Introduction
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.

Methods
Fourteen macrofossil samples were submitted to the Scottish Universities Environmental Research Centre (SUERC), East Kilbride. They were were pretreated 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 pretreated 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.

Results
The results, relating the radiocarbon measurements directly to calendar dates, are given in **Table X.1** and in **Figures X.1, X.4, X.7 and X.11** 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 X.1-X.4** have been calculated according to the maximum intercept method (Stuiver and Reimer 1986).

Beccles (2008) core 1
84cm
All four results from this level are 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.

330cm
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.

460cm
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.

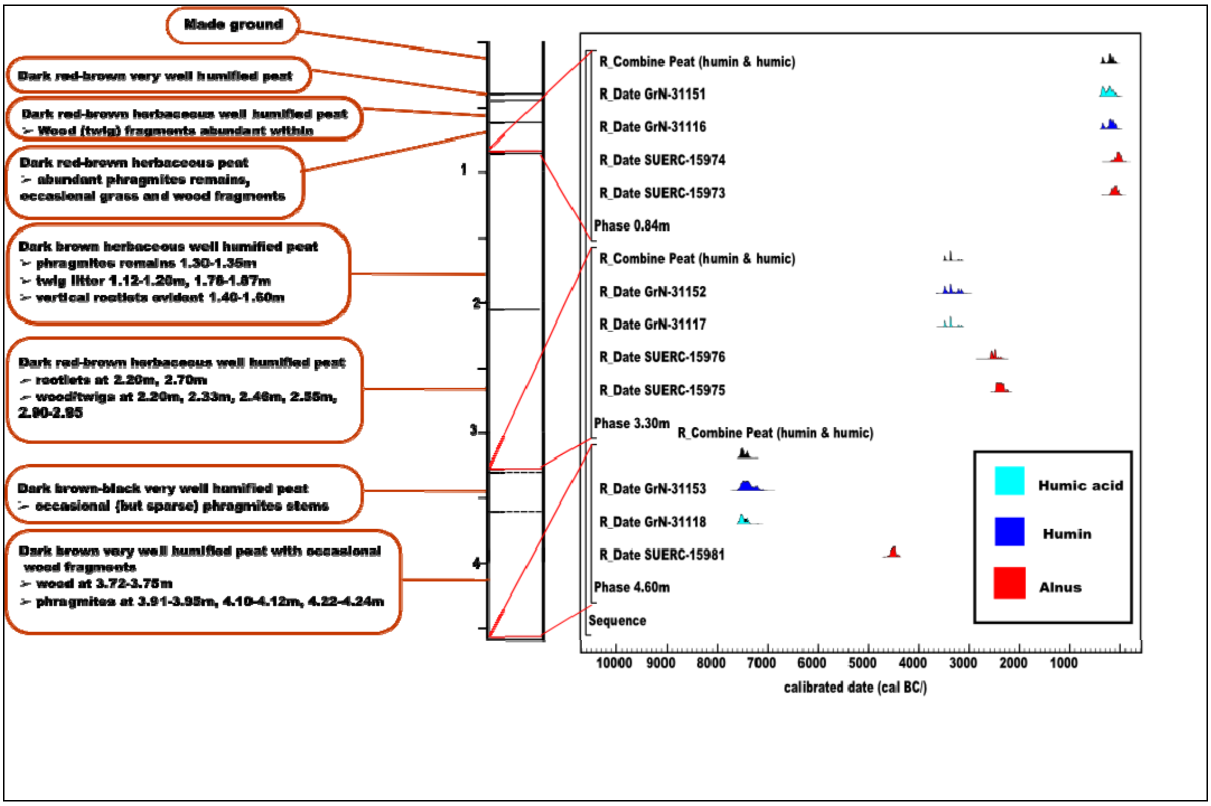

Figure X.1: Probability distributions of dates from Beccles (2008) core 1. Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993).

Interpretation
In two cases (330 cm and 460cm) the *Alnus* fragment(s) are 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 fact that phragmites remains are present in the sediments immediately overlying both of the horizons with discrepancies, between the wood and bulk sample measurements, raises the possibility that the alder fragments are intrusive. 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, we believe that this can be discounted as an interpretation due to the consistency of the humic and humin measurements. If the *Alnus* ages were correct then it would be expected that the humin fraction ages would be close in age to them, as humins are composed of organic detritus.

Organic fractions of the peat samples

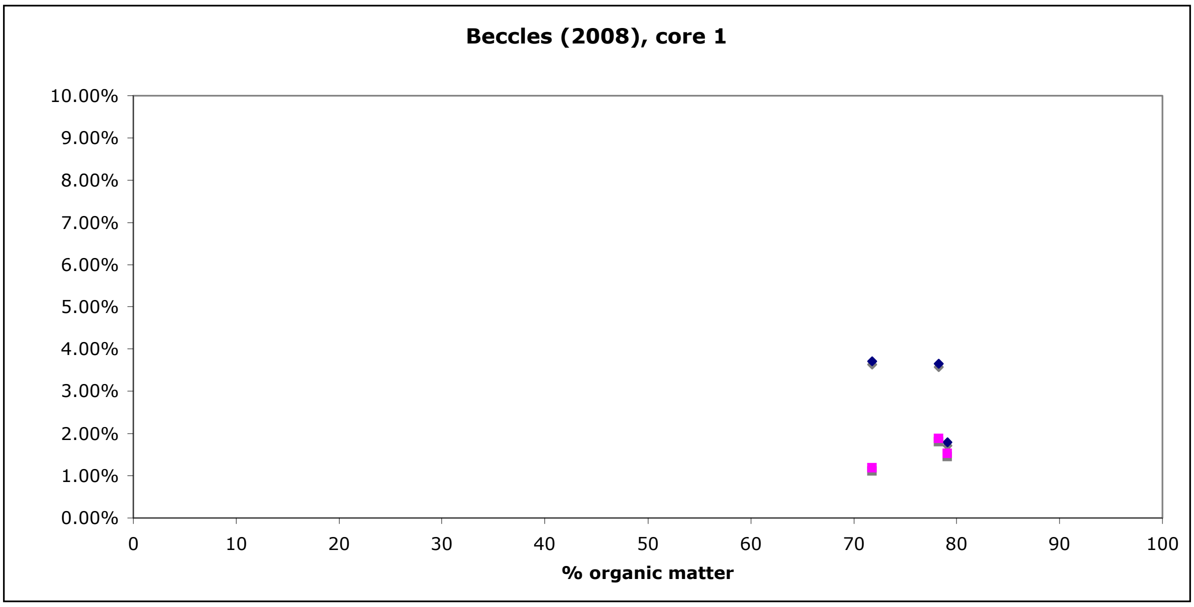

Figure X.2; Beccles (2008) core 1, % carbon content by weight of total sample weight and % organic content. [**pink = humic acid**, **blue = humin**]

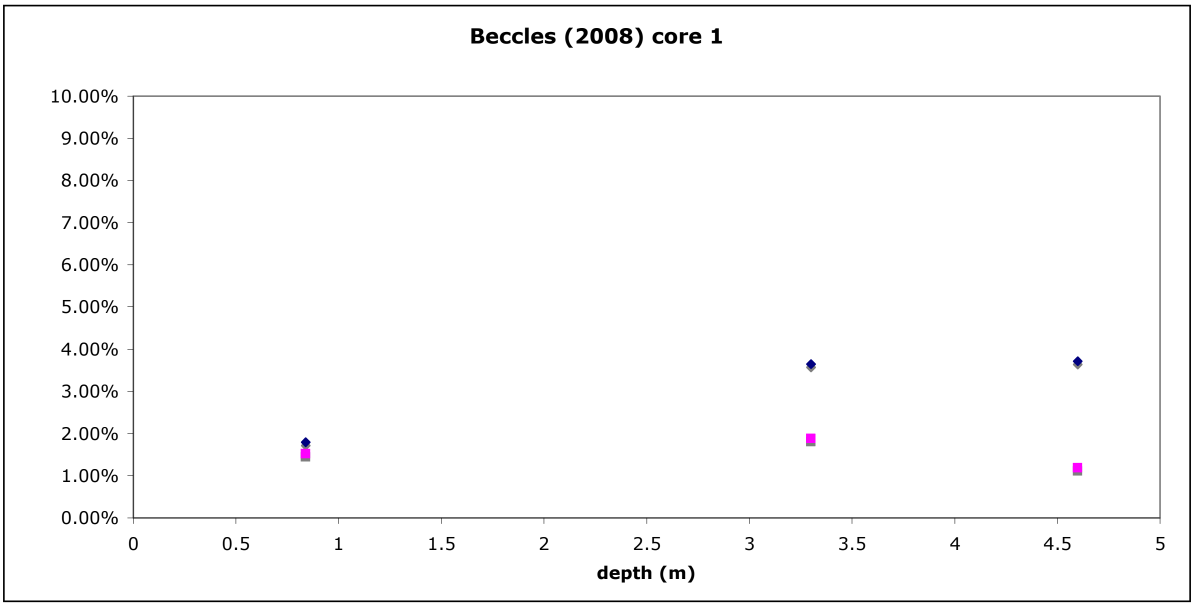

Figure X.3; Beccles (2008) core 1, % carbon content by weight of total sample weight and depth of sample. [**pink = humic acid**, **blue = humin**]

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 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, a soligenuous mire and raised mire complex compared with the floodplain environment at Beccles.

Beccles 2008, core 2

137cm

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).

359cm

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).

430cm

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

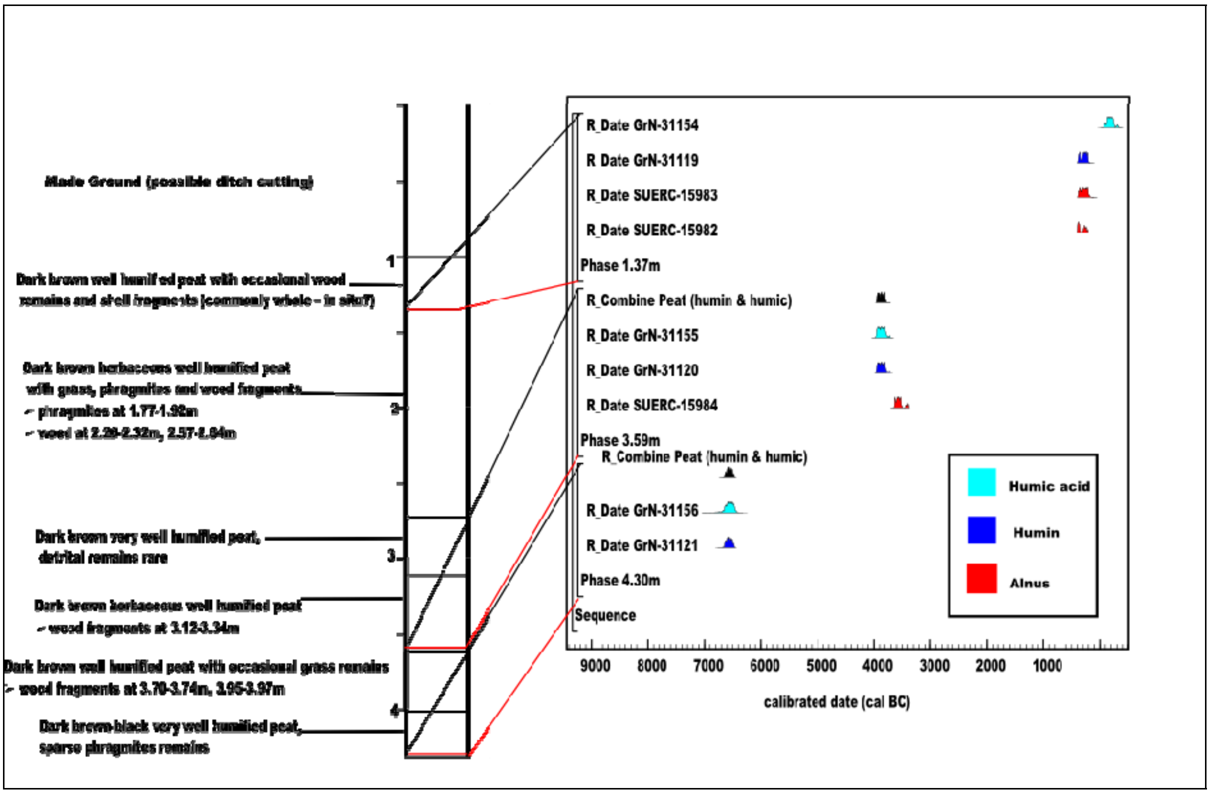

Figure X.4: Probability distributions of dates from Beccles (2008) core 2. Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993).

Interpretation

The picture from this core is less clear-cut than that for Beccles 2008, core 1, partially due to the lack of duplicate measurements from all date horizons. Although the alder fragment from 3.59m is again younger than the bulk sediment sample from the same horizon, the offset is noticeably smaller. This can perhaps be explained by the much lower incidence of phragmites remains from the core than Beccles 2008, core 1. The apparent discrepancy might therefore 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.

Organic fractions of the peat samples

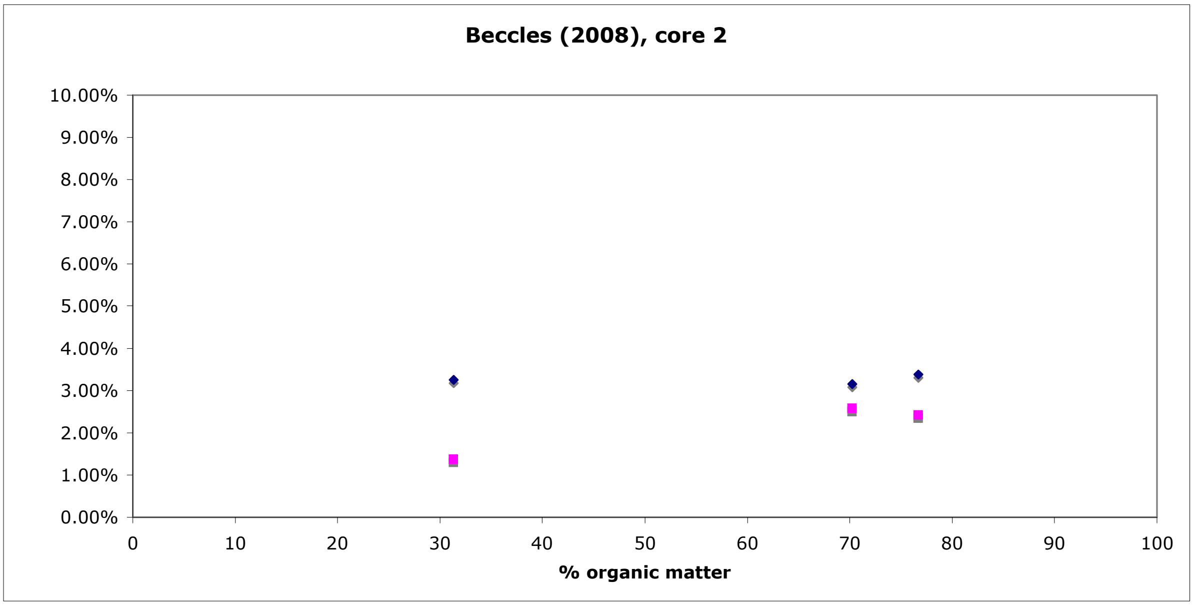

Figure X.5; Beccles (2008) core 2, % carbon content by weight of total sample weight and % organic content. [**pink = humic acid**, **blue = humin**]

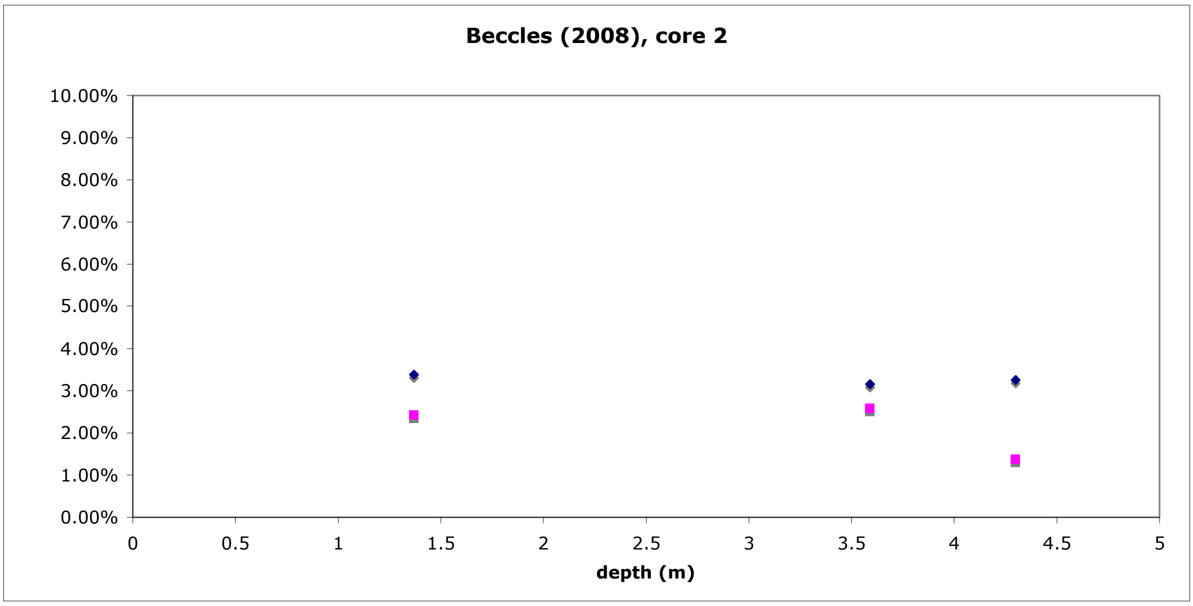

Figure X.6; Beccles (2008) core 2, % carbon content by weight of total sample weight and depth of sample. [**pink = humic acid, blue = humin**]

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 al* (1995) who found that humic acid contained most of the carbon (see above). The % carbon content of the humic fraction shows a very small increases with % organic matter, a similar pattern to Beccles (2008) core 1 (See **Fig X.2**).

Hengrave

47cm

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).

161cm

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

276cm

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).

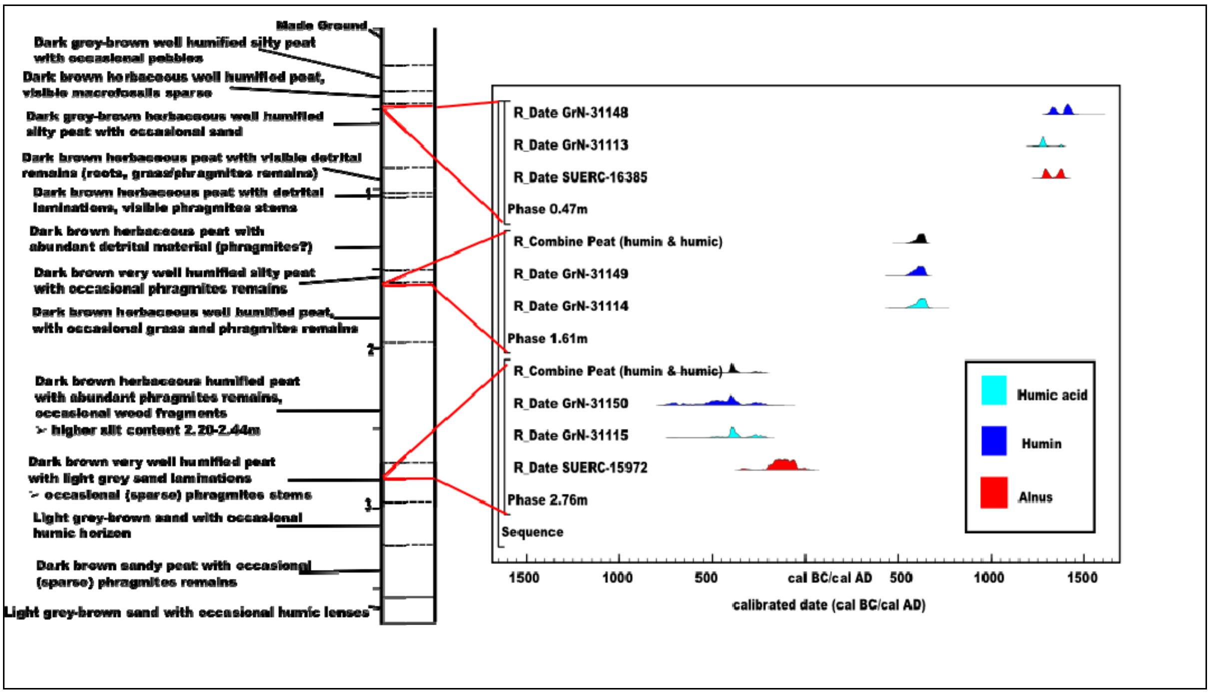

Figure X.7: Probability distributions of dates from Hengrave (2008). Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993).

Interpretation

The lack of duplicate measurements from all date horizons again makes interpretation slightly problematic. The alder fragment from 2.76m is again younger than the bulk sediment sample from the same horizon although the offset (see **Fig X.8**) is noticeably smaller than that from Beccles 2008, core 1. This can perhaps be explained by the much lower incidence of wood remains from the core than Beccles 2008, core 1, although there is a much greater incidence of phragmites.

Explanations for the age difference between the humic acid and humin/*Alnus* fragment include the upwards movement of humic acid or the intrusion of younger rootlets from above. Alternatively the measurement could be a simple statistical outlier.

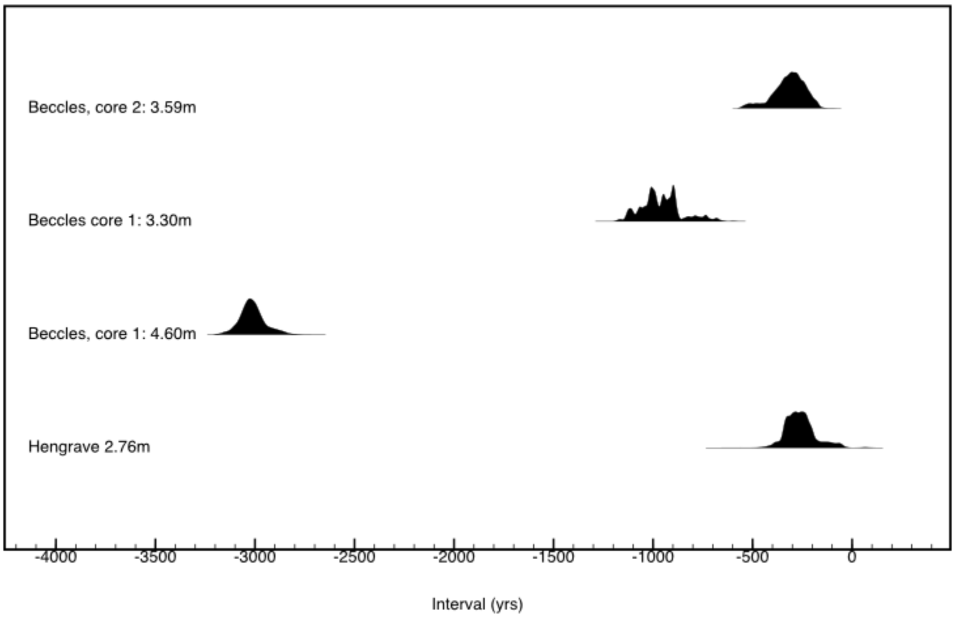

Figure X.8: Difference in age between bulk peat sample (weighted mean of humic/humin fraction) and *Alnus* fragment from selected horizons.

Organic fractions of the peat samples

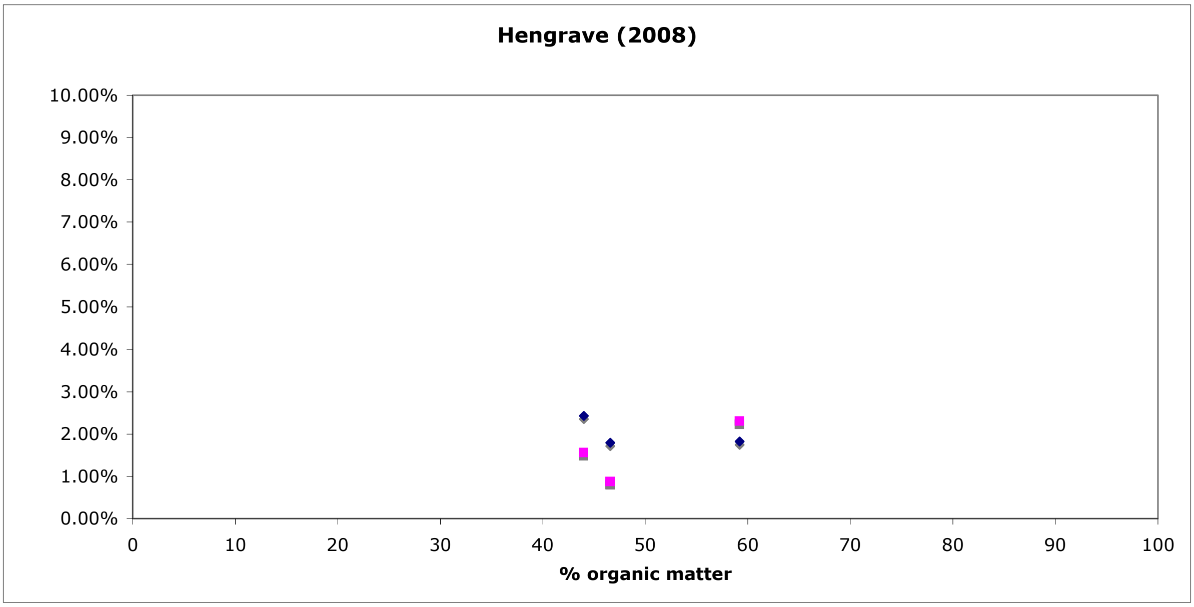

Figure X.9; Hengrave (2008) % carbon content by weight of total sample weight and % organic content. [**pink = humic acid, blue = humin**]

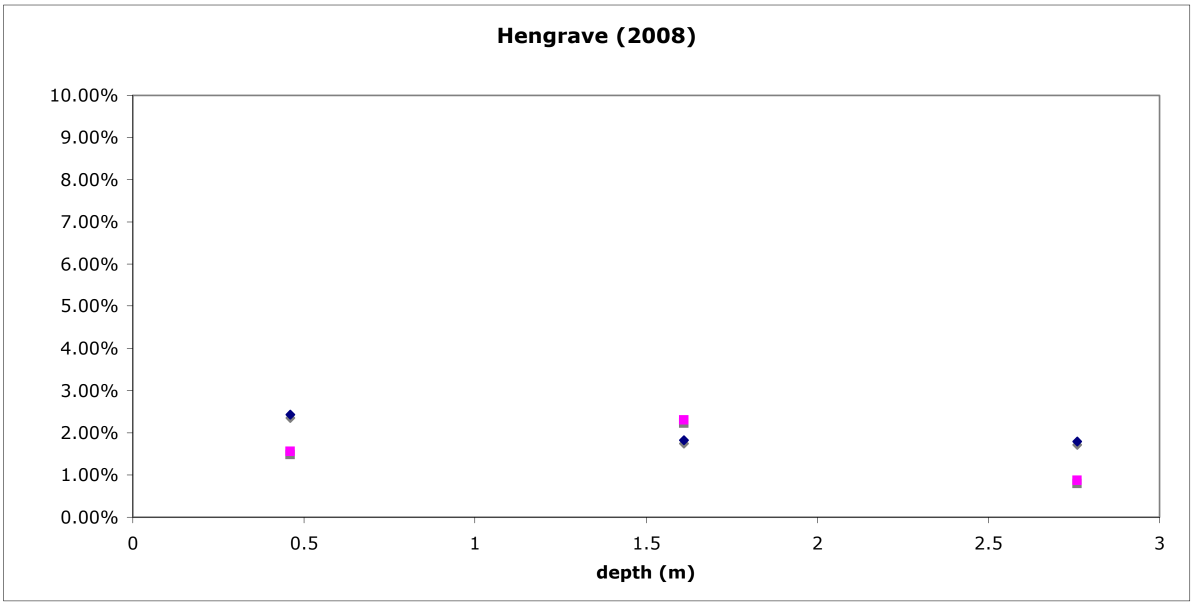

Figure X.10; Hengrave (2008) % carbon content by weight of total sample weight and depth of sample. [**pink = humic acid, blue = humin**]

Two of the samples show the humin fraction contains most of the carbon and therefore has the greatest influence on a combined age.

Ixworth
71cm
The humin and humic acid fractions are statistically consistent (T'=2.9; ν=1;T'(5%)= 3.8; Ward and Wilson 1978).

124cm
The humin and humic acid fractions are statistically consistent (T'=1.5; ν=1; T'(5%)=3.8; Ward and Wilson 1978).

239cm
The humin and humic acid fractions are statistically consistent (T'=0.1; ν=1; T'(5%)=3.8; Ward and Wilson 1978).

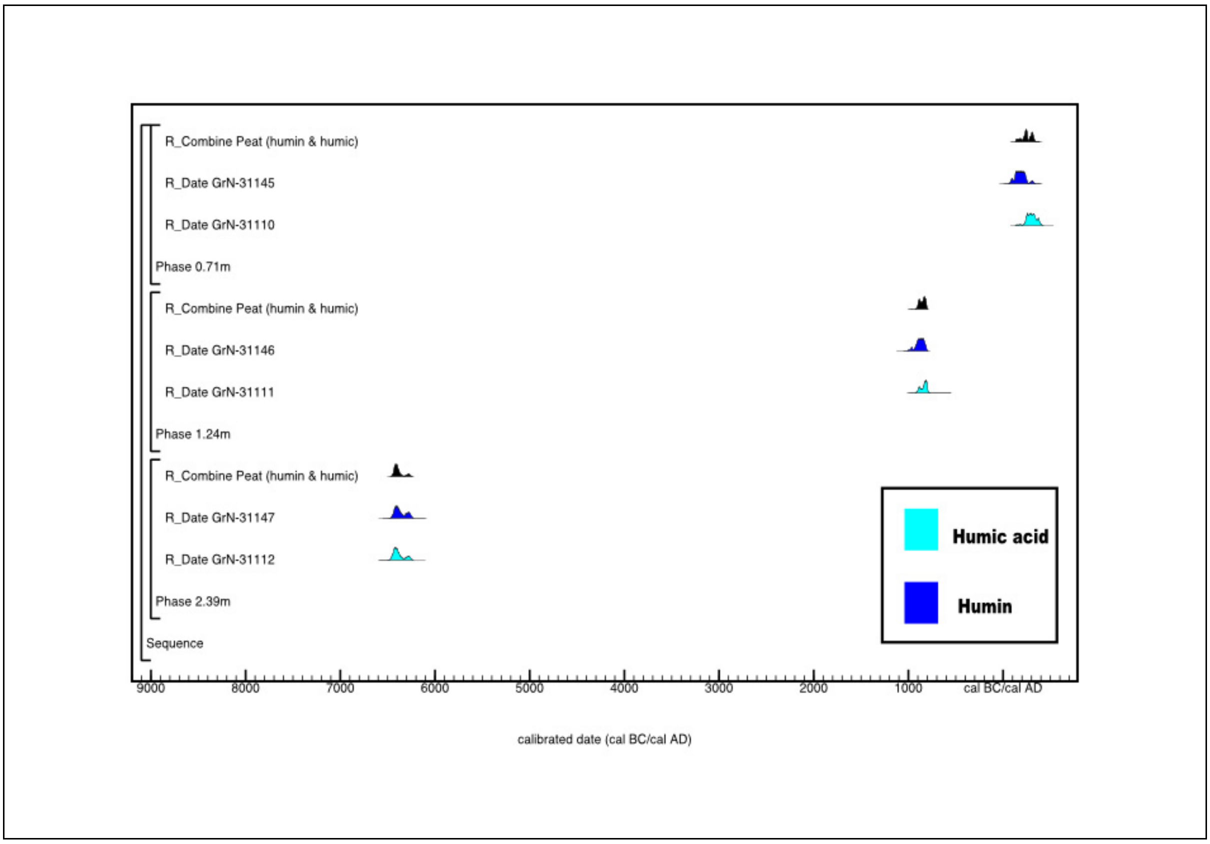

Figure X.11: Probability distributions of dates from Ixworth (2008). Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993).

Interpretation
Although the lack of any macrofossils hampers interpretation of the radiocarbon results, in particular the paucity of wood fragments is informative especially in light of the lack of evidence for phragmites. The humin and humic fractions would thus seem to provide a reliable chronology.

Organic fractions of the peat samples

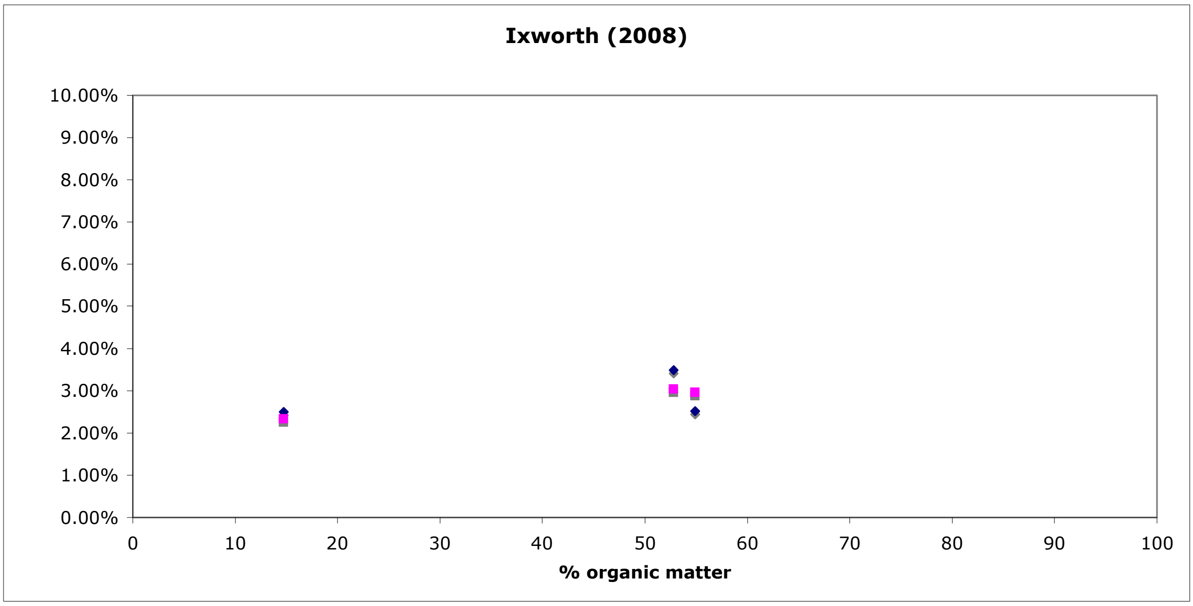

Figure 12; Ixworth (2008) % carbon content by weight of total sample weight and % organic content. [**pink = humic acid**, **blue = humin**]

Figure 13; Ixworth (2008) % carbon content by weight of total sample weight and depth of sample. [**pink = humic acid**, **blue = humin**]

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 1.24m does not seem to have an influence of the % carbon content.

Discussion

Beccles

Beccles (2007) core 1 (**Fig X.14**) came from close to the trackway that has extensive evidence for phragmites penetration and damage to the structural timbers. This would therefore seem to correlate with the fragments of dates on *Alnus* fragments that all appear to be too young, and especially with the pollen evidence that suggests the base of the core is immediately post-glacial in age and the *Alnus* rise occurs at *c*. 450cm.

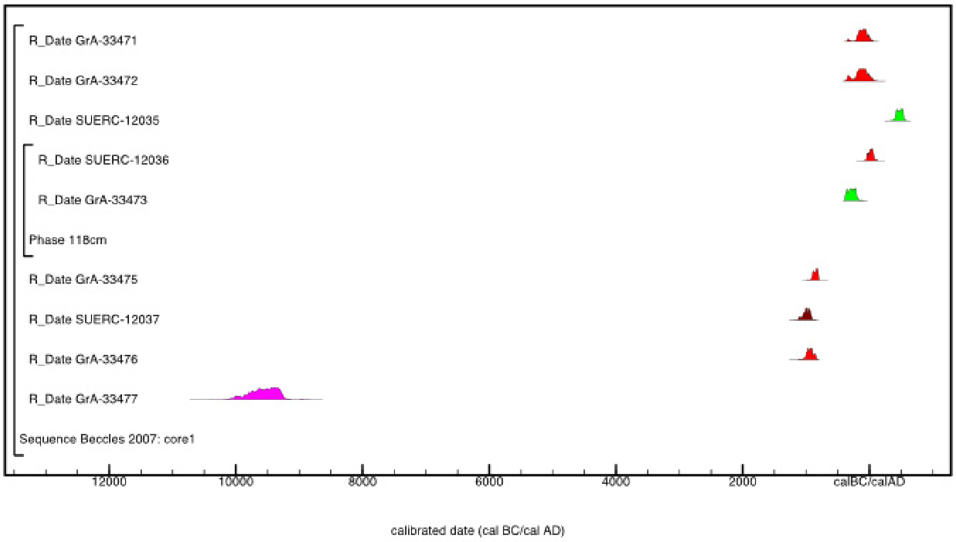

Figure X.14: Probability distributions of dates from Beccles (2007) core 1. Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993).

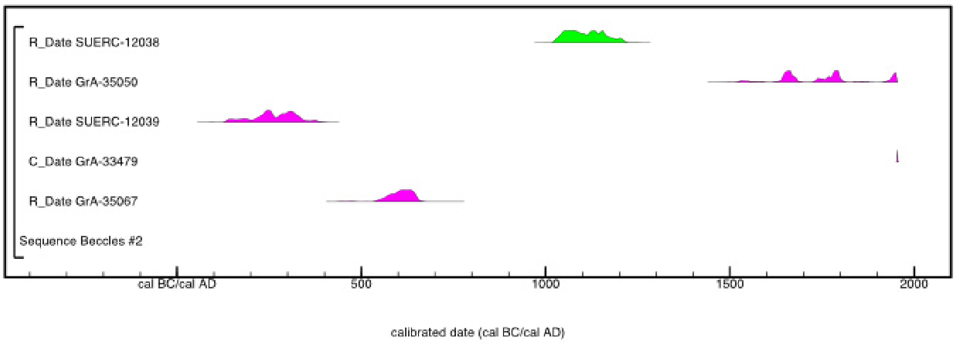

Figure X.15: Probability distributions of dates from Beccles (2007) core 2. Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993).

Hengrave

Given the evidence for phragmites in the Hengrave (2008) core (see **Fig X.7**), it is conceivable that the Poaceae fragments submitted from the Hengrave (2007) core (**Fig X.16**) are all phragmites and therefore may be instrusive?

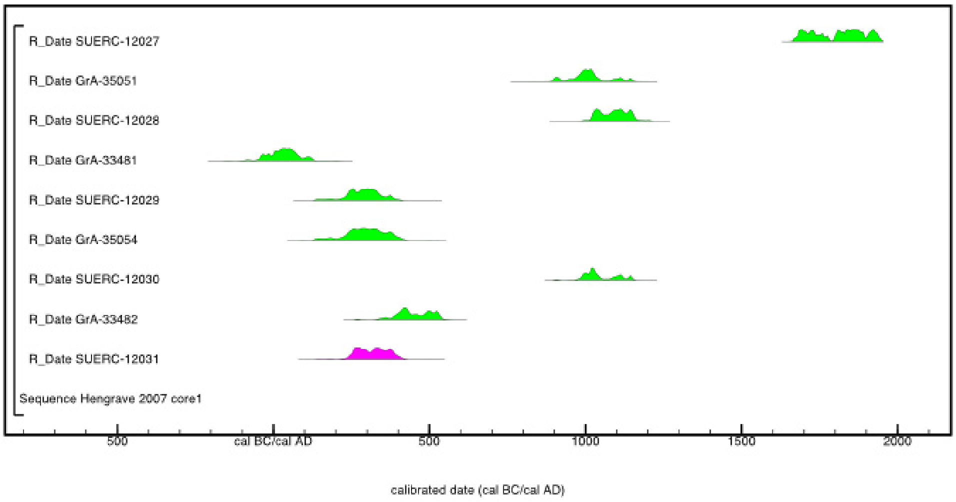

Figure X.16: Probability distributions of dates from Hengrave (2007). Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993).

Ixworth

The biostratigraphy would appear to suggest an almost complete Holocene sequence of environmental change. Discounting the Poaceae (GrA-35056 and SUERC-12021) and unidentified seed (GrA-35055) measurements from the top of the core (Fig X.17) the chronology does appear to be more, although not completely, in agreement with the pollen evidence.

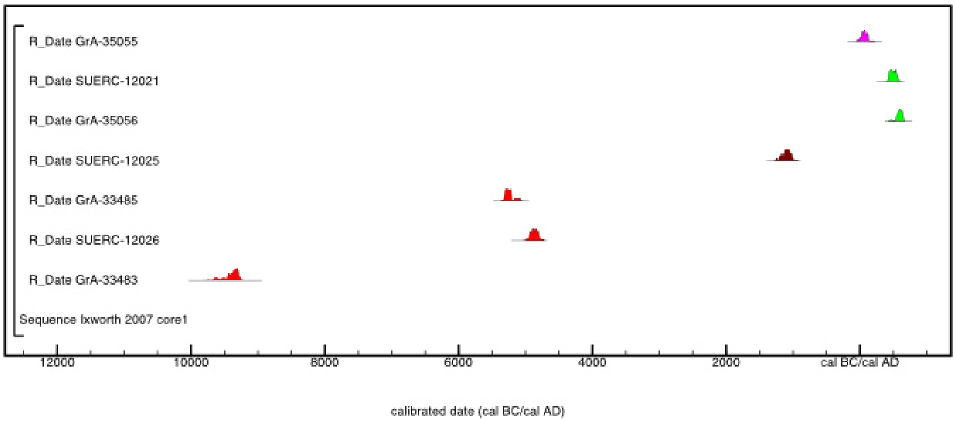

Figure X.17: Probability distributions of dates from Ixworth (2007). Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993).

δ^{13}C values

The plot of δ^{13}C values of macrofossils (**Fig X.18**) shows now discernable pattern, although the most negative sample (GrA-33479; -29.7) produced a modern date of cal AD 1956-1957.

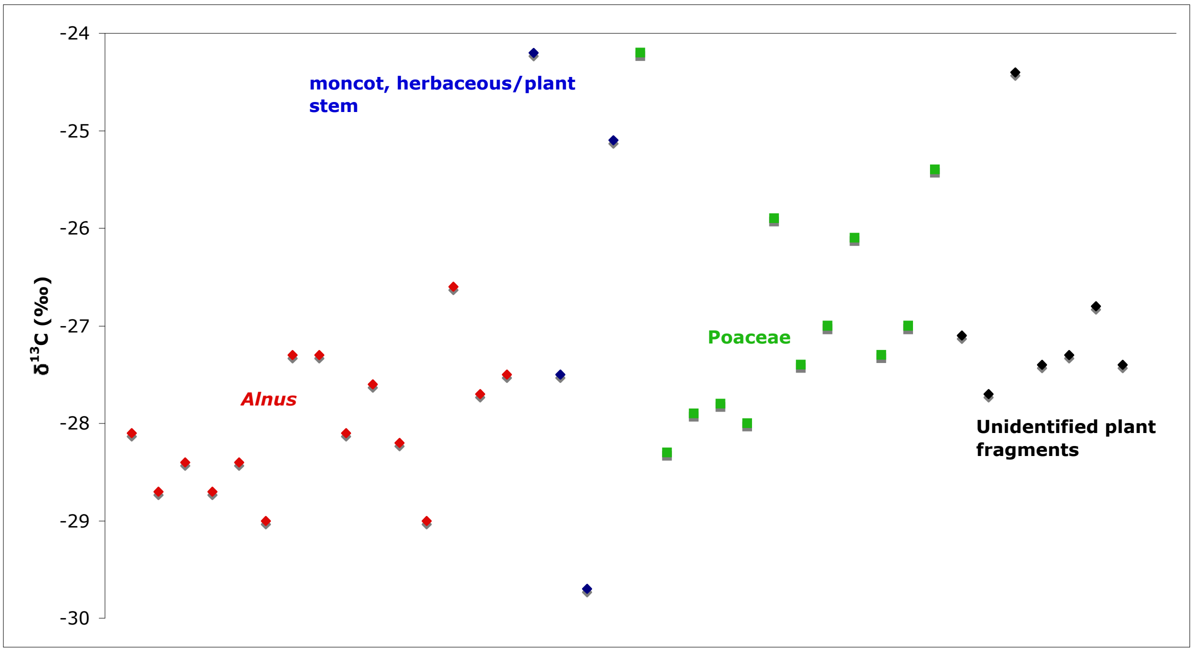

Figure X.18: δ^{13}C values of macrofossils dated as part of the Suffolk Rivers project

Conclusions

The results of the assessment suggest that:

- Where evidence of phragmites occurs macrofossils should only be dated if there is evidence that they grew *in-situ*. This is because the evidence suggests that phragmites might be the mechanism by which intrusive wood (twigs, etc) are deposited into earlier sediments. Although the exact process is not clear the correlation between phragmites and intrusive wood in the cores seems apparent.
- Bulk sediment samples, although it must be stressed not AMS size, might provide accurate age estimates.
- Submission of unidentified plant remains, monocot, Poaceae fragments should be avoided.

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Table X.1: Beccles (2008) core 1

Lab code	Sample ID	Material	Organic Content	ph	δ13C (‰)	Radiocarbon age (BP)	Weighted mean	Calibrated date (95% confidence)
GrN-31116	I–84cm	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–84cm	Peat (Humic acid)			-28.9	2160 ±50		
SUERC-15973	I–84cm A	Plant macrofossil: *Alnus* twig, (R Gale)			-29.5	2065 ±35		190–10 cal BC
SUERC-15974	I–84cm B	Plant macrofossil: *Alnus* twig (R Gale)			-28.1	2015 ±40		160–70 cal BC
GrN-31117	I–330cm	Peat (Humin)	78%	6.2	-28.00	4590 ±30	4590 ±26 BP (T'=0.0; ν=1; T'(5%)= 3.8)	3500–3340 cal BC
GrN-31152	I–330cm	Peat (Humic acid)			-28.7	4590 ±50		
SUERC-15975	I–330cm A	Plant macrofossil: *Alnus* wood (R Gale)			-30.8	3885 ±35		2480–2210 cal BC
SUERC-15976	I–330cm B	Plant macrofossil: *Alnus* wood (R Gale)			-30.7	3970 ±35		2580–2350 cal BC
GrN-31118	I–460cm	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–460cm	Peat (Humic acid)			-28.0	8340 ±80		
SUERC-15981	I–460cm	Plant macrofossil: cf. *Alnus* twig (R Gale)			-28.4	5660 ±35		4560–4400 cal BC

Table X.2: Beccles (2008) core 2

Lab Code	Sample ID	Material Dated	Organic Content	ph	δ13C (‰)	Radiocarbon age (BP)	Weighted mean	Calibrated date (95% confidence)
GrN-31119	2–137cm	Peat (Humin)	76%	5.6	-28.7	2230 ±30		390–200 cal BC
GrN-31154	2–137cm	Peat (Humic acid)			-28.6	1830 ±40		cal AD 70–320
SUERC-15982	2–137cm A	Plant macrofossil: *Alnus* twig, 1 growth ring (R Gale)			-28.7	2275 ±35		400–210 cal BC
SUERC-15983	2–137cm B	Plant macrofossil: *Alnus* twig, 1 growth ring (R Gale)			-28.4	2215 ±35		390–180 cal BC
GrN-31120	2–359cm	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	2–359cm	Peat (Humic acid)			-28.0	5060 ±40		
SUERC-15984	2–359cm	Plant macrofossil: *Alnus* roundwood, c. 8 growth rings (R Gale)			-29.0	4765 ±35		3650–3380 cal BC
GrN-31121	2–430cm	Peat (Humin)	31%	4.3	-27.6	7740 ±40	7735 ±35 BP (T'=0.1;	6640–6480 cal BC

GrN-31156	2–430cm	Peat (Humic acid)			-27.7	7720 ±70	ν=1; T'(5%)= 3.8)	
GU-6796	2–430cm	Plant macrofossil: *Alnus* twig, *c.* 1 growth ring (R Gale)				Sample failed		

Table X.3: Hengrave (2008)

	Sample ID	Material Dated	Organic Content	ph	δ13C (‰)	Radiocarbon age (BP)	Weighted mean	Calibrated date (95% confidence)
GrN-31113	47cm	Peat (Humin)	44%	6.0	-29.1	715 ±30		cal AD 1260–1380
GrN-31148	47cm	Peat (Humic acid)			-29.7	540 ±40		cal AD 1300–1450
SUERC-16385	47cm	Plant macrofossil: stem fragment (D Robinson)			-25.1	660 ±35		cal AD 1270–1400
GrN-31114	161cm	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	161cm	Peat (Humic acid)			-28.5	1450 ±30		
GU-6786	161cm	Plant macrofossil: herbaceous stem (R Gale)				Sample failed		
GrN-31115	276cm	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	276cm	Peat (Humic acid)			-30.5	2340 ±60		
SUERC-15972	276cm	Plant macrofossil: monocot culm (R Gale)			-27.5	2095 ±35		210–1 cal BC

Table X.4: Ixworth (2008)

	Sample ID	Material	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		