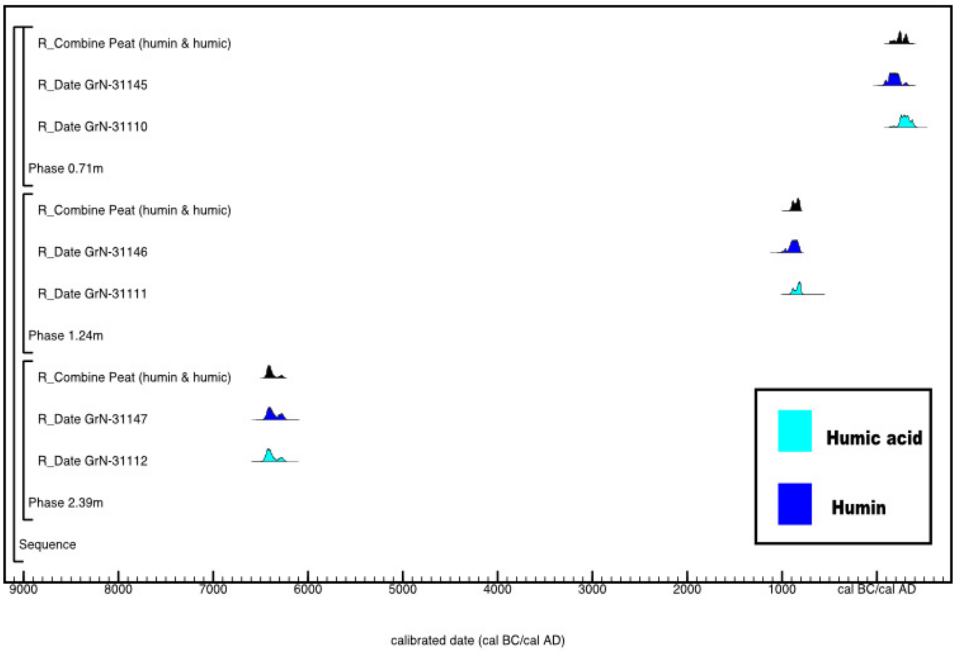


Figure 16: Probability distributions of dates from Ixworth (2008). Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993).

Lab Code	Sample ID	Material Dated	Organic Content	pH	δ13C (‰)	Radiocarbon Age (BP)	Weighted mean	Calibrated date (95% confidence)
GrN-31110	71cm	Peat (Humin)	55%	5.6	-29.6	1740 ±35	1779 ±27 BP (T'=2.9; ν=1; T'(5%)= 3.8)	cal AD130–340
GrN-31145	71cm	Peat (Humic acid)			-29.2	1830 ±40		
GrN-31111	124cm	Peat (Humin)	14%	7.0	-29.3	2670 ±40	2700 ±29 BP (T'=1.1; ν=1; T'(5%)= 3.8)	910–800 cal BC
GrN-31146	124cm	Peat (Humic acid)			-29.3	2730 ±40		
GrN-31112	239cm	Peat (Humin)	53%	5.9	-28.9	7530 ±50	7520 ±36 BP (T'=0.1; ν=1; T'(5%)= 3.8)	6460–6260 cal BC
GrN-31147	239cm	Peat (Humic acid)			-28.3	7510 ±50		
GU-6798	124cm	Plant macrofossil: *Alnus* wood				Sampled failed		

Table 5: Results of radiocarbon dating from Ixworth (2008).

Figures 17 and 18 show the organic fractions of the peat samples encountered in sample core Ixworth (2008). Two of the samples show the humin fraction contains most of the carbon and therefore has the greatest influence on a combined age. The very low organic content of the sample from 1.24 m however does not seem to have had an influence of the % carbon content.

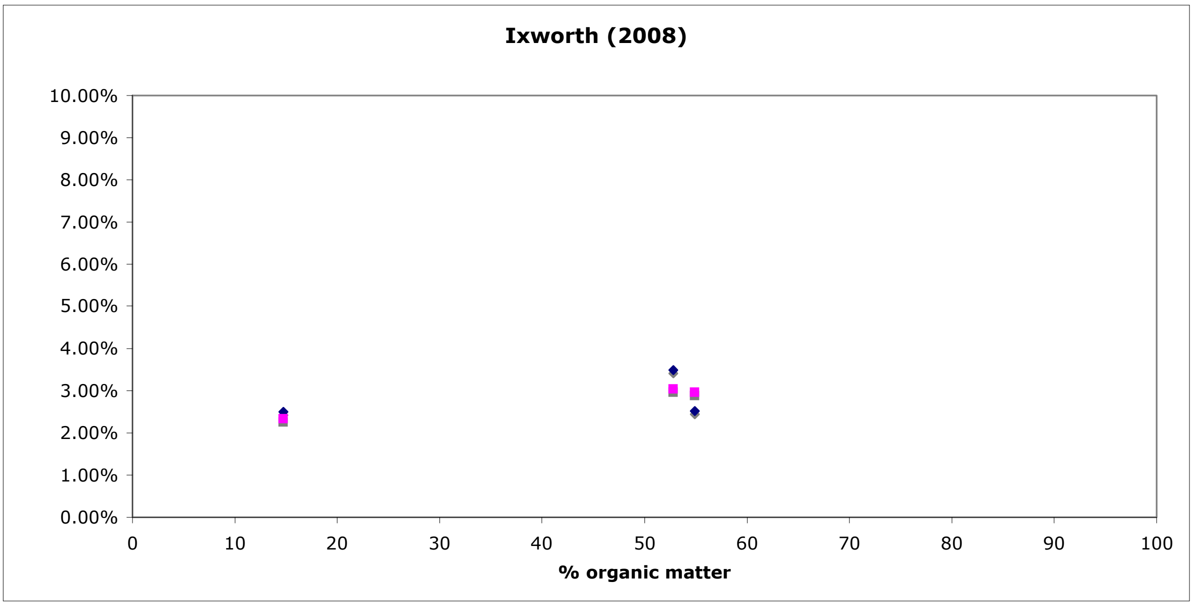


Figure 17: Ixworth (2008) % carbon content by weight of total sample weight and % organic content. [**pink = humic acid**, **blue = humin**]

Figure 18: Ixworth (2008) % carbon content by weight of total sample weight and depth of sample.
[**pink = humic acid**, **blue = humin**]

5 DISCUSSION

The radiocarbon dating of samples from the top, middle and bottom of each Phase 2 sample core proved to be much more successful than the dating results obtained during Phase 1 of the project. The rigorously designed dating methodology, combined with the improved understanding of the stratigraphic sequences under consideration enabled suitable samples to be selected for radiocarbon dating from a number of different components of the organic spectrum (plant macrofossils as well as bulk humic and humin fractions).. In general, it can be stated that:

- In general, the humin and humic acid fraction dating results are statistically consistent.

- When sufficient plant macrofossils were present to allow dating, the radiocarbon age estimates of the plant macrofossil remains were found to be of a slightly younger age than those provided by the humin and humic acid fractions.

These age discrepancies subsequently resulted in overall statistically inconsistent measurements being provided for each sample. However, the results in their entirety make overall chronological ‘sense’, in that there are no cases of age inversions or modern age estimates being encountered within the stratigraphic sequence of each core. Therefore, although the following discussion does highlight such statistical inconsistencies between the obtained results, these can, to an extent, be accounted for.

5.1 BECCLES

During Phase 1, Beccles (2007) Core 1 was sampled from close to the excavations of a prehistoric post alignment that provided extensive evidence for *Phragmites* penetration. The invasive nature of the *Phragmites* had resulted in substantial damage to the structural timbers. Subsequent radiocarbon and dendrochronological dating confirmed that the structure was constructed in the late Iron Age (dendrochronological analyses indicated felling of the timbers occurred in the spring of 75 BC). When taking into account the abundance of *Alnus* and Poaceae fragments that all date to the late Iron Age period (see Figure 19), these dates approximately correlate with the construction of the post alignment. All of these radiocarbon results therefore appear to be too young, especially when taking into account the age of the basal radiocarbon sample at 5.34 m depth (10,040–9220 cal BC; GrA-33477). In addition, the pollen evidence from Phase 1 suggests the base of the core is early Holocene (Hill *et al*., 2008b). The *Alnus* rise within the Beccles (2007) Core 1 pollen diagram is shown to occur at *c*. 4.50 m depth, which suggests an approximate age of *c*. 8000yrs BP. This is based on the known immigration and subsequent establishment of alder at a number of sites in southeast England during the early Holocene (Tallantire, 1992). Radiocarbon dating at 3.50 m depth however revealed a date of 1030–830 cal BC (GrA-33476), which is substantially younger than suggested by the inferred biostratigraphy.

It can therefore be concluded that the radiocarbon results from Beccles (2007) Core 1 were heavily influenced by vertical mixing of the floodplain sequence proximal to the trackway. This may have resulted from either the invasive *Phragmites* acting as a mechanism through which intrusive plant macrofossil remains are physically dragged down into earlier sediments, or such fragments may even be washed into *Phragmites* root channels exposed during dry periods, or a combination of the two processes. Alternatively, the actual vertical displacement of the sedimentary sequence may have occurred during the construction of the post alignment, through human and/or animal trampling of the waterlogged floodplain surface. Such activity could have introduced surface detrital remains (twigs etc) deep into the sedimentary archive, resulting in younger dates being obtained during the subsequent assessment. Such potential explanations would therefore account for the lack of chronological integrity encountered in Core 1 during Phase 1 of the Suffolk River valleys Project.

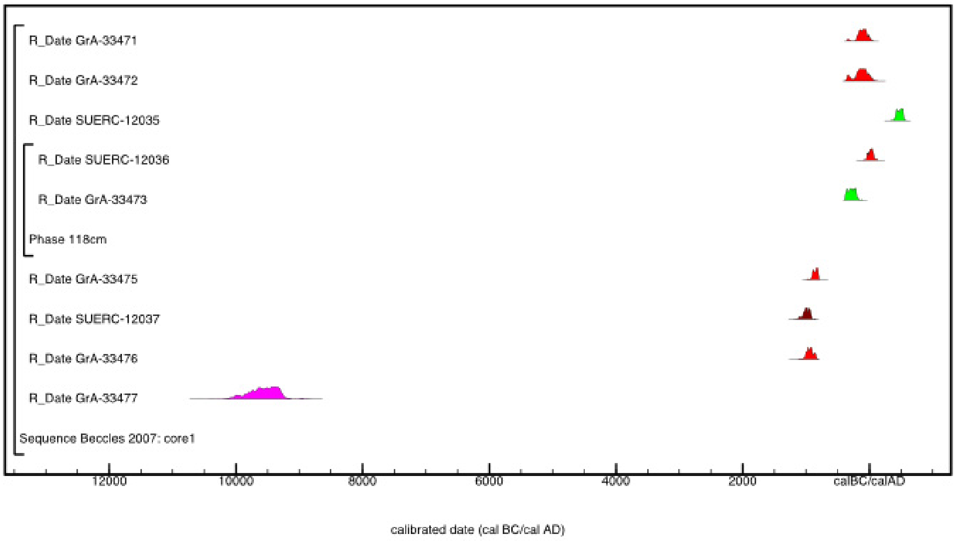
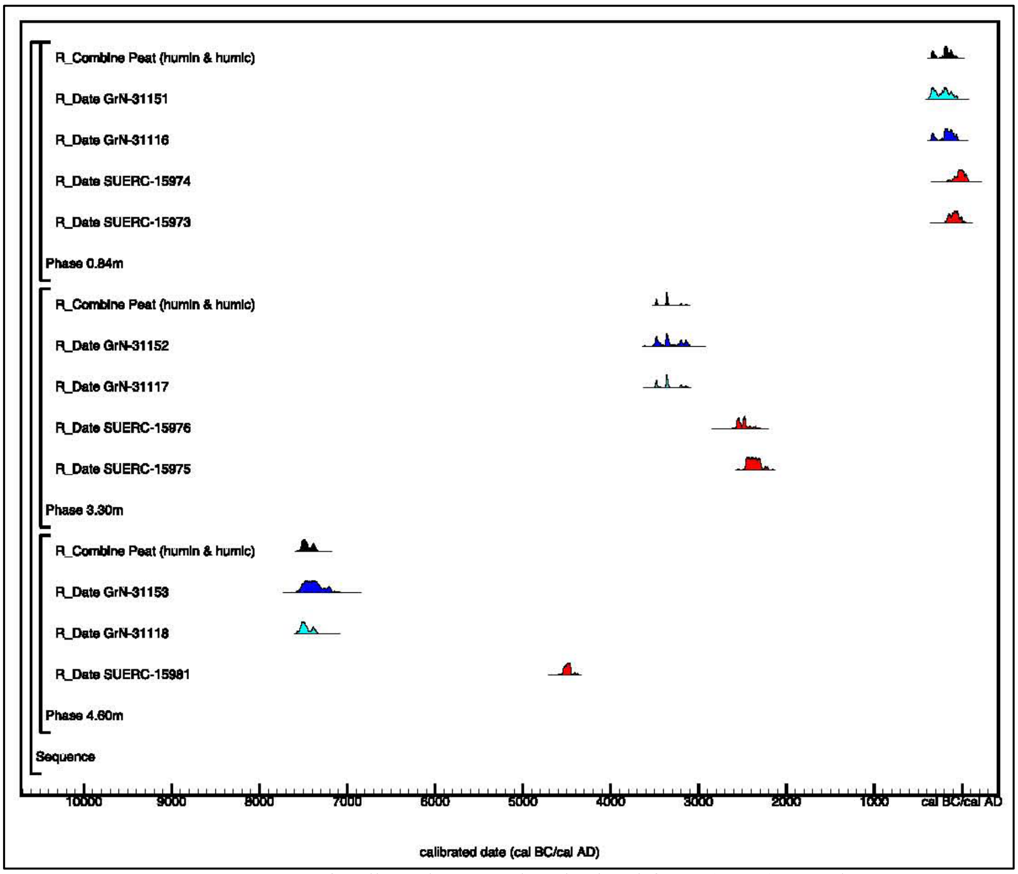


Figure 19: Probability distributions of dates from Beccles (2007) core 1. Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993). The green radiocarbon plots relate to the dating of *Poaceae* fragments, red plots relate to *Alnus* fragments, whilst the pink plot relates to the dating of unidentified plant macrofossil remains.

When considering the radiocarbon results obtained from Beccles (2008) Core 1 (Figure 20), no age inversions are present, whilst all four dated samples from 0.84 m depth are deemed statistically consistent. In addition, although the four dated samples from 3.30 m depth are not statistically consistent with one another, the humic acid and humin fractions are deemed consistent, as are the two dated plant macrofossil fragments. One trend was noted however, in that in two cases (3.30 m and 4.60 m) the *Alnus* fragment(s) were younger than the bulk sediment measurements from the same level. The stratigraphic consistency of both sets of data when analysed independently thus raises the possibility that either could be accurate. However, the high resolution stratigraphic assessment of the sample core revealed that *Phragmites* remains were present in the sediments immediately overlying both of the horizons in which the dating discrepancies were evident. This therefore raises the possibility that the alder fragments are intrusive and that the bulk samples are providing reliable dating measurements. As suggested in the assessment of Beccles 2007 Core 1 (see above), possible mechanisms for this might relate to *Phragmites* roots pushing small twigs through the sediment or material falling down *Phragmites* root channels during dry periods, etc. An alternative explanation is that the alder fragments are providing an accurate chronology and that the bulk sediment measurements are inaccurate. However, through discussions with the English Heritage Dating Team, it was concluded that this can be discounted as an interpretation due to the consistency of the humic and humin measurements. If the *Alnus* ages were indeed correct then it would be expected that the humin fraction ages would be closer in age to the macrofossil dates, as humins are composed of organic detritus.



<u>Figure 20:</u> Summary of radiocarbon results obtained from (2008) Beccles Core 1

The radiocarbon results obtained from the second core taken from Beccles (Beccles 2008 Core 2) also warrant discussion. The three sets of radiocarbon dates obtained from plant macrofossil and bulk samples, as with Beccles (2008) Core 1, once again make chronostratigraphic sense (Figure 21). The humin and humic acid fractions are statistically consistent at 3.59 m and 4.30 m depths, whilst statistical consistency is also evident between the two macrofossil and humin dating results from 1.37 m depth. The overall consistency between humin and humic acid fractions does therefore imply that these data sets provide the more reliable age estimates for each dated sample depth. The picture from this core is less clear-cut than that for Beccles 2008 Core 1 however, partially due to the lack of duplicate measurements from all horizons (resulting from the failed plant macrofossil dating at 4.30 m depth). Although the alder fragment from 3.59 m is again younger than the bulk sediment sample from the same horizon, the offset is noticeably smaller. This may be due to the lower abundance of *Phragmites* encountered within the sedimentary sequence surrounding the radiocarbon sampling horizon or the apparent discrepancy might be simply a result of SUERC-15984 being a statistical outlier. Alternatively the humin fraction may comprise older woody material around which finer peat has accumulated; such an explanation might be supported by the presence of occasional wood fragments at this level.

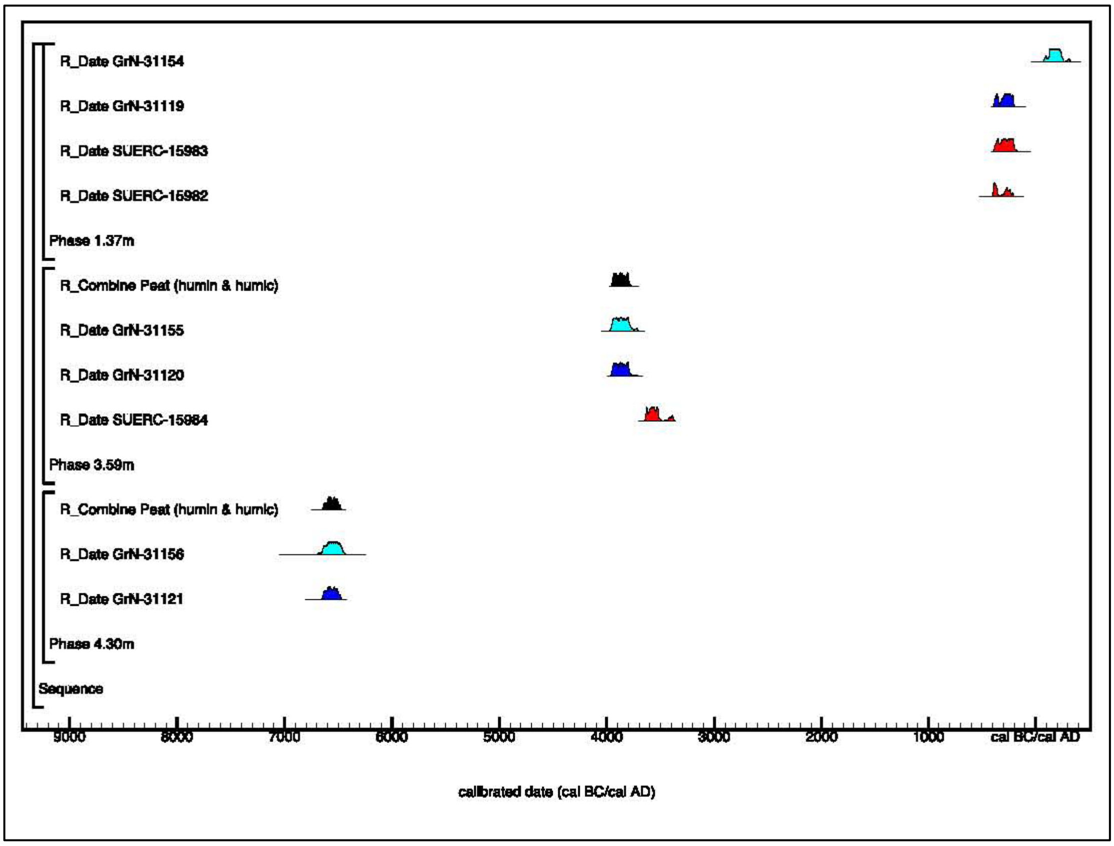


Figure 21: Summary of radiocarbon results obtained from (2008) Beccles Core 2

It is interesting to note that comparisons between the radiocarbon results of both Beccles (2008) Core 1 and 2 do show relatively similar chronostratigraphic trends. Although the stratigraphy was not *precisely* mirrored within each core, the overall similarity enabled radiocarbon sampling to be undertaken within similar sedimentary units and at similar depths. Dating of the humic acid and humin fractions from the basal deposits revealed age estimates of between 7580-7370 cal BC in Core 1 (4.60 m depth) and 6640-6480 cal BC in Core 2 (4.30 m depth). Humin and humic acid dating of the samples from the middle of the cores also revealed similar results, with dates of 3500-3340 cal BC in Core 1 (3.30 m depth) and 3960-3785 cal BC in Core 2 (3.59 m depth). Finally, the upper age estimates vary between 360-10 cal BC in Core 1 (0.84 m depth) and 400 cal BC and 320 cal AD in Core 2 (1.37 m depth). The overall similarities between the dating results can be used as supporting evidence for sedimentation occurring uniformly across the floodplain at Beccles. This would have taken place through *in-situ* organic accumulation in the backswamp floodplain setting.

Some tentative comparisons can also be made between the Phase 2 radiocarbon results and the palynological investigations undertaken during Phase 1 at Beccles (Figure 22). The pollen assessments undertaken on Beccles (2007) Core 1, although somewhat restrictive in interpretative value, suggested that a biostratigraphically conformable sedimentary archive was present (Hill et al., 2008b). However, due to the problems experienced relating to the radiocarbon results from Phase 1, the lack of a reliable chronology restricted the interpretative value of the palaeoenvironmental assessments. In contrast, the apparently conformable dating results obtained from Phase 2, provides a suitable chronostratigraphic framework to which the pollen record can be compared. The initial dominance and subsequent decline in *Pinus sylvestris* (Scots' pine) within the basal pollen assemblage zone (BCC1) implies a pine community on the floodplain at this time. The Beccles (2008) Core 1 at 4.60 m depth provided a date of 7,580-7,370 cal BC, indicating this period of pine dominance during the early Holocene period. In addition, *Alnus* appears in the Beccles pollen record at *c*. 4.70 m depth. Alder is believed to immigrated to the UK from West Germany and Holland, becoming established within southeastern England by *c*. 8000 yrs BP (Tallantire, 1992). These data suggest that the sequence has good biostratigraphic integrity.

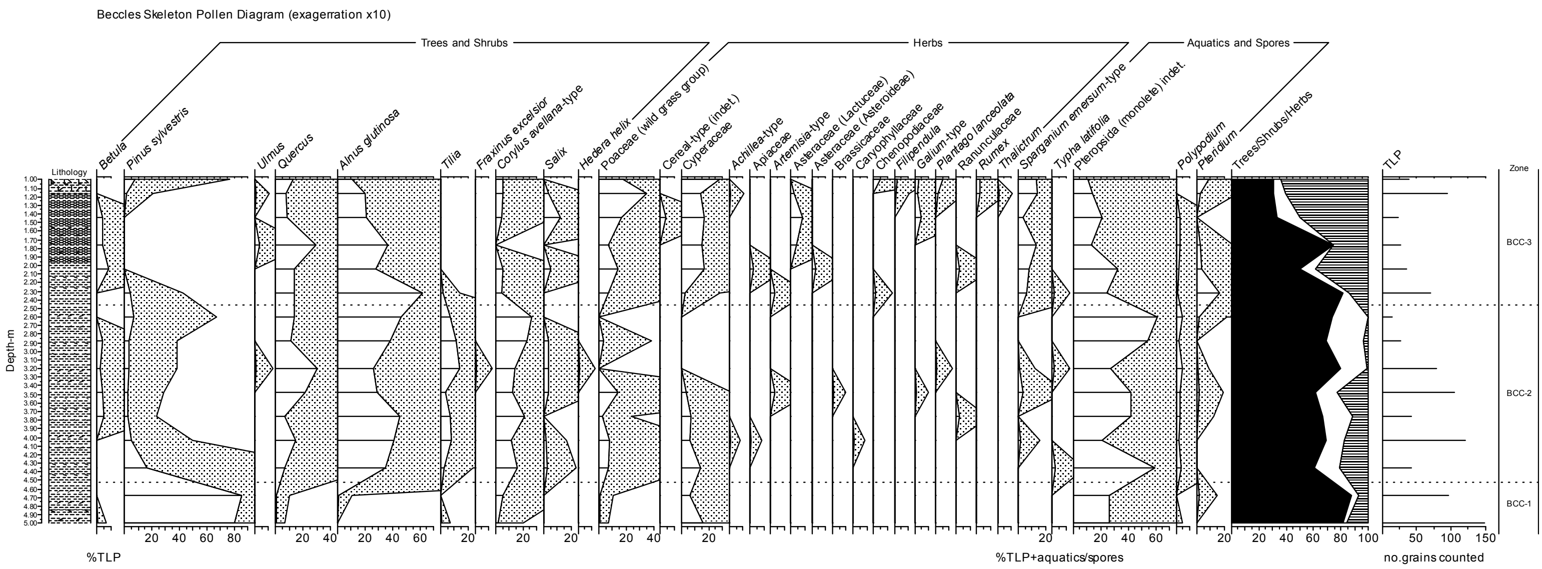


Figure 22: Pollen diagram from Beccles (2007) Core 1

5.2 HENGRAVE

As reported for Beccles (see above), the radiocarbon results obtained from Hengrave, for each dated horizon make chronostratigraphic sense (Figure 23). No age inversions are present, whilst the humic acid and humin fractions are statistically consistent at 1.61 m and 2.76 m depths. In addition, at 0.47 m depth, the plant macrofossil and humin fractions are also statistically consistent. The lack of duplicate measurements from all date horizons (due to the failure of plant macrofossil dating at 1.61 m depth) however again makes interpretation slightly problematic. The alder fragment from 2.76 m is again younger than the bulk sediment sample from the same horizon although the offset between the bulk and macrofossil dating when compared to those encountered at Beccles (see Figure 24) is noticeably much smaller. This can perhaps be explained by the much lower incidence of wood remains from the core at Hengrave than Beccles 2008 Core 1, although there is a much greater incidence of *Phragmites*.

The statistical consistency encountered between the humin and humic acid fractions present at 1.61 m and 2.76 m depths suggests that there was overall water table stability within the floodplain during the initial development of the stratigraphic sequence, which would have prevented the vertical movement of such fractions. In contrast however, explanations for the age difference between the humic acid and humin/*Alnus* fragment at 0.47 m depth may include the upwards movement of humic acid or the intrusion of younger rootlets from above.

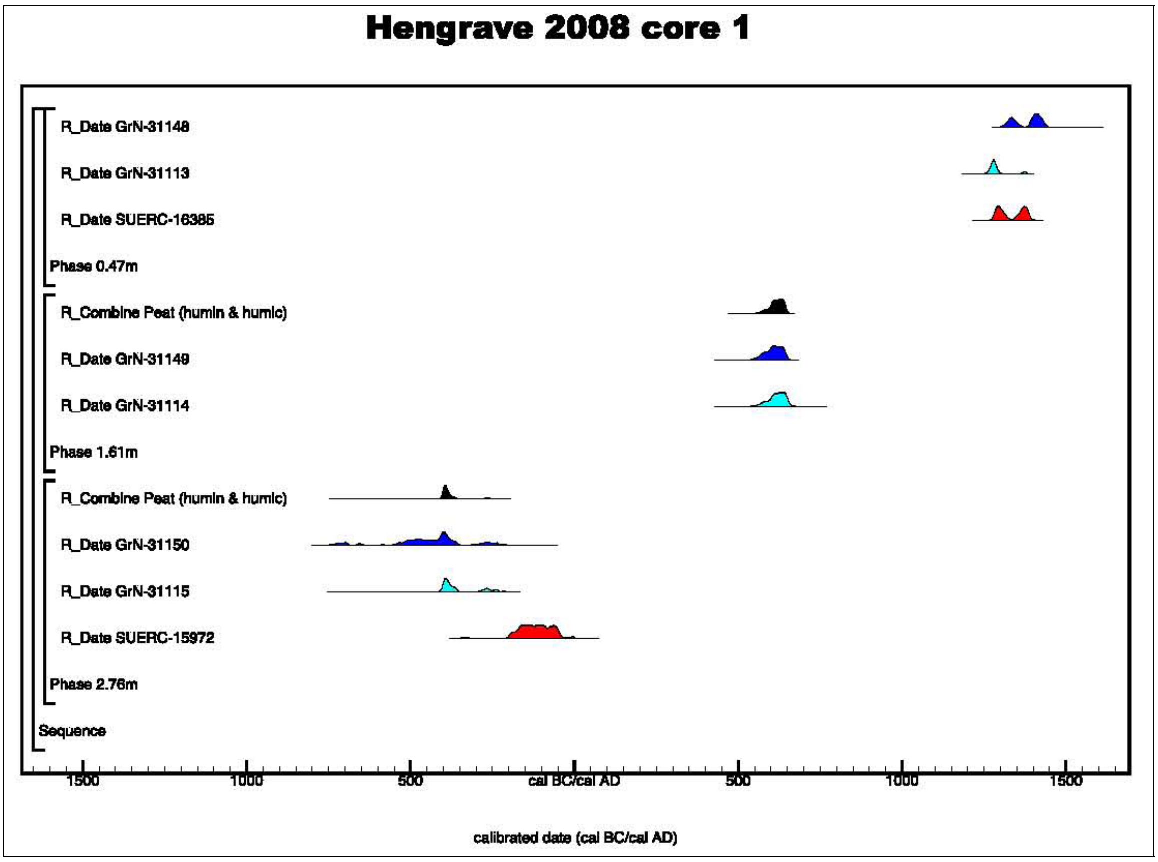


Figure 23: Summary of radiocarbon results obtained from (2008) Hengrave

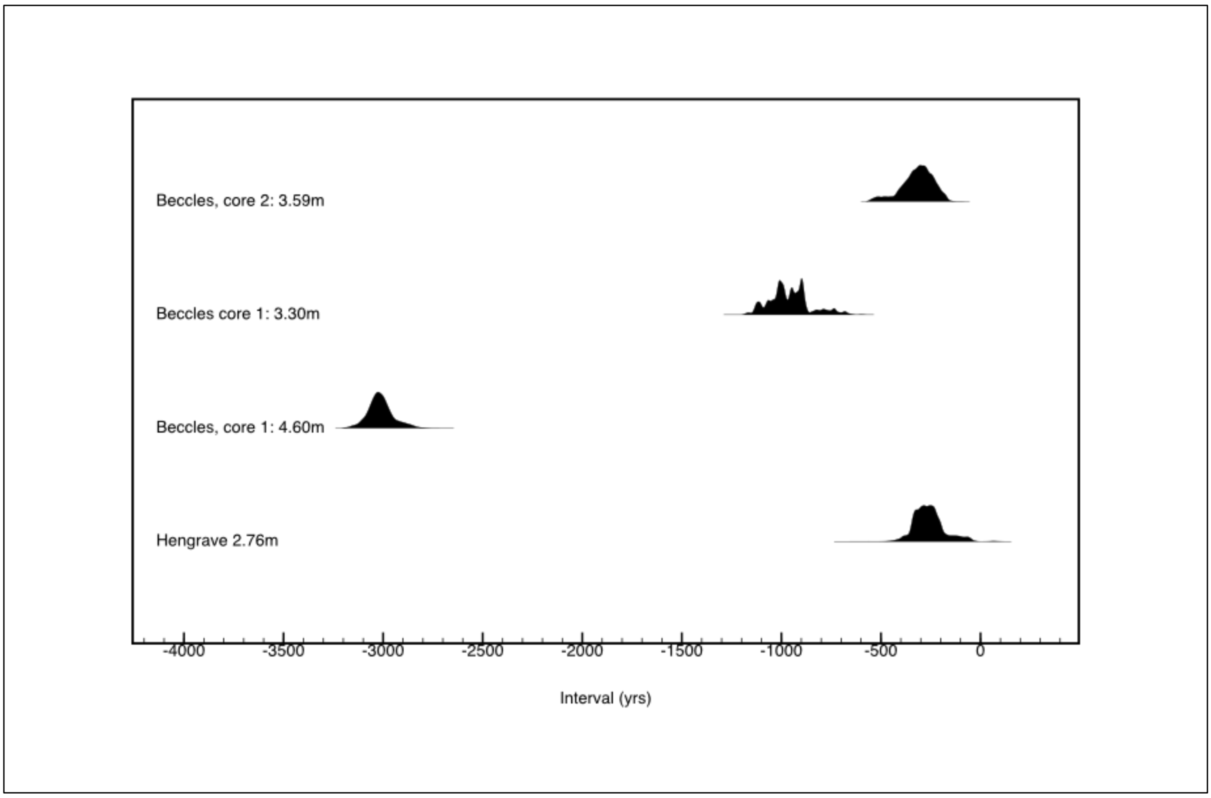


Figure 24: Difference in age between bulk peat sample (weighted mean of humic/humin fraction) and *Alnus* fragment from selected horizons.

The radiocarbon results from Phase 2 have provided a more reliable chronology for Hengrave than that obtained during Phase 1. With good chronological control, the sedimentary sequence developed over the last *c*. 2,500 yrs can be compared favourably to the palynological assessments undertaken during Phase 1 (Hill *et al*., 2008b). The biostratigraphy at Hengrave did not suggest any obvious unconformities (as indicated by the original radiocarbon dating). Supported by the new radiocarbon dating results, the pollen sequence reflects environmental change taking place during the later Holocene, with vegetation in the pollen source area suggesting an open agricultural landscape (arable and pastoral).

When taking into account the abundance of *Phragmites* in the Hengrave (2008) sample core, some comments may be made regarding the radiocarbon errors experienced during Phase 1. Due to the overall absence of suitable plant macrofossils for radiocarbon dating at Hengrave, the majority of the remains submitted for radiocarbon dating during Phase 1 were Poaceae fragments (see Figure 25). It is therefore conceivable that the Poaceae fragments submitted from the Hengrave (2007) core (Figure 25) were all *Phragmites* and therefore may be intrusive. This would sufficiently account for the poor chronological integrity encountered during Phase 1.

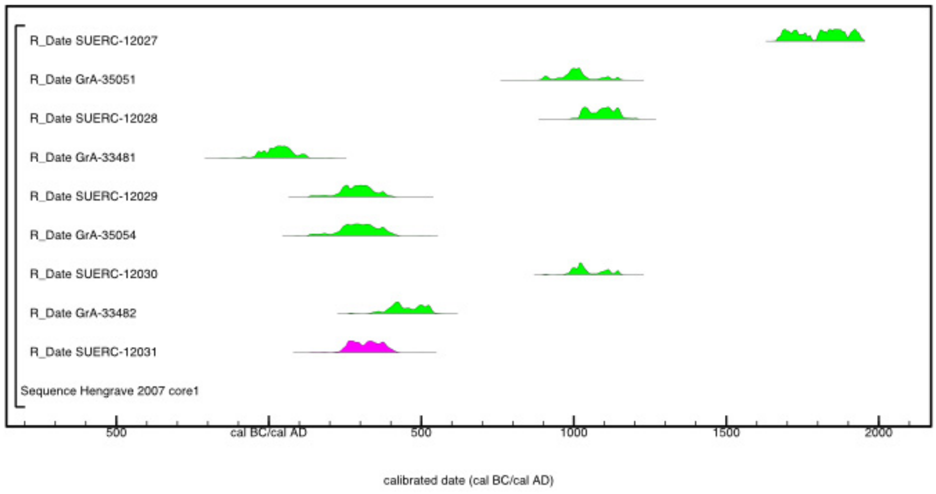


Figure 25: Probability distributions of dates from Hengrave (2007). Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993). Green radiocarbon plots indicate the dating of Poaceae fragments, whilst the pink radiocarbon plot indicates the dating of an unidentified plant macrofossil.

5.3 IXWORTH

Although the lack of any datable macrofossil remains encountered at Ixworth hampers interpretation of the radiocarbon results, no age inversions are present and all humic acid and humin fractions are deemed statistically consistent. Consequently, the radiocarbon results provide a reliable chronology for the development of the sedimentary sequence. The stratigraphic assessment of the sample core highlighted the overall absence of plant macrofossil remains (including *Phragmites*) which is especially informative given the paucity of wood fragments.

The biostratigraphy would appear to suggest an almost complete Holocene sequence of environmental change is preserved in the sedimentary archive at Ixworth (Hill *et al.*, 2008b). The basal pollen zone was interpreted to suggest early Holocene landscape conditions, with open birch scrub prior to the expansion of an alder carr community supported by lime and hazel. The subsequent high values of pollen spectra suggesting predominantly pastoral activity (dandelions, docks) were eventually replaced by cereal pollen indicating agricultural activity in close proximity to the sampling site in the later Holocene. The new radiocarbon dating results for Ixworth therefore strongly support the original biostratigraphic evidence obtained during Phase 1.

Although radiocarbon dating during Phase 1 provided erroneous results, some further comments can be made in response to the Phase 2 radiocarbon dating strategy and stratigraphic assessments. If the original Phase 1 results obtained through the dating of the Poaceae (GrA-35056 and SUERC-12021) fragments and the unidentified seed (GrA-35055) measurements from the top of the core (Figure 27) are discounted, the chronology does appear to be more, although not completely, in agreement with the pollen evidence.

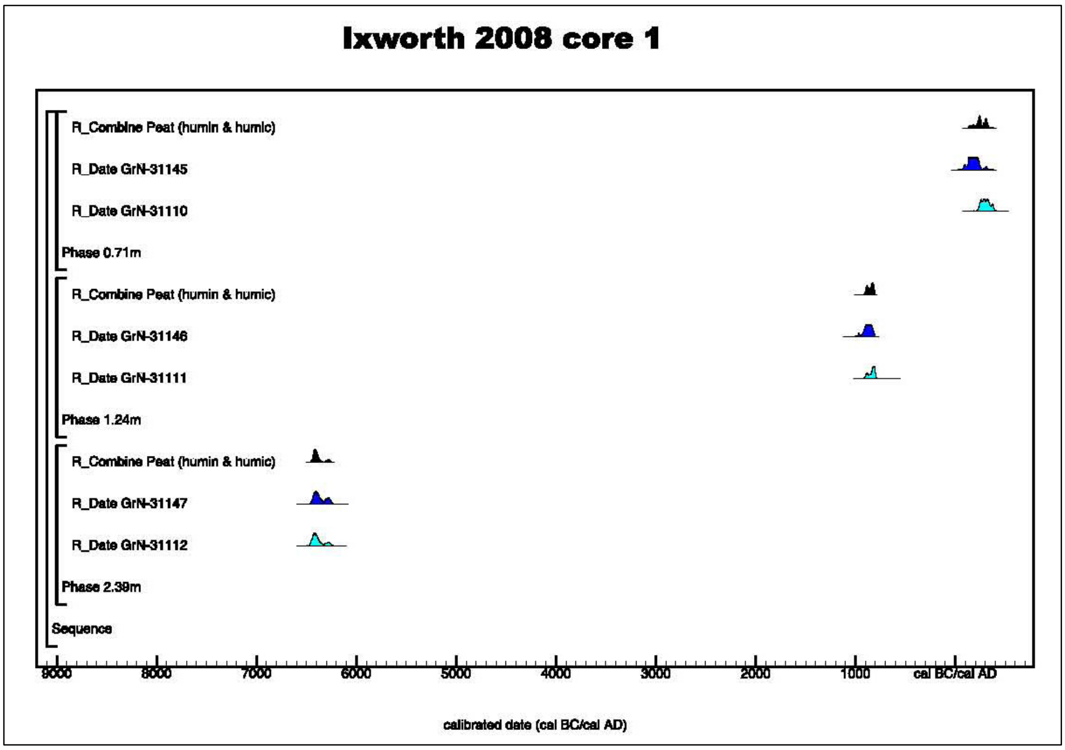


Figure 26: Summary of radiocarbon results obtained from (2008) Ixworth

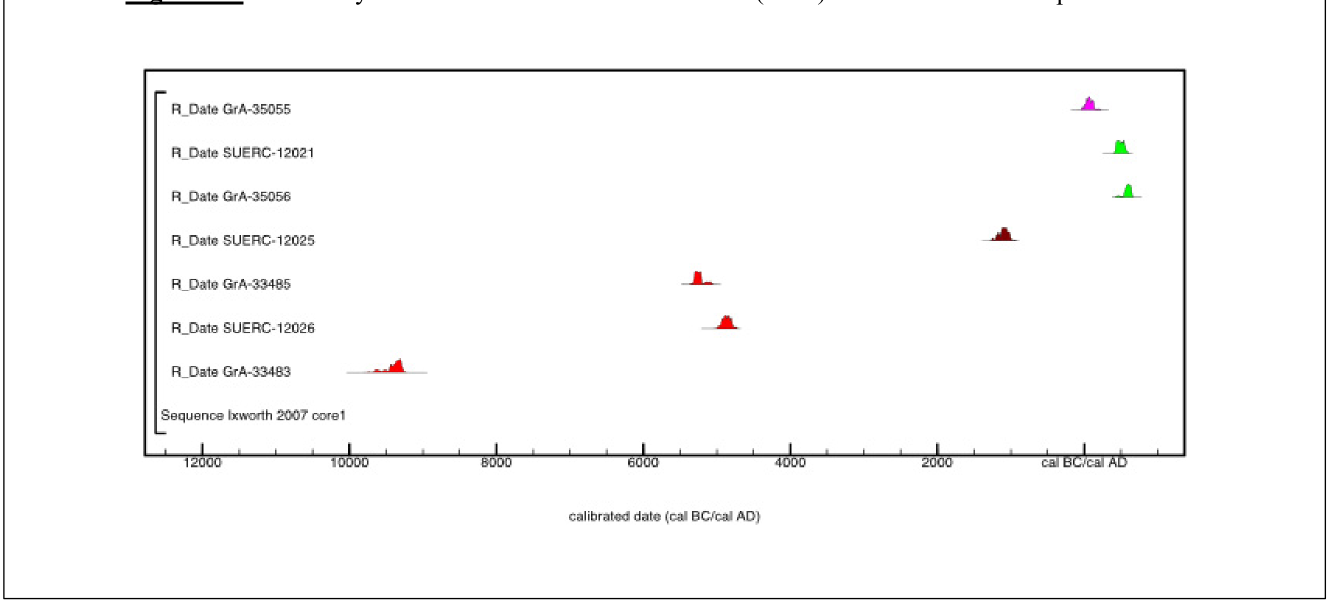


Figure 27: Probability distributions of dates from Ixworth (2007). Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993). Green radiocarbon plots indicate the dating of Poaceae fragments, whilst the pink radiocarbon plot indicates the dating of an unidentified plant macrofossil (seed).

6 CONCLUSIONS

The radiocarbon dating programme which formed a key component of Suffolk River Valleys Project Phase 2 has provided valuable chronological information to contribute to the developing environmental and cultural archaeological understanding of the county of Suffolk. Prior to Phase 1 of the Suffolk River Valleys Project, the majority of archaeological and environmental work had been undertaken on the Pleistocene landscapes with little consideration of the Holocene (post-glacial) record.

However it has also provided significant insights into methodological considerations when designing radiocarbon dating protocols within alluvial landscapes.

The radiocarbon dating results obtained as a result of Phase 1 suggested that the lowlands of Suffolk contained sedimentary archives with highly complex depositional histories. The presence of radiocarbon dating sequences in which no statistically consistent results could be identified highlighted a major problem within lowlands susceptible to the potential threat of gravel extraction. It was therefore essential from a curatorial perspective to assess whether or not the dating anomalies encountered during Phase 1 was a generic problem associated with radiocarbon dating of valley floor deposits in the East Anglia region.

Through collaboration with the English Heritage scientific dating team, a new radiocarbon dating methodology was developed in Phase 2 in order to reassess the sites with proven palaeoenvironmental records. Plant macrofossil radiocarbon analyses were supported by the measurement of humin and humic acid fractions from bulk peat samples. The radiocarbon analyses at Beccles, Hengrave and Ixworth revealed that the sedimentary sequences recorded during Phase 1 did not provide evidence of age inversions or modern ages (as previously encountered). Humin and humic acid fractions were commonly found to be statistically consistent, whilst the associated plant macrofossil-derived radiocarbon dates were often found to be younger in age. In addition, stratigraphic analyses of the sample cores under investigation indicated that the *Alnus* fragments commonly provided younger dates than the humic/humin fractions; these younger dates were commonly found to be associated with high levels of invasive *Phragmites* within the sample core.

A number of conclusions can therefore be put forward:

- The radiocarbon dating problems experienced during Phase 1 of the Suffolk River Valleys Project were probably the result of a combination of factors. These include some sampling error (use of a gouge auger in one instance), the use of unidentified plant macrofossil material for radiocarbon dating, actual issues surrounding disturbance by *Phragmites* and other poorly understood processes relating to sediment accumulation and intrusion by alder etc.

- Where there is evidence of *Phragmites* within sedimentary sequences, macrofossils should only be dated if there is evidence that they have grown *in-situ*. This is because the results suggest that *Phragmites* might be the mechanism by which intrusive wood fragments (but conceivably a range of other organic material), could become incorporated into stratigraphically earlier sediments. Although the exact process is not clear the results from the Suffolk

River Valleys Project suggests the correlation between *Phragmites* and intrusive wood in the cores is apparent. This is certainly an area of research that would merit further consideration.

- The statistical consistency present between the dating results from the humin and humic acid fractions suggests that the dating of bulk sediment samples may provide accurate age estimates. However, it must be stressed that AMS sample sizes would not sufficient to produce reliable results.

- Submission of unidentified plant remains, monocot, Poaceae fragments etc. should be avoided.

The results of dating analysis as part of both Phases 1 and 2 of this project have highlighted a number of hitherto unreported problems associated with chronologies derived from the dating of natural sediments within complex landscapes. Whilst this project has provided some answers, it has highlighted a number of avenues of future geochronological research, which would merit further investigation.

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APPENDIX I

BOREHOLE LOGS

Degree of Darkness	
nig.4	black
nig.3	
nig.2	
nig.1	
nig.0	white

Degree of Stratification	
strf.4	well stratified
strf.3	
strf.2	
strf.1	
strf.0	no stratification

Degree of Elasticity	
elas.4	very elastic
elas.3	
elas.2	
elas.1	
elas.0	no elasticity

Degree of Dryness	
sicc.4	very dry
sicc.3	
sicc.2	
sicc.1	
sicc.0	water

	Sharpness of Upper Boundary
lim.4	< 0.5mm
lim.3	< 1.0 & > 0.5mm
lim.2	< 2.0 & > 1.0mm
lim.1	< 10.0 & > 2.0mm
lim.0	> 10.0mm

	Sh	*Substantia humosa*	Humous substance, homogeneous microscopic structure
I Turfa	*Tb*	*T. bryophytica*	Mosses +/- humous substance
	Tl	*T. lignosa*	Stumps, roots, intertwined rootlets, of ligneous plants
	Th	*T. herbacea*	Roots, intertwined rootlets, rhizomes of herbaceous plants
II Detritus	*Dl*	*D. lignosus*	Fragments of ligneous plants >2mm
	Dh	*D. herbosus*	Fragments of herbaceous plants >2mm
	Dg	*D. granosus*	Fragments of ligneous and herbaceous plants <2mm >0.1mm
III Limus	*Lf*	*L. ferrugineus*	Rust, non-hardened. Particles <0.1mm
IV Argilla	*As*	*A.steatodes*	Particles of clay
	Ag	*A. granosa*	Particles of silt
V Grana	*Ga*	*G. arenosa*	Mineral particles 0.6 to 0.2mm
	Gs	*G. saburralia*	Mineral particles 2.0 to 0.6mm
	Gg(min)	*G. glareosa minora*	Mineral particles 6.0 to 2.0mm
	Gg(maj)	*G. glareosa majora*	Mineral particles 20.0 to 6.0mm
	Ptm	*Particulae testae molloscorum*	Fragments of calcareous shells

Physical and sedimentary properties of deposits according to Troels-Smith (1955)

Beccles 2008 Core 1 (TM 42357 91943)

Surface Elevation 0.028m O.D.

0.00-0.40m Made Ground

0.40-0.45m

Da	St	El	Dr	UB
3	0	0	2	-

Sh3, Dg1, Th+, Dh+, Ag+
Dark red-brown very well humified peat

0.45-0.62m

Da	St	El	Dr	UB
3	0+	1+	2	2

Dg2, Dh1, Sh1, Th+, Ag+
Dark red-brown herbaceous well humified peat

- Wood (twig) fragments abundant within

0.62-0.85m

Da	St	El	Dr	UB
3	0+	2	1+	1

Dh2, Dg1, Sh1, Th+, Ag+
Dark red-brown herbaceous peat

- abundant *phragmites* remains, occasional grass and wood fragments

0.85-2.06m

Da	St	El	Dr	UB
3	0	2	2	1

Dg2, Dh1, Sh1, Th+, Dl+
Dark brown herbaceous well humified peat

- *phragmites* remains 1.30-1.35m
- twig litter 1.12-1.20m, 1.78-1.87m
- vertical rootlets evident 1.40-1.60m

2.06-3.30m

Da	St	El	Dr	UB
3	0	1+	2	1

Dg2, Dh1, Sh1, Dl+, Th+, Ag+
Dark red-brown herbaceous well humified peat

- rootlets at 2.20m, 2.70m
- wood/twigs at 2.20m, 2.33m, 2.46m, 2.55m, 2.90-2.95

3.30-3.60m

Da	St	El	Dr	UB
3+	0	1	2	1

Sh2, Dg2, Th+, Dh+
Dark brown-black very well humified peat

- occasional (but sparse) *phragmites* stems

3.60-4.60m

Da	St	El	Dr	UB
3	0	2	2	1

Dg2, Sh2, Dh+, Dl+, Th+
Dark brown very well humified peat with occasional wood fragments

- wood at 3.72-3.75m
- *phragmites* at 3.91-3.95m, 4.10-4.12m, 4.22-4.24m

Beccles 2008 Core 2 (TM 42387 91946)

Surface Elevation 0.017m O.D.

0.00-1.00m Made Ground (possible ditch cutting)

1.00-1.38m

Da	St	El	Dr	UB
3	1	2	2	-

Dg2, Sh1, Dh1, Dl+, Th+, Ptm+, Ag+
Dark brown well humified peat with occasional wood remains and shell fragments (commonly whole – in situ?)

1.38-2.75m

Da	St	El	Dr	UB
3+	0	1	2	1

Dg2, Dh1, Sh1, Dl++, Th+, Ag+
Dark brown herbaceous well humified peat with grass, *phragmites* and wood fragments

- *phragmites* at 1.77-1.92m
- wood at 2.20-2.32m, 2.57-2.64m

2.75-3.10m

Da	St	El	Dr	UB
3+	0	1+	2	1

Sh2, Dg2, Dh+, Th+
Dark brown very well humified peat, detrital remains rare

3.10-3.60m

Da	St	El	Dr	UB

Dg2, Dh1, Sh1, Th+, Dl+, Ag+
Dark brown herbaceous well humified peat

- wood fragments at 3.12-3.34m

3.60-4.00m

Da	St	El	Dr	UB

Dg2, Sh1, Dh1, Th+, Dl+
Dark brown well humified peat with occasional grass remains

- wood fragments at 3.70-3.74m, 3.95-3.97m

4.00-4.30m

Da	St	El	Dr	UB

Dg2, Sh2, Dh+, Th+
Dark brown-black very well humified peat, sparse *phragmites* remains

Hengrave (TL 82848 69227)

Surface Elevation 20.509m O.D.

0.00-0.20 Made Ground

0.20-0.38m

Da	St	El	Dr	UB
3	0	1	2	1

Dg2, Sh1, Ag1, Dh+, Th+, Fl+, Ggmin+
Dark grey-brown well humified silty peat with occasional pebbles

0.38-0.47m

Da	St	El	Dr	UB
3	0	1	2	1

Dg2, Dh1, Sh1, Th+, Ag++
Dark brown herbaceous well humified peat, visible macrofossils sparse

0.47-0.80m

Da	St	El	Dr	UB
3+	0+	1	2+	1

Sh2, Dg1, Ag1, As+, Th+, Dh+, Ga+
Dark grey-brown herbaceous well humified silty peat with occasional sand

0.80-1.02m

Da	St	El	Dr	UB
3	1	1+	2+	1

Sh2, Dh1, Dg1, Ag+, As+, Ga+, Th+
Dark brown herbaceous peat with visible detrital remains
(roots, grass/*phragmites* remains)

1.02-1.05m

Da	St	El	Dr	UB
2	2	1+	2	2

Dg2, Dh2, Sh+, Th+, Ag+
Dark brown herbaceous peat with detrital laminations, visible *phragmites* stems

1.05-1.51m

Da	St	El	Dr	UB
3	1+	1	2	1

Dg2, Dh1, Sh1, Th+
Dark brown herbaceous peat with abundant detrital material (*phragmites*?)

1.51-1.62m

Da	St	El	Dr	UB
3	0+	1+	2	1

Sh2, Dg2, Th+, Ag+, Dh+
Dark brown very well humified silty peat with occasional *phragmites* remains

1.62-1.95m

Da	St	El	Dr	UB
3	0	1+	2	1

Dg2, Dh1, Sh1, Th+, Ag+
Dark brown herbaceous well humified peat, with occasional grass and phragmites remains

1.95-2.77m

Da	St	El	Dr	UB
3	1	1+	2	1

Dg2, Dh2, Sh+, Th+, Ga+, Dl+
Dark brown herbaceous humified peat with abundant *phragmites* remains, occasional wood fragments

- higher silt content 2.20-2.44m

2.77-2.95m

Da	St	El	Dr	UB
2+	0+	0+	3	2

Sh2, Dg1, Ga1, Ag+, Th+, Dh+
Dark brown very well humified peat with light grey sand laminations

- occasional (sparse) *phragmites* stems

2.95-3.20m	Da	St	El	Dr	UB
	1+	2	0	3	2

Ga3, Sh1, Dg+, Dh+, Ag++, As+
Light grey-brown sand with occasional humic horizons within

3.20-3.60m	Da	St	El	Dr	UB
	3	0	0+	2	1

Sh2, Ga2, Th+, Dg+, Ag+, As+
Dark brown sandy peat with occasional (sparse) *phragmites* remains

3.60-3.70m	Da	St	El	Dr	UB

Ga4, Sh+, Ag+
Light grey-brown sand with occasional humic lenses

Ixworth (TL 93709 69722)

Surface Elevation 27.231m O.D.

0.00-0.70m	Da	St	El	Dr	UB
	1+	0	0	3	-

Ag2, As2, Sh+, Th+, Dh+
Light grey-brown clayey silt with occasional organics (unsampled)

0.70-0.89m	Da	St	El	Dr	UB
	3	0	1+	2	2

Dg2, Sh2, Dh+, Th+, Ag+, As+
Dark brown well humified peat with occasional herbaceous fragments

0.89-0.95m	Da	St	El	Dr	UB
	3	1	1	2	1

Dg2, Sh1, Ag1, As+, Dh+, Th+
Dark grey-brown silt-rich well humified peat

0.95-1.25m	Da	St	El	Dr	UB
	3	1	1	2	1

Dg2, Sh2, Ga+, Ag+, Th+, Dh+
Dark brown well humified peat with occasional sand and silt horizons within

1.25-1.57m	Da	St	El	Dr	UB
	2	2	1	2	2

Dg2, Sh1, Ga1, Ag++, Th+
Medium grey-brown well humified peat with abundant sand and silt

1.57-2.40m	Da	St	El	Dr	UB
	3	0	2	2	1

Dg2, Dh1, Sh1, Th+, Dl+, Ag+
Dark brown herbaceous well humified peat with occasional wood fragments

APPENDIX II

RADIOCARBON RESULTS