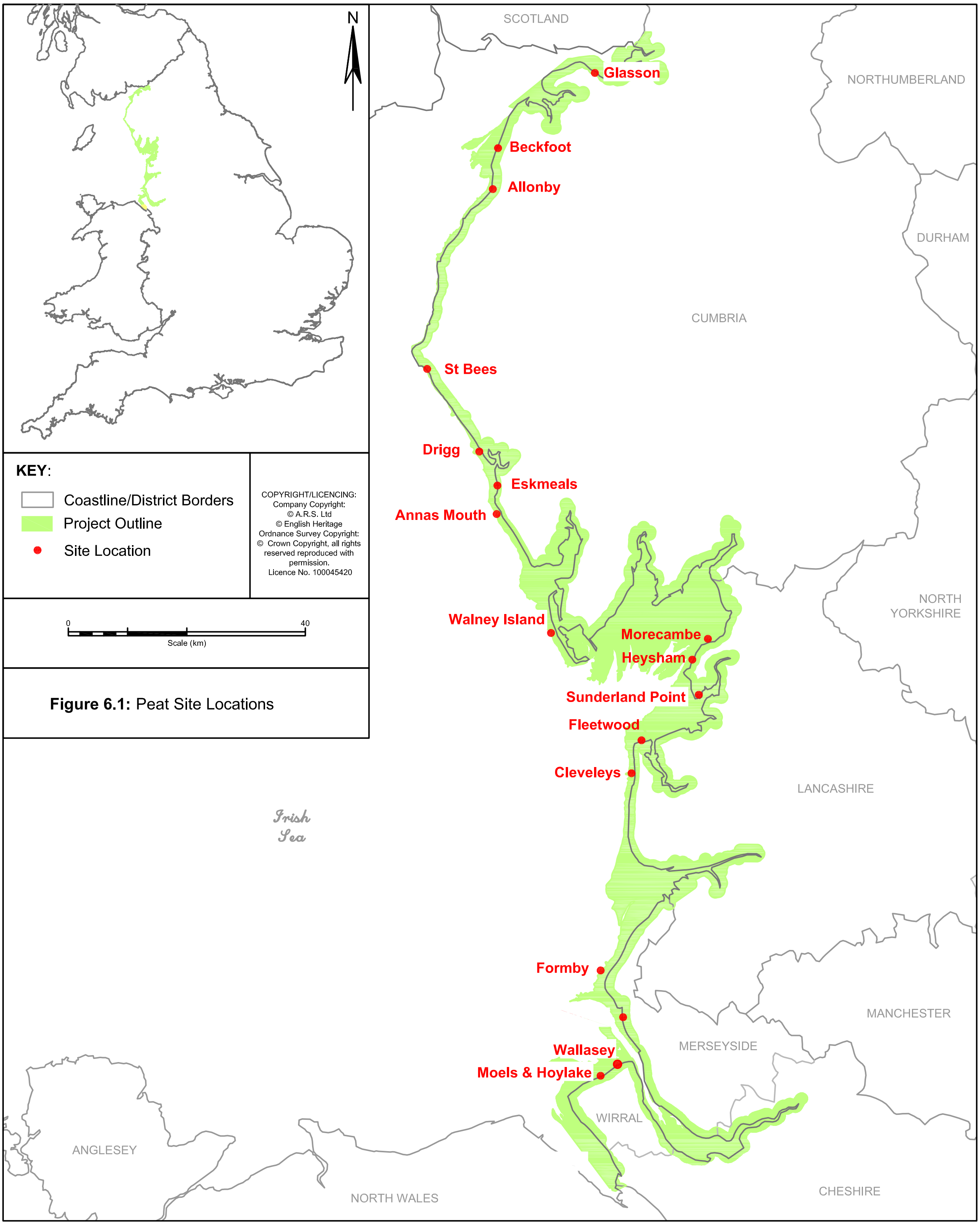

Figure 6.1: Peat Site Locations

6. PALAEOENVIRONMENTAL ANALYSIS

By Gillian Eadie
With contributions by Ian Boomer, Emma Hopla, Peter Marshall, Gordon Cook, Alan Hogg and Paula Reimer

6.1 Introduction

Nineteen sites along the North West coast were identified as having the potential to yield valuable palaeoenvironmental evidence based on sources such as the English Heritage Inter-tidal and Coastal Peat Database (Hazell, 2008), literature reviews (e.g. Tooley, 1974, 1980, 1985) as well as discussions with local specialists. All of these sites were visited at least once between February and May 2012 to assess and record the spatial extent and stratigraphical record of superficial palaeoenvironmental archives. Peat was the main focus of attention, but additionally the presence of what are considered to be inter-tidally deposited, detrital sediments (silts and clays) was also recorded although no subsamples were taken. All peats were sampled for pollen, plant macrofossil evidence and ^{14}C dating. The results of this assessment have been added to the English Heritage Inter-tidal and Coastal Peat Database (Hazell, 2008) using the pro-forma online submission forms. The extent of the exposed peats and the location of all samples were recorded using a DGPS unit in the same manner as the archaeological sites recorded in Chapters 2-5 and this data has been provided to the relevant regional HERs.

6.2 Methods

The nature of dynamic inter-tidal environments is such that the changing beach morphology may variously expose, and later cover, features such as the peats during normal spring to neap tidal cycles or as a result of episodic storm events that can mobilise large volumes of sediment. Such natural variability was observed even within the timescale of the current study (see Section 6.15). Given that some of the sources used to identify potential sites were of records dating from the late 19th century, it is not surprising that some of the occurrences could not be validated or sampled. Where no exposures were observed, hand-augering of the sandy inter-tidal zone, usually to a depth of 0.5-0.7m was undertaken, but never encountered otherwise obscured peat deposits.

Where organic rich sediments were identified *in situ*, their spatial extent was recorded using DGPS and a representative stratigraphical and sedimentological record was made based on shallow cores or small pits and cleaned sections. Given the relatively cohesive nature of such sediments, it was not considered necessary to record sediments deeper than *c.*1m below the modern inter-tidal surface as these are unlikely to be significantly eroded in the short to medium term. Stratigraphical sequences are shown in the relevant sections that follow together with cross-sections of the foreshore zone to illustrate the positions of the exposures relative to the local shore topography and geomorphology at the time of study.

The nineteen sites visited are discussed as they occur from south to north, and those sites which were sampled for palynological analysis and C^{14} dating are discussed, and the results of these investigations are provided, within this structure.

6.2.1 Pollen Sampling and Analysis

A total of twenty subsamples (Table 6.1) were assessed for pollen from seven sites along the North West coast; at Beckfoot, Cleveleys, Heysham, St. Bees, Drigg, Annas Mouth and Walney. Pollen preparation followed standard techniques including potassium hydroxide

(KOH) digestion, hydrofluoric acid (HF) treatment and acetylation (Moore *et al.*, 1991). At least 125 total land pollen grains (TLP) excluding aquatics and spores are usually counted for each sample at assessment level, however, pollen concentrations were very low in P014 (Beckfoot) and all five samples from St. Bees and full counts were not possible for these samples

The results for Drigg, Annas Mouth and Walney are presented in the form of pollen diagrams produced using the computer programmes TILIA and TILIA*GRAPH (Grimm 1991). All percentage figures are of Total Land Pollen (TLP) unless otherwise specified. The samples from Beckfoot, St. Bees, Cleveleys and Heysham contained only low pollen concentrations.

Site	***Code***	***Sample***	***Context***	***interval***
Cleveleys	P003	#A #B	Foreshore core	2-10 cm 31-38 cm
Cleveleys	P004	#A	Foreshore core	19-30 cm
Heysham	P005	#A	Foreshore core	2-8 cm
Annas Mouth	P007	#A #B #C	Foreshore core	0-8 cm 65-67 cm 71-76 cm
Annas Mouth	P008	#A #B	Foreshore surface peat Foreshore *in situ* tree wood	2 cm interval
St Bees	P009	#A #B #C #D #E	Foreshore core	8-12 cm 16-20 cm 30-34 cm 42-45 cm 56-59 cm
Drigg	P011	#A #B #C	Peat section in cliff	15-20 cm 35-40 cm 60-65 cm
Walney	P012	#A	Foreshore core	2-12 cm
Walney	P013	#A #B	Foreshore core	22-27 cm 36-41 cm
Beckfoot	P014	#A	Foreshore section	2 cm interval

Table 6.1 List of pollen samples recovered during this study for further analysis.

6.2.2 Radiocarbon Sampling and Analysis

A total of thirty-one radiocarbon measurements have been obtained on samples (Table 6.2) from eight sites along the North West coast; at Beckfoot, Cleveleys, Heysham, St. Bees, Bootle, Drigg, Annas Mouth and Walney.

Six bulk peat samples were submitted to The University Waikato Radiocarbon Dating Laboratory. The samples were acid washed using 10% concentration HCL, rinsed and then washed in hot 1% NaOH. Humic acids were obtained from the base soluble fraction which was acidified, rinsed, and dried, while a further step involving an acid wash in 10% HCL, prior to the sample being rinsed and dried was employed prior to the base soluble fraction being selected for dating. The radiocarbon ages for each sample (humic and humin) were then determined by liquid scintillation counting of benzene (Hogg *et al* 1987).

The eight samples dated at The Queen's University Belfast were processed using an acid-alkali-acid pre-treatment as first outlined in Vries and Barendsen (1952). The pretreated and dried samples were placed in quartz tubes with a strip of silver ribbon to remove nitrates, chlorides, and CuO. The samples were then sealed under vacuum and combusted to CO_2 overnight at 850°C. The CO_2 was converted to graphite on an iron catalyst using the zinc reduction method (Vogel *et al* 1984). The graphite samples were analysed with an 0.5MeV NEC pelletron compact accelerator, with the $^{14}C/^{12}C$ ratios corrected for fractionation using the on-line measured $^{13}C/^{12}C$ ratio and in accordance with Stuiver and Polach (1977).

Eleven samples were dated at the Scottish Universities Environmental Research Centre. The bone and antler were pre-treated using a modified Longin method (Longin 1971) and the waterlogged wood and plant macrofossils as described by Stenhouse and Baxter (1983). CO_2 obtained from the pre-treated samples was combusted in pre-cleaned sealed quartz tubes (Vandeputte *et al* 1996) and then converted to graphite (Slota *et al* 1987). The samples were dated by AMS as described by Freeman *et al* (2010).

All three laboratories maintain continual programmes of quality assurance procedures, in addition to participating in international inter-comparisons (Scott 2003; Scott *et al* 2010). These tests indicate no significant offsets and demonstrate the validity of the precision quoted.

The results are conventional radiocarbon ages (Stuiver and Polach 1977), and are quoted in accordance with the international standard known as the Trondheim convention (Stuiver and Kra 1986).

The calibrations of these results, which relate the radiocarbon measurements directly to the calendrical time scale, are given in the relevant site discussions. All have been calculated using the datasets published by Reimer *et al* (2009) and the computer program OxCal v4.1 (Bronk Ramsey 1995; 1998; 2001; 2009). The calibrated date ranges cited are quoted in the form recommended by Mook (1986), with the end points rounded outward to 10 years. The ranges have been calculated according to the maximum intercept method (Stuiver and Reimer 1986) and the probability distributions shown are derived from the probability method (Stuiver and Reimer 1993).

Site	Code	Grid Ref.	Spit/ cm from the surface	Description	Species	Notes	Dating Potential	Further work	EH Sample Ref.
Annas Mouth	PO17	SD 07519 89175	base: 26-27cm	bulk peat sample	N/A		humic & humin fractions	No	NWRCZA AM1
Annas Mouth	PO17	SD 07519 89175	middle: 4-5cm	Roundwood, thin bark	*Betula* S.P (birch)	12 years old, felled in summer	C14	No	NWRCZA AM2
Annas Mouth	PO17	SD 07536 89177	surface timber	Large timber	*Populus* (poplar) poss *salix* (willow)		C14	No	NWRCZA AM3
Beckfoot	PO15	NY 08543 48554	total peat: 2-5cm	bulk peat sample	N/A		humic & humin fractions	No	NWRCZA B1
Beckfoot	PO15	NY 08546 48549	surface timber	Dia dist. Final growth ring present	*Fagacae, Castenea sativa?* (Chestnut)		C14	Ring count	NWRCZA B2
Cleveleys	PO20	SD 31117 43469	base: 20-21cm	bulk peat sample	N/A		humic & humin fractions	No	NWRCZA C1
Cleveleys	PO20	SD 31137 43245	surface timber	Round wood. Bark and pith	*Aesclus hippocataneum* (horse chestnut)		C14	Ring count	NWRCZA C2
Drigg	PO11	SD 04700 98560	top: 0-2cm	bulk peat sample	N/A		humic & humin fractions	No	NWRCZA D1
Drigg	PO11	SD 04700 98560	middle: 38-40cm	Small sub sample. Roundwood final growth rep	*Prob salix poss populus*		C14	No	NWRCZA D2
Drigg	PO11	SD 04700 98560	5cm from base	Seed	unidentified		Seed C14	Seed ID	NWRCZA D3-A
Drigg	PO11	SD 04700 98560	5cm from base	Roundwood final growth rep	*Alnus* (alder)		C14	No	NWRCZA D3-B
Heysham	PO19	SD 41415 62227	base: 9-10cm	bulk peat sample			humic & humin fractions	No	NWRCZA H1
Heysham	PO19	SD 41415 62227	surface timber	Large timber	*Quercus* (oak)	50-70 rings	Dendro	No	NWRCZA H2
St Bees	PO16	NX 96214 11503	base: 33-35cm	Roundwood. Sap no bark	*Salix or populus*		C14	No	NWRCZA SB1
St Bees	PO16	NX 96214 11503	middle: 18-20cm	Seed	unidentified		Seed C14	Seed ID	NWRCZA SB2-A
St Bees	PO16	NX 96214 11503	middle: 18-20cm	Small twig. Lots of bits Roundwood	*Tilia* (lime) *or corylus* (hazel)		C14	No	NWRCZA SB2-B
St Bees	PO16	NX 96214 11503	top: 3-4cm	Seed	unidentified		Seed C14	Seed ID	NWRCZA SB3-A
St Bees	PO16	NX 96214 11503	top: 3-4cm	Roundwood	unidentified		C14	No	NWRCZA SB3-B
Walney - west	PO18	SD 18878 65209	base: 16-18cm	bulk peat sample	N/A		humic & humin fractions	No	NWRCZA W1
Walney - west	PO18	SD 18878 65209	surface timber	Bark present	*Alnus* (alder)		C14	No	NWRCZA W2

Bootle	P021	SD 07940 90970	top 15cm of peat	Sue Stallibrass providing sample	Hazelnut shell x 2		Shell C14	No	NWRCZA BO1
Walney - southwest	P022	SD 20984 61005	top of the silt	David Coward providing sample	*bos* skull		C14	No	2012.1
Walney - southwest	P022	SD 20984 61005	top of the silt	David Coward providing sample	red deer antler		C14	No	2012.2

Table 6.2 NWRCZA palaeoenvironmental samples submitted for radiocarbon dating

6.3 Meols & Hoylake (SJ 21608 89787 to SJ 22623 90842)
Peat database record 239 details the occurrence of a submerged forest from Adams (2002). The area consists of extensive sand flats with occasional patches of silts and silty sands on the surface. The inter-tidal area at Meols yielded no *in-situ* peats, nor were there any exposures of Holocene fine-grained, intertidal clays and silts. The occurrence of occasional eroded and well rounded 'peat-balls' and rounded wood clasts indicates the presence of organic-rich deposits in the area, either at some distance laterally (perhaps below modern LAT – Lowest Astronomical Tide) or at depth, covered by the present inter-tidal surface. Reconnaissance shallow hand augering (<50cm) did not encounter anything other than modern inter-tidal sands and occasional grey silty-sands, also exposed along some tidal channel margins where they form vertical channel sides, detailed observations show these to be silty sands (<20% silt estimated) with little if any significant organic component. No *in situ* peats were observed along this stretch of coastline.

Near to the high-tide zone there is evidence of pioneer saltmarsh associated with stands of *Spartina anglica* and a grass, probably *Festuca rubra*, which show as slightly elevated and irregular patches across the modern inter-tidal sand flats (Figure 6.2). These macrophytes have stabilised numerous small patches (<2m) of the upper 15-30cm of the intertidal environment and enhance further sedimentation. As a result, these stands resist tidal reworking and mobilisation of the locally-dominant medium sand and therefore stand above the main intertidal surface. Shallow hand-coring has shown that these stands are not related to any buried or subsurface organic deposits. Reconnaissance coring across the area (up to 100m from the sea wall) indicates that medium to dark grey silty-sand occurs at depth, from about 0.5m to a depth of at least 1m.

Figure 6.2 Patchy vegetation in the upper inter-tidal zone at Hoylake (scale = 1m).

6.4 **Wallasey** (SJ 26262 92259)

Although not referenced in the peat database, sediments/peats have been observed outcropping along this coastline (Sue Stallibrass *pers comm.*). When visited, the site exhibited extensive sand flats with shallow channels. Minor bank-side erosion along channels exposes some dark sediments of medium to dark grey silty-sand 0.2-0.4m below the modern inter-tidal surface. However, no peats, inter-tidal clays or silts were observed.

6.5 **Crosby** (SD 29236 01335)

Human footprints have been recorded preserved within what are though to be Holocene sediments exposed in the inter-tidal zone at Crosby (Current Archaeology 265 2012, 10). The best exposures along this part of the coast are seen just north of Antony Gormley's 'Another Place' installation (the men in the sea). The highest part of the foreshore consists of red-brick and stonework masonry building rubble fronting a small (<1.5m) cliff through a soil profile. The rubble provides a mobile cobble to boulder grade storm beach covering a series of Holocene inter-tidal clays/silts and sands that are exposed at the seaward margin of the building rubble (Figure 6.3).

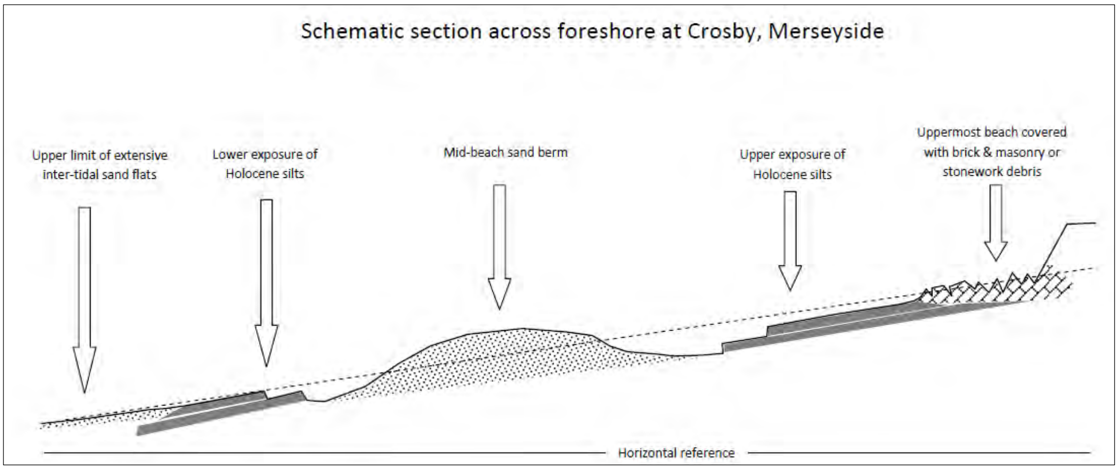

Figure 6.3 shows the relative position of the major morphological elements observed on the Crosby foreshore on 8th February 2012. The vertical and horizontal scales are exaggerated and based on field observation only, they are not meant to represent measured distances or elevations. The dashed line represents an approximate mean beach gradient.

The Holocene sediments consist of three separate layers of grey silty-clay each of approximately 0.2-0.25m thickness, and the three are separated by small (<1cm) layers of fine-medium sand. The sands provide a structural weakness to the sediments and results in the sand layer eroding and under-cutting the silty clays which are therefore lost/eroded a layer at a time, often in significant blocks (Figure 6.4). The footprints were not observed during this study, but from photographic records they would appear to be imprinted on the uppermost of the recorded silts.

Shallow hand-augering shows these fine-grained sediments to be underlain by inter-tidal sand suggesting that these are mid- to late Holocene in age; early Holocene sediments of this nature usually overlie late-glacial tills or outwash deposits.

Two discrete exposures of the Holocene sediments are recognised, separated by a mid-beach berm of fine-medium sand. No peat deposits or otherwise organic-rich clastic deposits were observed *in situ*. Occasional large (<1m) clasts of detrital "peat balls" were observed *ex-situ* on the modern surface.

Figure 6.4 Thinly inter-bedded silts and sands at Crosby (scale = 1m).

6.6 Formby Dunes (SD 28378 10635)

Numerous records in the peat database refer to organic-rich deposits and the presence of fossil footprints in this area (records 216, 217, 241, 476 & 537). At the time of visit, little of the inter-tidal foreshore was accessible so no investigations could be made in that area, but the dune system was clearly exposed being subjected to significant shore-face erosion of the unconsolidated fine sand. One significant palaeosol exposed within the eroded dune sections (Figure 6.5) can be traced laterally to show that it is developed on an uneven surface. A second, less well-developed palaeosol is present towards the base of the sequence. The upper surface of the main palaeosol can be observed in section and plan view and is clearly related to the presence of an overlying layer of woody remains, some of which are *in situ* tree stumps (largely pine and birch). This distinct palaeosol and its overlying woody remains probably represent a period of planting and stability during the 20th century. This dating is confirmed by the presence at the base of the sequence of what is clearly *in situ* 20th century block paving, upon which rests the entire observed dune sequence. This may correlate to database record 537 from Tooley (1985), which he referred to as a 'fossil dune slack'.

The palaeosols described above consist of largely fine-grained aeolian sand but with a matrix of dark-grey to black comminuted organic material (carbonised wood). This is a poorly developed soil, typical of such coastal settings. A modern example of which can be seen landward of the existing dune systems.

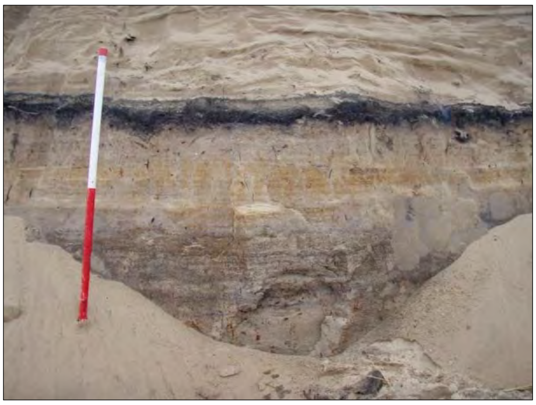

Figure 6.5 above left, shows details of organic rich palaeosol in section through Formby dunes; above right, illustrates the lateral continuity of the same palaeosol (scale = 1m).

6.7 **Fleetwood** (SD 32102 48306)

Peat database record 496 refers to a late 19th century record of fossil trees. The extensive tidal flats were surveyed visually on the surface and to a depth of <50cm via hand augering. No sediments were recorded other than those associated with the present day mobile inter-tidal system. No peats or tree remains were observed at this time.

6.8 **Cleveleys** (SD 31023 43312 Map Figure 6.8)

The shoreline at Cleveleys is protected by extensive sea walls. Mobile intertidal sands run all the way up to the sea wall on the landward side and running parallel to the sea is a very prominent mid-beach sand berm. Beneath the berm and sea wall trapped water flows have caused erosion and the creation of a relatively low-lying coast parallel tidal channel within which discrete peat exposures were identified by Peter Iles. At least five separate discrete exposures of organic material were observed on the Cleveleys foreshore, comprising one upper peat, and a lower organic-rich silt. At two of these localities, significant *in situ* tree boles are preserved (Figures 6.6).

One of these exposures was just exposed at the low tide water's edge and consisted of a *c.*15x5 m exposure of peat with at least five prostrate and parallel-aligned tree-trunks of *c.*0.25-0.3m diameter recorded on the upper surface. The alignment was broadly coast normal and probably reflects the alignment of tree fall following a final high-wind or storm event affecting what would likely have been a stand of dead or dying trees due to marine encroachment.

The four more proximal exposures (244) occur within the relatively low-lying coast-parallel tidal channel, bordered seawards by an extensive sand berm. The peats and associated silts/clays exposed at the modern surface are underlain by at least 0.5m of additional silts and clays (Figure 6.7).

Figure 6.6; above left, typical exposure of peats in the inter-tidal zone at Cleveleys; above right, an example of a large *in situ* tree stump at Cleveleys (scale = 1m).

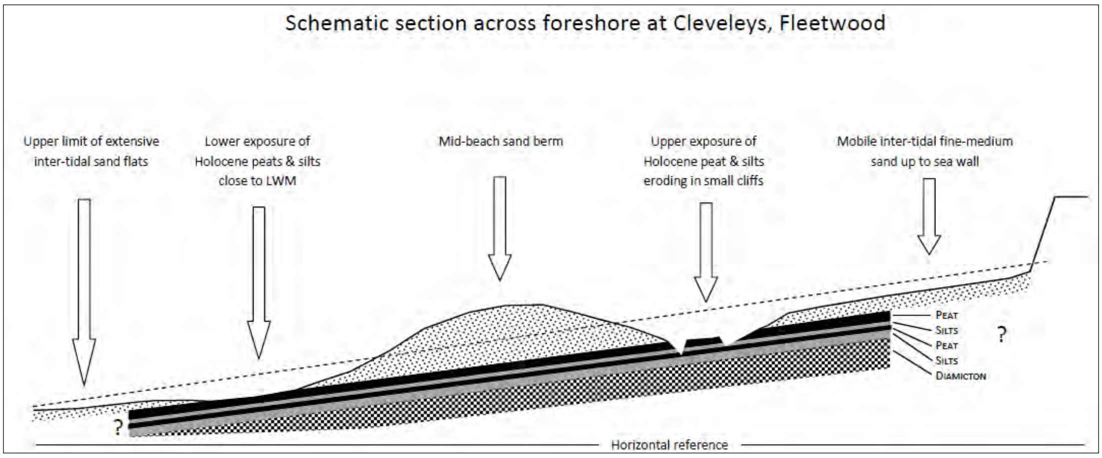

Figure 6.7 Section above shows the relative position of the major morphological elements observed on the Cleveleys foreshore on 9th February 2012. The vertical and horizontal scales are exaggerated and based on field observation only, they are not meant to represent measured distances or elevations. The dashed line represents an approximate mean beach gradient. The uppermost exposures occur as patchy exposures, each of ~10 to ~100 m2, along a beach-parallel natural channel that lies immediately landward of a mid-beach sand berm. The top surface of the upper peat bears a number of prostrate tree trunks and branches (<45cm diameter). *In situ* tree-stumps also observed. "?" indicate uncertainty beyond existing exposure.

6.8.1 Pollen Analysis

Two pollen cores (P003&P004) were taken from this site and contained only low pollen concentrations and these are presented in Table 6.3.

P003 #A	P003 #B	P004 #A
2-10 cm	31-38 cm	17-30 cm
No pollen	*Corylus avellana*-type (1) Poaceae (1) *Sparganium* indet. (1)	Poaceae (1) *Potentilla erecta* (1)

Table 6.3 Pollen record (counts) from Cleveleys foreshore peats

6.8.2 Radiocarbon Analysis

Bulk peat samples from the base of the peat (P020 – peat) were submitted for radiocarbon dating through the extraction of humic and humin acid fractions. A sample from a prostrate tree on the surface of the peat (P020 – timber) was also submitted for dating.

Measurements on the humic and humin fractions of the peat sample are not statistically consistent (T'=24.5; ν=1; T'(1%)=6.4; Ward and Wilson 1978). Humic acid fractions are often younger than the humin fraction as a result of downward movement of humic acid through profiles (Dresser 1970; Shore *et al* 1995; Hammond *et al* 1991, Brock *et al* 2011). Thus in this where the humin and humic acid fractions are not statistically consistent (cf Cook *et al* 1988) we have chosen to use the humin result as providing the 'true' age of the date of peat formation (Bartley and Chambers 1992).

The results (Table 6.4 and Figure 6.8) show that peat accumulation at Cleveleys, recorded in the channel, dates from *c* 13110–12150 cal BC (Windermere Interstadial) and that inundation by the sea here occurred by 7040–6680 cal BC.

Laboratory number	Sample	Material	$\delta^{13}C$ (‰)	Radiocarbon Age (BP)	Calibrated Date (95% confidence)
Wk-35930	C1	Peat (324g) humic acid fraction from 1cm spit 20–21cm from the top of the peat	-20.3	11976±77	12070–11710 cal BC
Wk-35924	C1	Peat (324g) humin fraction from 1cm spit 20–21cm from the top of the peat	-18.0	12410±39	13110–12150 cal BC
SUERC-44440	C2 -surface timber	*Populus/Salix*	-27.4	7936±28	7040–6650 cal BC

Table 6.4: Cleveleys – North West Rapid Coastal Zone Assessment – radiocarbon results

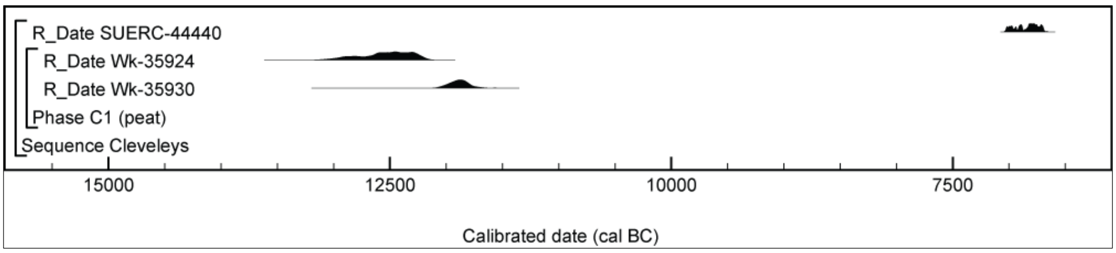

Figure 6.8 Probability distributions of dates from Cleveleys. The distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993)

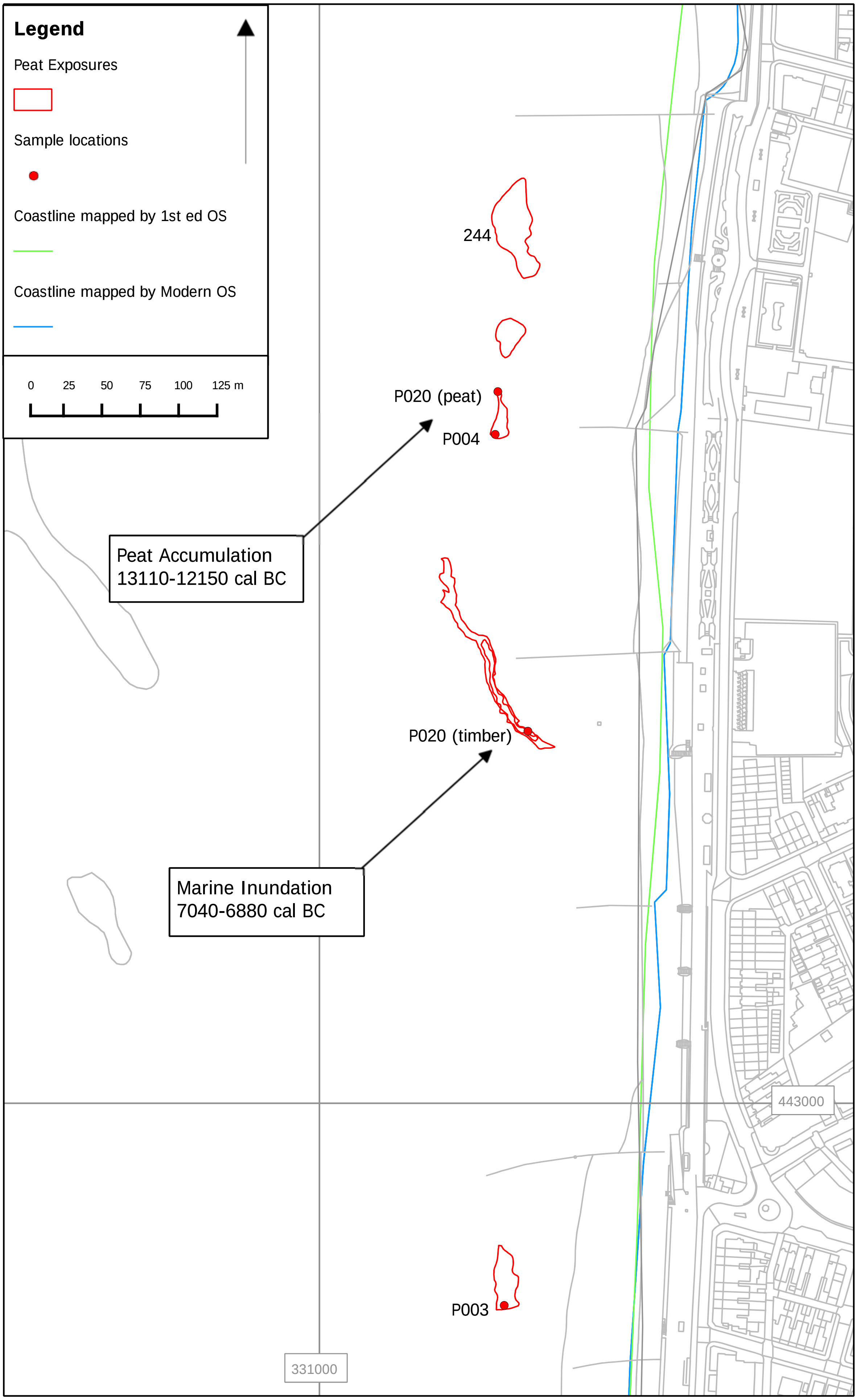

Figure 6.9 Location and radiocarbon dates of samples taken at Cleveleys

6.9 **Sunderland Point** (SD 40012 56393)

The setting here is of extensive tidal grazing marsh fronted by inter-tidal sand flats. No peats were observed in association with either of these two sub-environments. The saltmarsh is dissected by a number of small drainage creeks, within which tidally-laminated clastic sediments are clearly exposed as clay and silt alternations (Figure 6.10). No peats were encountered within 0.5m of the base of these creeks.

The inter-tidal sand flats expose a series of WW II anti-aircraft landing obstacles, many of which outwardly resemble *in situ* trees within the inter-tidal zone, however, no evidence of any organic-rich/peat remains (*in-situ* or *ex-situ*) could be confirmed at the time of survey.

Figure 6.10 Tidally-laminated sediments exposed in saltmarsh channels at Sunderland Point.

6.10 **Heysham** (SD 40501 61520 Map Figure 6.15)

The peat database (record 225) refers to 'a bed of peaty mud... with birch trunks' occurring in the foreshore which were first recorded in the late 19th century. The stretch of coastline examined has been the subject of recent coastal defence work with the construction of a sea-wall and coastal path fronted by large limestone boulder armouring (Figure 6.11). The natural inter-tidal zone comprises an uppermost berm of medium to coarse sand below which there is an extensive medium-grained sand flat with significant areas covered by cobbles (Figure 6.12).

At a number of localities across the inter-tidal zone there are exposures of much older fine-grained, laminated clastic sediments which are occasionally overlain by thin muddy-peats (< 21cm) and even a few remains of small trees (root boles and prostrate trunks), the latter trending SW-NE and generally denoted by the higher coverage of filamentous green algae. These almost certainly represent the material referred to in record 225.

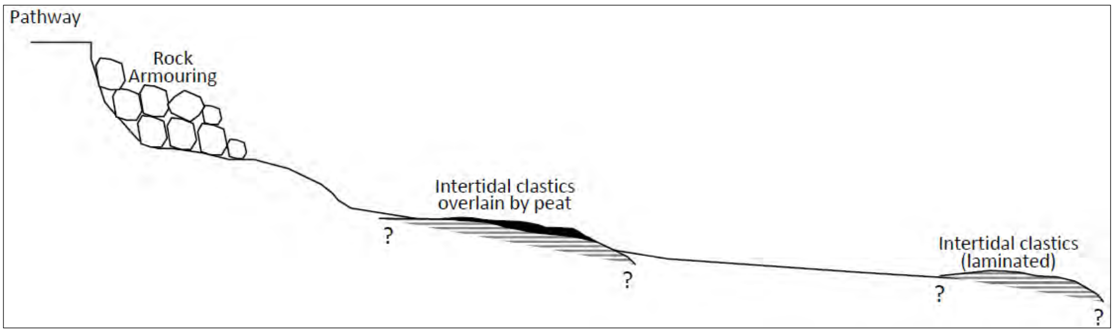

Figure 6.11 Idealised section across the beach at Heysham.

Figure 6.12 View across the Heysham shore from the coastal path.

6.10.1 Pollen Analysis

A short core (P005) was taken at this site (Grid Ref SD 41421 62235, Figure 6.13), and a pollen sample taken, but no pollen were recorded

These peats appear to be the last remnants of a now degraded and eroded former peat cover which rests above the fine-grained inter-tidal sediments. The muddy-peats appear to be absent from the more seaward exposures where only the clastic units remain, where they display probably tidal alternations.

6.10.1 Radiocarbon Analysis

Bulk peat samples from the base of the peat (P019 – peat) were submitted for radiocarbon dating through the extraction of humic and humin acid fractions. A sample from a prostrate tree on the surface of the peat (P019 – timber) was also submitted for dating.

Measurements on the humic and humin fractions of a large bulk peat sample are statistically consistent (T'=6.2; ν=1; T'(1%)=6.4; Ward and Wilson 1978) and a weighted mean has been taken (7353±54 BP) as the best estimate for the age of the peat. The results (Table 6.5; Figure 6.14) show that peat accumulation started at approximately

6380–6070 cal BC and that inundation by the sea had probably occurred by the time the oak tree died in 5895–5740 cal BC.

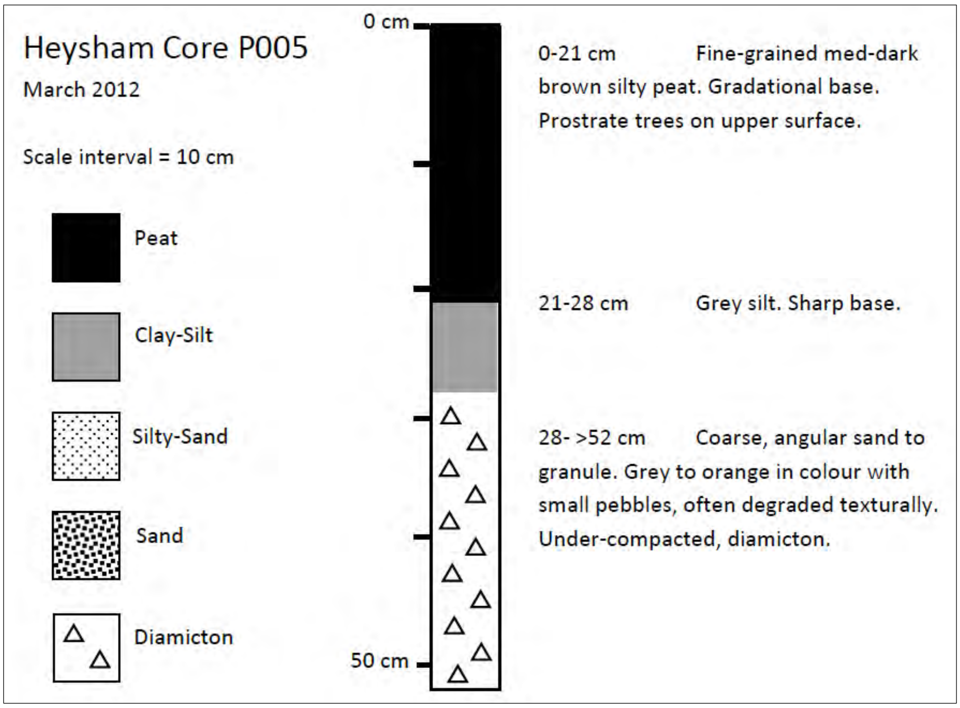

Figure 6.13 Core P005 from foreshore at Heysham.

Laboratory number	Sample	Material	$\delta^{13}C$ (‰)	Radiocarbon Age (BP)	Calibrated Date (95% confidence)
Wk-35928	H1	Peat (110g) humic acid fraction from 1cm spit 9–10cm from the top of the peat	-29.0	7404±58	
Wk-35922	H1	Peat (110g) humin fraction from 1cm spit 9–10cm from the top of the peat	-29.7	7002±147	
	HI	T'=6.2; ν=1; T'(1%)=3.8		7353±54	6380–6070 cal BC
UBA-22194	H2 -surface timber sample A	*Quercus* sp. outer sapwood rings and bark of 50–70 rings of knotty branch wood	-25.5	6963±39	
SUERC-44448	H2 -surface timber sample B	*Quercus* sp. outer sapwood rings and bark of 50–70 rings of knotty branch wood		6941±29	
	H2 -surface timber	T'=0.2; ν=1; T'(1%)=3.8		6949±24	5895–5740 cal BC

Table 6.5: Heysham – North West Rapid Coastal Zone Assessment – radiocarbon results

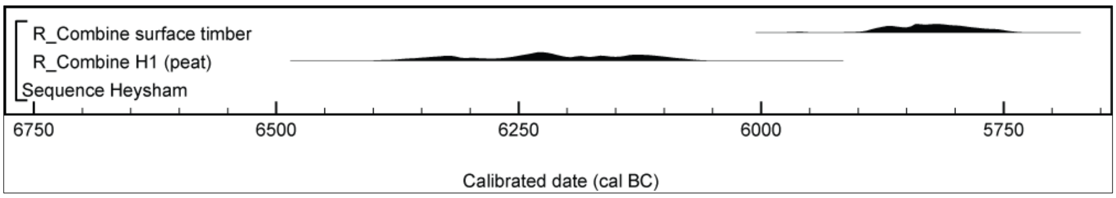

Figure 6.14 Probability distributions of dates from Heysham. The distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993)

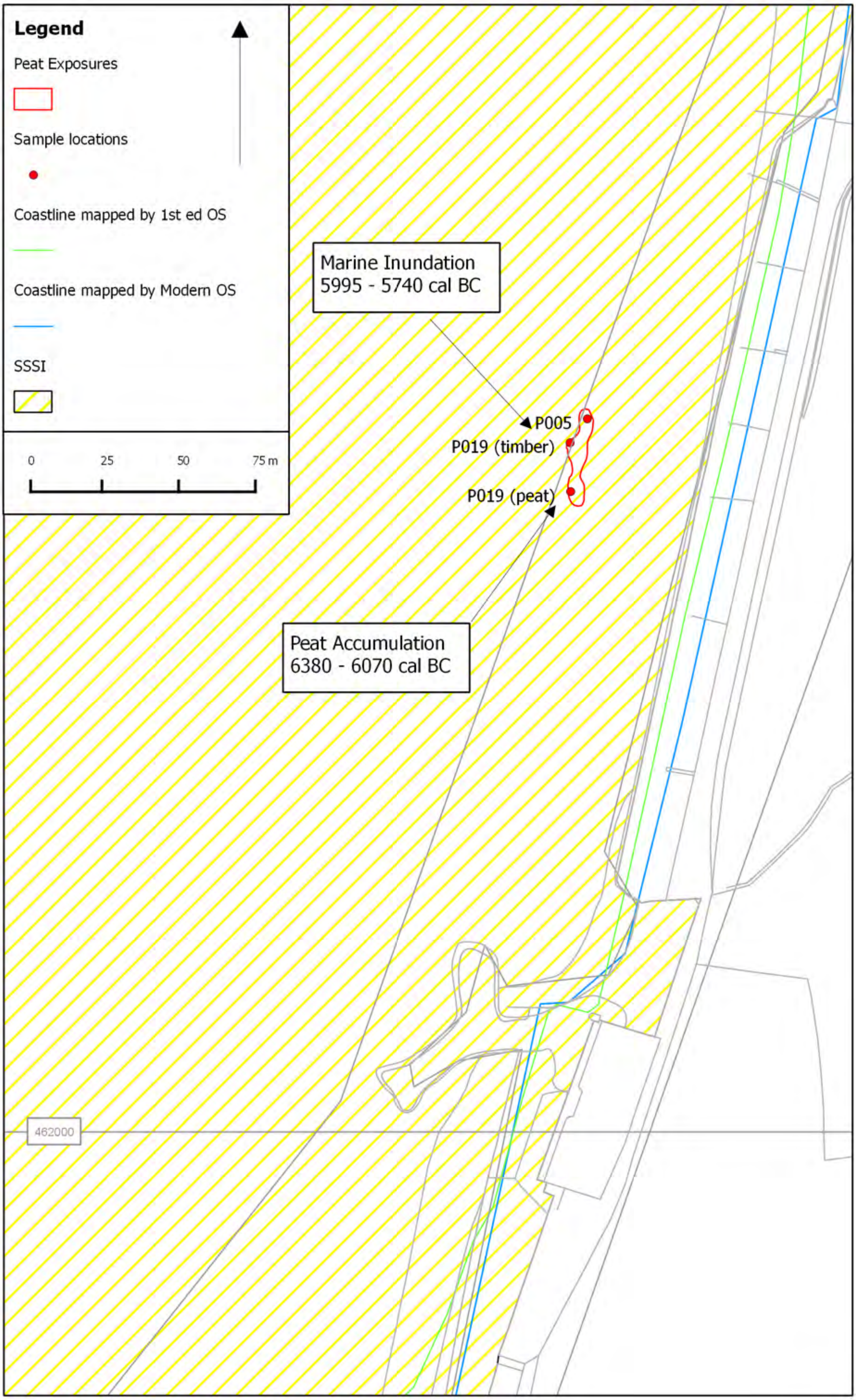

Figure 6.15 Location and radiocarbon dates of samples taken at Heysham

6.11 Morecambe and Bare (SD 41499 62930)

This coastline has been subjected to a significant programme of coastal protection engineering works over the last three decades. Much of the modern intertidal zone is now covered by a mosaic of fine sands and thixotropic muds, the latter make access to parts of the inter-tidal zone hazardous. The engineering works will have significantly affected the sediment budgets and therefore will have changed the coastal geomorphology to such an extent that any records of peat exposure from before the mid-20th century will be difficult, if not impossible, to confirm or investigate. No Holocene sediments were observed in any of the areas that were accessible during this study. [Details of the coastal protection work can be found at www.lancaster.gov.uk/planning/environmental-management/coastal-protection/history-coastal-protection].

6.12 Bardsea (SD 30804 74498)

The inter-tidal zone at Bardsea comprises a saltmarsh, relatively compressed against the coastal road, which is fronted by a zone of flat (medium to fine-grained) sands with occasional silts and clays. The saltmarsh vegetation is rooted on silty to clay-rich sand, but no organic-rich deposits were recorded at this locality, despite peat database record 252 referring to subsurface peats.

6.13 Walney Island (SD 18462 69485) (SD 18688 68833 Map Figure 6.21) (SD 20984 61005)

Three potential palaeoenvironmental sites were examined on the island; one on the eastern side; one on the western side one off the southwest corner of the island. One record of peats exposed on the eastern, landward side of the island was too dangerous to access due to a thick sequence of inter-tidal mud resting on a relatively steeply angled channel margin. Local reports suggest that at low spring tides the upper surface of peats can still be seen at the channel base (David Coward, *pers. comm.*).

On the western, seaward coastline a number of Holocene exposures were recorded on the inter-tidal zone. The coastline backs on to fields which are fronted by a thin strip of large boulders of armouring or 2m cliffs of red-brown diamicton. The upper beach is composed of a relatively steep, storm-derived sand-pebble bank seaward of which is an inter-tidal sand flat with a high proportion of cobbles (Figure 6.16).

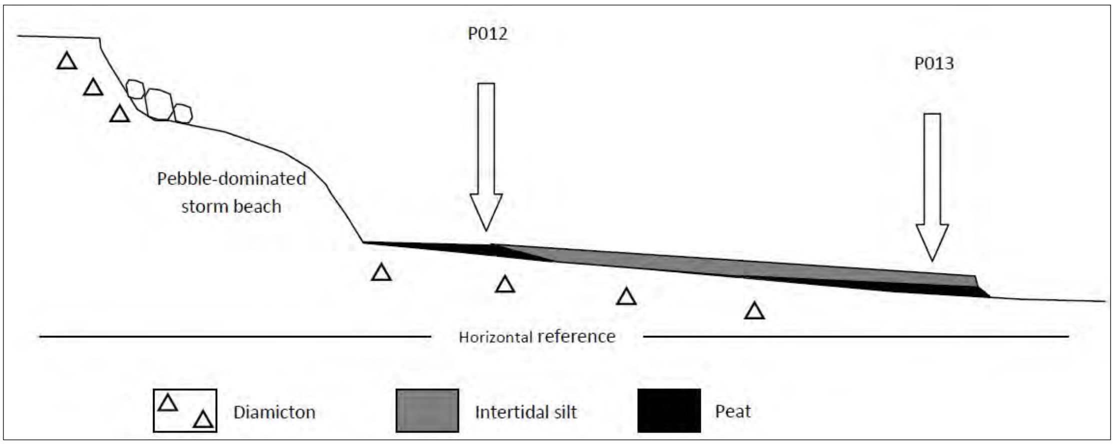

Figure 6.16 This cross section shows the relative position of the major morphological elements and the main late-glacial units observed on the western Walney foreshore at grid ref. SD 18859 65232 in March 2012. The vertical and horizontal scales are exaggerated and based on field observation only, they are not intended to represent measured distances or elevations. The Holocene peat and silt exposures generally occur as patchy exposures, each of ~5 to ~10 m^2. The top surface of the upper peat bears a number of prostrate tree trunks and branches (<55 cm diameter). *In situ* tree-stumps also observed.

Amongst the lower inter-tidal unit is a varied exposure of Holocene clays/silts and peat deposits (Figure 6.17). Coring and lateral tracing of these deposits suggests that the deposits represent an upper blue-grey silt overlying a lower peat (Figure 6.18). These units progressively pinch-out landward and all seem to rest on the local diamicton at shallow depth. The maximum depth of Holocene sediments encountered at any one point was just 0.64m.

Figure 6.17 above left, typical poorly-exposed organic sediments amongst cobble material on western side of Walney Island (scale = 1m); above right, cored sequence through clastic and organic layers, western shoreline, Walney Island.

Off the southwest end of the island a series of eroding inter-tidal silt deposits have been identified by local amateur archaeologist, David Coward. Areas within these silt deposits contain preserved cloven-hoofed animal prints and a further exposure also contained several large antler fragments and a cow skull. The relationship between these sediments has yet to be confirmed, as the deposits were not visible at the time of survey. However there is likely to be an association between the faunal remains and the hoof prints. No peat was identified at this location.

6.13.1 Pollen Analysis

Two short cores were taken P012, P013 from the peat exposed on the western side of the island (SD 18688 68833) and three samples were obtained from the upper, middle and base of a dark brown silty peat. All three samples (8-12 cm, 22-27 cm and 36-41 cm) displayed good concentrations and preservation was generally very good throughout the sequence. A relatively low range of taxa were recorded, with *Betula*, *Corylus* and Poaceae the main components (Figure 6.19). An apparent rise in *Corylus, Quercus* and Poaceae is evident towards the top of the sequence. The impression is thus of peat accumulation initially within a birch fen; the presence of *Sphagnum* (c.10-20%) in all three samples may be evidence of such acidic, nutrient poor conditions. The subsequent expansion in *Corylus* and *Quercus* might reflect hydroseral processes associated with the accumulation of peat and development of conditions more suitable for hazel-oak woodland locally. Alternatively, this short sequence may indicate the successional expansion of deciduous woodland in the wider landscape during the earlier Holocene. The absence of *Alnus* from the record may support the latter inference.

No pollen samples were taken from the peat on the eastern side of the island, or the silts off the southwestern side.

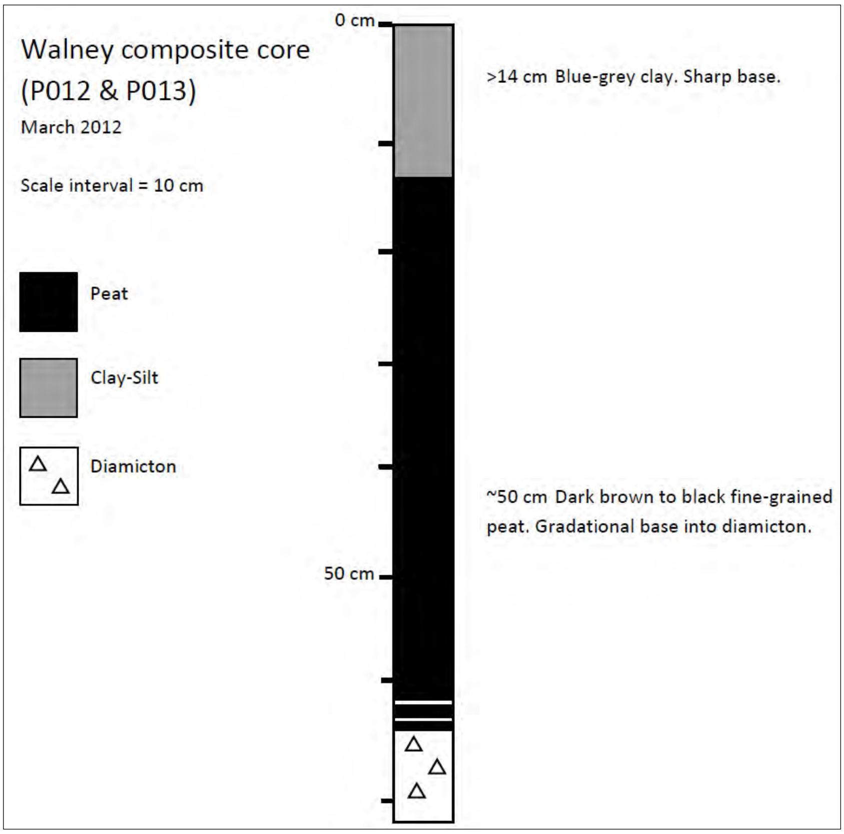

Figure 6.18 This composite log is based on cores P012 & P013 on western side of Walney Island.

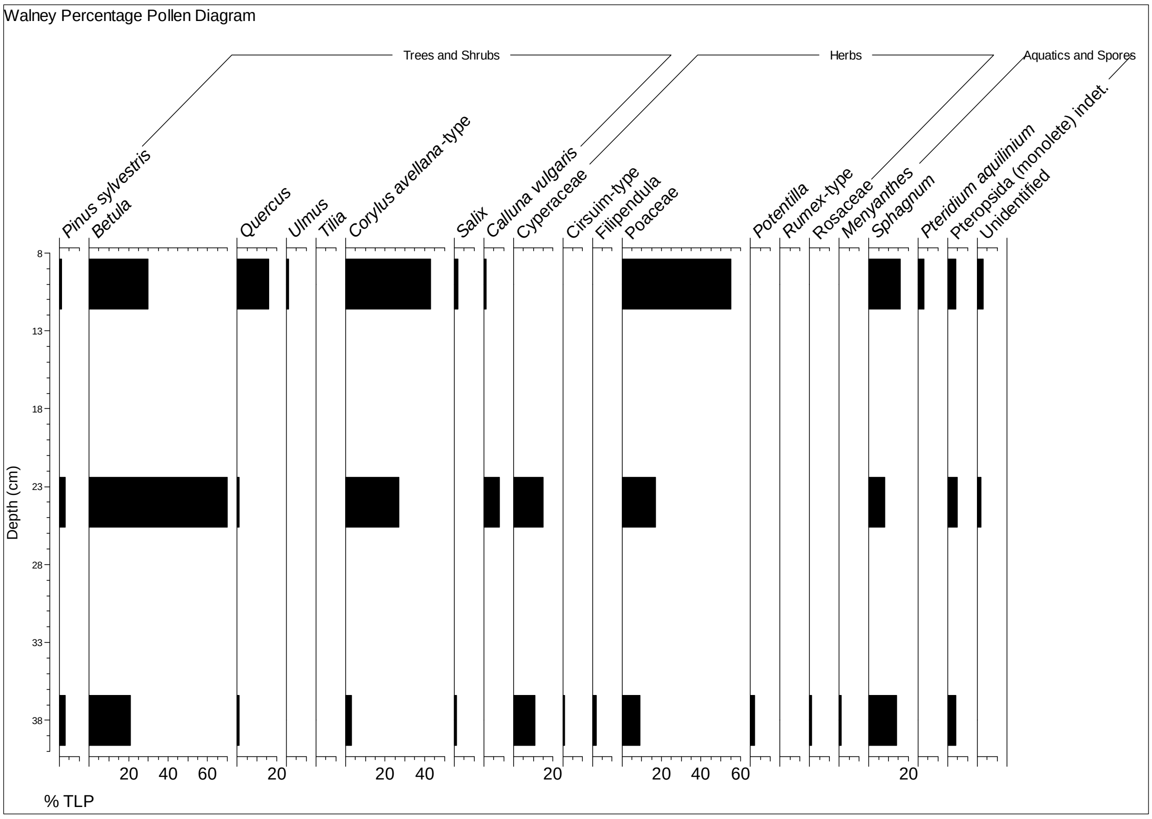

Figure 6.19 Percentage Pollen record from the western side of Walney Island.

6.13.2 Radiocarbon Analysis

Bulk peat samples from the base of the peat on the western side of the island (P018 – peat) were submitted for radiocarbon dating through the extraction of humic and humin acid fractions. A sample from a prostrate tree on the surface of this peat (P018 – timber) was also submitted for dating.

A cow skull and antler from the silt deposits on the south-western end of the island were also submitted for radiocarbon dating.

Measurements on the humic and humin fractions of a large bulk peat sample are statistically consistent (T'=5.1; ν=1; T'(1%)=6.4; Ward and Wilson 1978) and a weighted mean has been taken (9623±31 BP) as the best estimate for the age of the peat. The results (Table 6.6; Figure 6.20) show that peat accumulation on the western side of the island started early in the Holocene at approximately 9230–8830 cal BC and that inundation by the sea here occurred by 6250–6090 cal BC.

The cow skull and antler from the southwestern end of the island are of different ages (Table 6.6; Figure 6.20), with the antler being 500 years older than the cow skull. The cow skull was date twice as the first sample (SUERC-43962) had a highly enhanced 13C measurement. The second sample (SUERC-46229) has a 13C measurement indicative of a fully terrestrial diet and it is therefore assumed that the original sample was contaminated.

The relationship between the peat on the western side of the island and the silts at the southwestern end has yet to be established on the ground; however the dating sequence indicates that the faunal remains within the silt deposits are later in date than the peat on the western side of the island.

Laboratory number	**Sample**	**Material**	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**	**C:N**	**Radiocarbon Age (BP)**	**Calibrated Date (95% confidence)**
SUERC-44444	W2 - surface timber	*Alnus* roundwood including bark, from prostrate tree on the surface of the peat	-31.1			7347±27	6250–6090 cal BC
Wk-35929	W1	Peat (200g), humic acid fraction, from 2cm spit at a depth of 16–18cm from the top of the peat	-27.6			9553±43	
Wk-35923	W1	Peat (200g), humin fraction, from 2cm spit at a depth of 16–18cm from the top of the peat	-28.8			9689±42	
	W1	T'=5.1; ν=1; T'(1%)=6.4				9623±31	9230–8830 cal BC
SUERC-43962	2012.1	*Bos* skull found in association with a number of red deer antlers eroding from silt deposits on the foreshore	-12.8	4.9	3.2	4080±30	2860–2490 cal BC
SUERC - 46229	2012.1 sample b	As SUERC – 43962	-21.7	5.7	3.3	3270±	1630-1450 cal BC
SUERC-43963	2012.2	Red deer antler found in association with a number of other red deer antlers and a cattle skull eroding from silt deposits on the foreshore	-22.2	5.7	3.3	3653±30	2140–1940 cal BC

Table 6.6 Walney – North West Rapid Coastal Zone Assessment – radiocarbon results

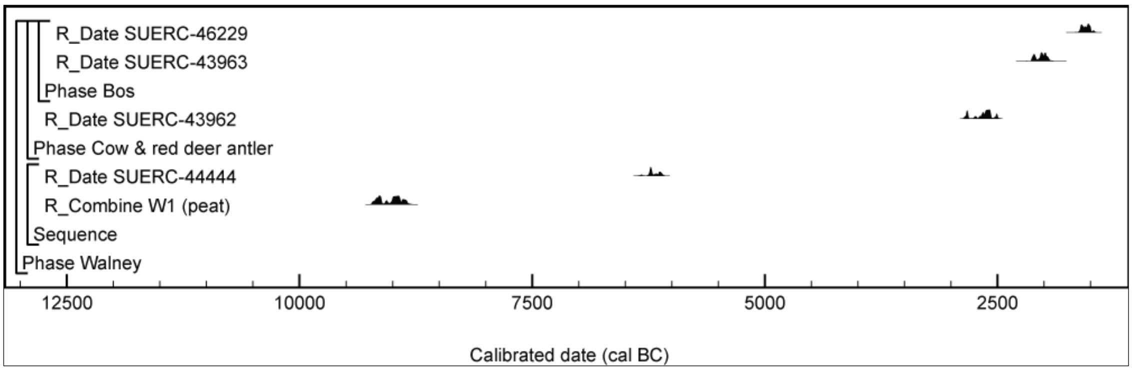

Figure 6.20: Probability distributions of dates from Walney. The distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993)

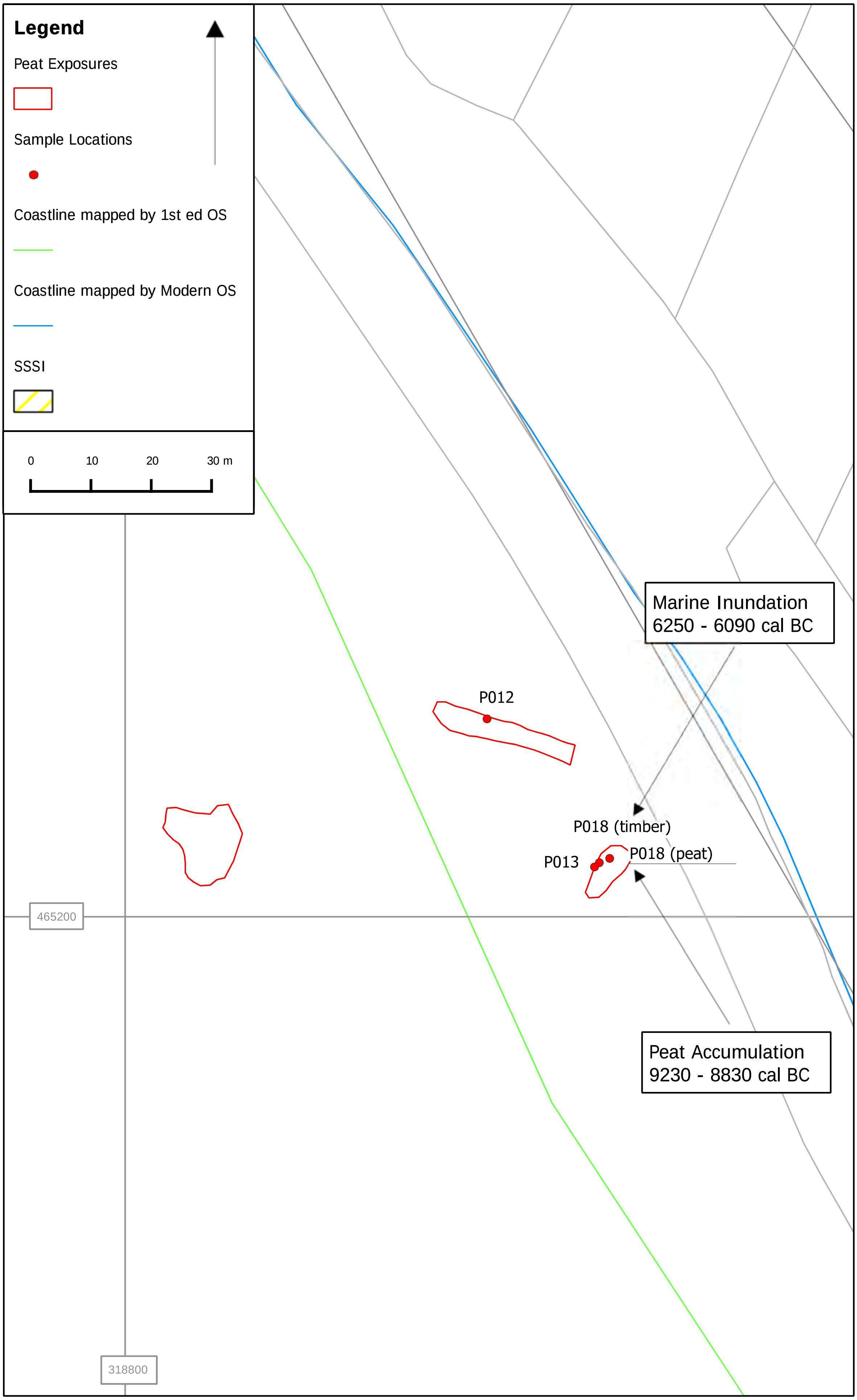

Figure 6.21 Location and radiocarbon dates of samples taken on the west side of Walney Island

6.14 Annas Mouth (SD 07681 88414 Map Figure 6.28)
Tooley (1985) records a site of interest at the mouth of the Annas (database record 527), but with no detail other than an elevation of +6.6mOD. The coastline south of Eskmeals reveals a series of low lying cliffs, predominantly of alluvial material related to the River Annas which outfalls along this coast, and Tooley's record must be from these exposures. The sediments are seen to exhibit sedimentary evidence of gravel bar systems and low-energy cut-offs (meanders/oxbows) in section (Figure 6.22). These lie 1-2m above the current high beach mark and probably relate to mid-late Holocene sedimentation and accretion under isostatic rebound. These sediments are subject to limited erosion by both wave/tidal activity, mainly during storms, and by river undercutting/avulsion.

Figure 6.22 Typical section through mid-late Holocene fluvial sediments at Annas Mouth (scale = 1m).

Below the cliff-line lies a predominantly cobble-sized storm beach, and below this is a mixed sand-cobble inter-tidal flat area. At least two separate organic-rich units of presumed Holocene age are exposed on this lower foreshore, and their surface geometries suggest a relatively steep 2-3° seaward dip (Figure 6.23 and 6.24).

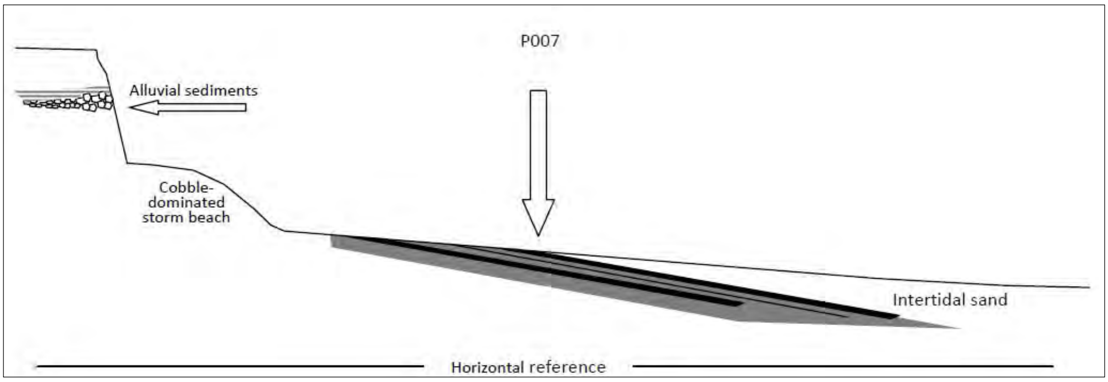

Figure 6.23 Stylistic beach section at Annas Mouth

Figure 6.24 Exposure of organic-rich deposits on foreshore, Annas Mouth.

6.14.1 Pollen Analysis

Coring (P007&P008) suggests that there may be at least three separate peats within this sequence although it is likely that one or more may be detrital remnants (re-deposited) of older *in-situ* peats (Figure 6.25).

Analysis of the samples from Annas Mouth showed they were from brown fine grained detrital peat layers intercalated with silts and clays (Figure 6.26). The upper sample (0-8cm) displayed excellent preservation and concentration of palynomorphs. The sample was dominated by trees and shrubs largely consisting of *Corylus avellana*-type (hazel) and *Alnus glutinosa* (alder) but with *Quercus*, *Betula* and *Pinus sylvestris* also recorded. Percentages of herbaceous taxa were low. Concentrations became lower further down the sequence, but assessment level counts were still possible. Preservation also deteriorated down-profile and was particularly poor in the sample from 65-67cm.

One sample from the base of a sub-fossil tree contained many grains exhibiting signs of corrosion and splitting. These basal samples were also dominated by *Corylus avellana*-type, *Alnus glutinosa*, *Quercus*, *Betula* and *Pinus sylvestris.* Herbs, in particular Poaceae (grasses) were present in slightly greater proportions than the uppermost sample with a peak in this taxon of *c.*40% evident at 71-76cm. Other herbs recorded at this level include Cyperaceae (sedges), *Filipendula, Plantago lanceolata, Potentilla* and *Rumex.* Aquatics and spores were recorded at low and sporadic values in all the samples, although *Sparganium*-type reaches *c.*10% in the basal sample.

This sequence indicates the presence of mixed deciduous woodland in the close vicinity of the sampling site, perhaps reflecting a mid Holocene timeframe for peat accumulation. The low percentages of herbs suggest closed canopy conditions. The higher values of Poaceae and presence of herbs, including ribwort plantain, docks and cinquefoils towards the base, might reflect more open, possibly disturbed conditions in the wider landscape. However, the current data are insufficient to establish if this might have been associated with human activity. Poaceae may also reflect the presence of wetland grasses such as *Phragmites* on and around the sampling site.

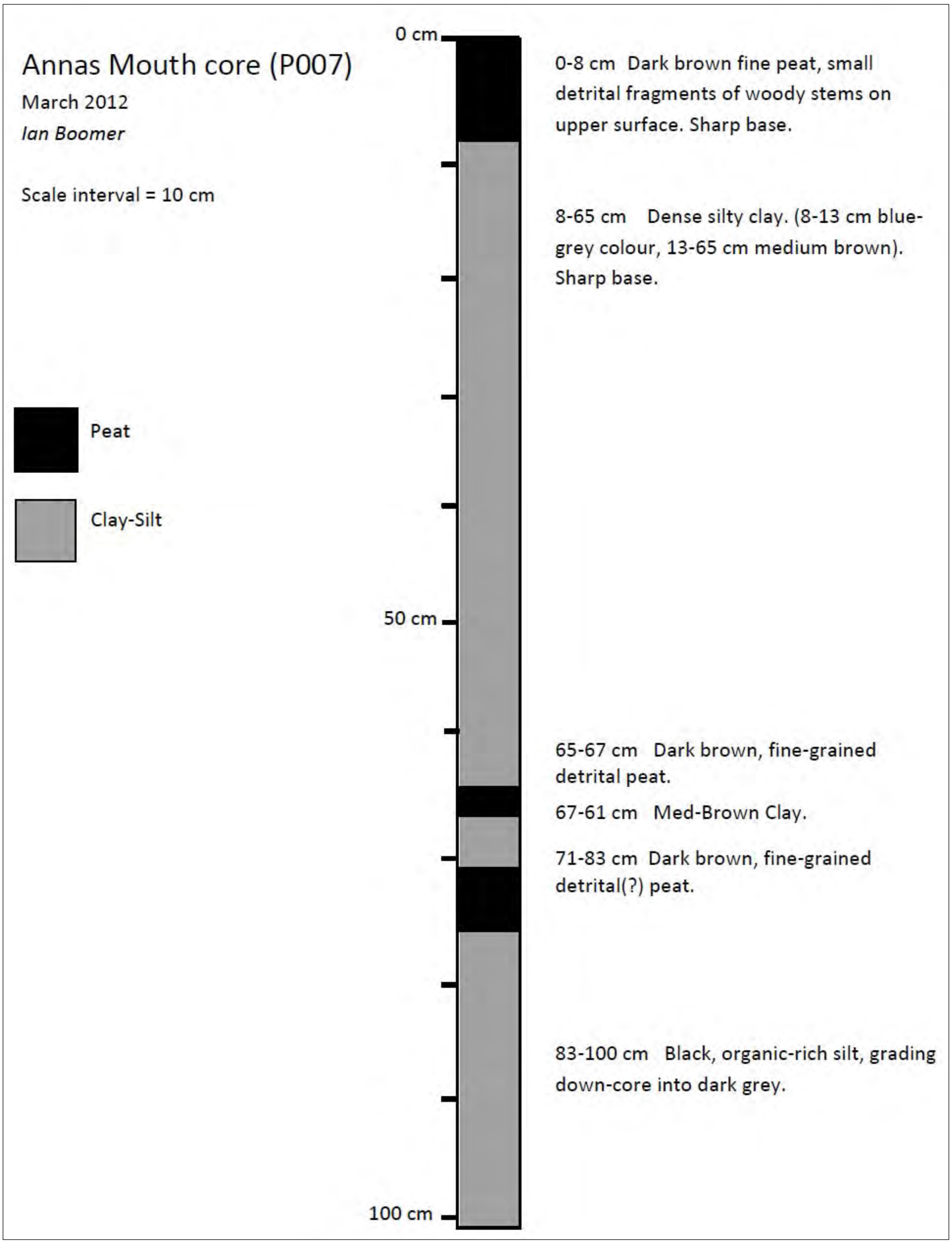

Figure 6.25 Core through mid-late Holocene foreshore sediments at Annas Mouth (SD 07641 89085).

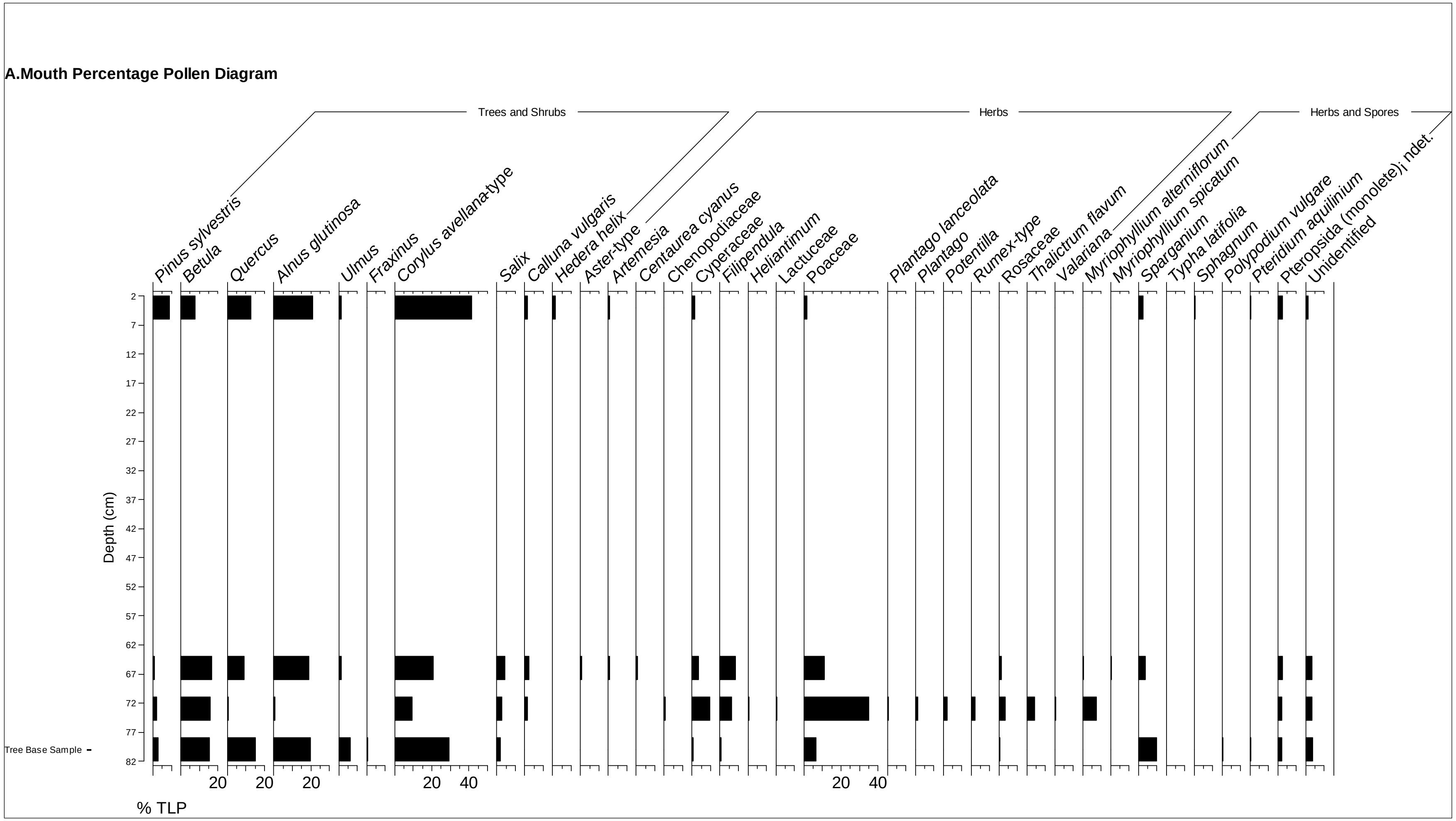

Figure 6.26 Pollen record at Annas Mouth.

6.14.2 Radiocarbon Analysis

Bulk peat samples from the base of the peat (P017 – peat) were submitted for radiocarbon dating through the extraction of humic and humin acid fractions. A *Betula* roundwood sample (AMS2) from a depth of 4-5cm from the top of the peat and a sample from an *in situ* tree stump on the surface (P017 – timber) were also submitted for dating. The depth of peat sampled for radiocarbon dating differs from that sampled for pollen analysis due to the slightly different sample locations. The dating samples were taken from the shoreward side of a large peat exposure which provided a greater depth of peat than that sampled for pollen further up the beach.

Measurements on the humic and humin fractions of a peat sample from the base of the uppermost peat are not statistically consistent (T'=31.8; ν=1; T'(5%)=3.8; Table 6.7; Figure 6.27). The humin fraction provides the best estimate of the date of formation of the upper peat of 7590–7480 cal BC. The *Betula* roundwood sample (SUERC-44447) from 4–5cm is clearly intrusive given it is younger than the *in situ* tree on the surface of the peat (UBA-22191; 7180–6810 cal BC).

Laboratory number	Sample	Material	$\delta^{13}C$ (‰)	Radiocarbon Age (BP)	Calibrated Date (95% confidence)
Wk-35931	AM1	Peat (263g) humic acid fraction, from 1cm at the base of the peat deposit 26–27cm from the top	-29.2	8112±44	7190–7040 cal BC
Wk-35925	AM1	Peat (263g) humin fraction, from 1cm at the base of the peat deposit 26–27cm from the top	-29.2	8463±44	7590–7480 cal BC
SUERC-44447	AMS2 [4–5cm]	*Betula* sp. roundwood 12 years old with bark	-28.6	6784±27	5730–5640 cal BC
UBA-22191	AM3 [surface timber]	*Populus/Salix* outer rings of large timber	-26.1	8065±61	7180–6810 cal BC

Table 6.7: Annas Mouth – North West Rapid Coastal Zone Assessment – radiocarbon results

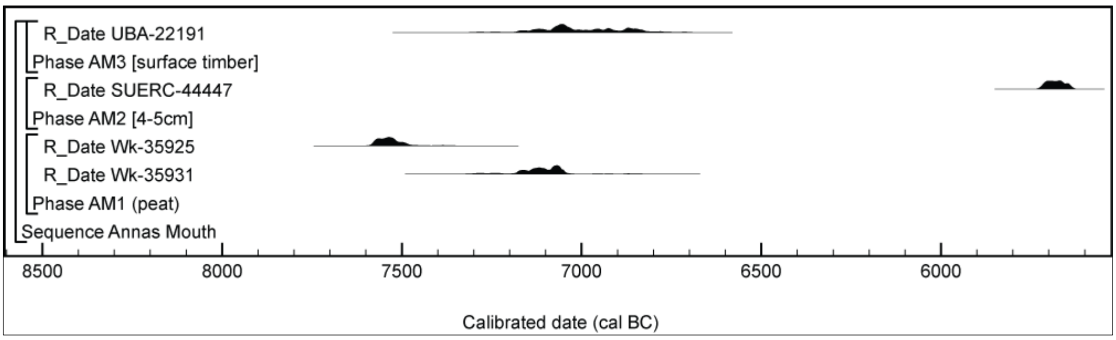

Figure 6.27: Probability distributions of dates from Annas Mouth. The distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993)

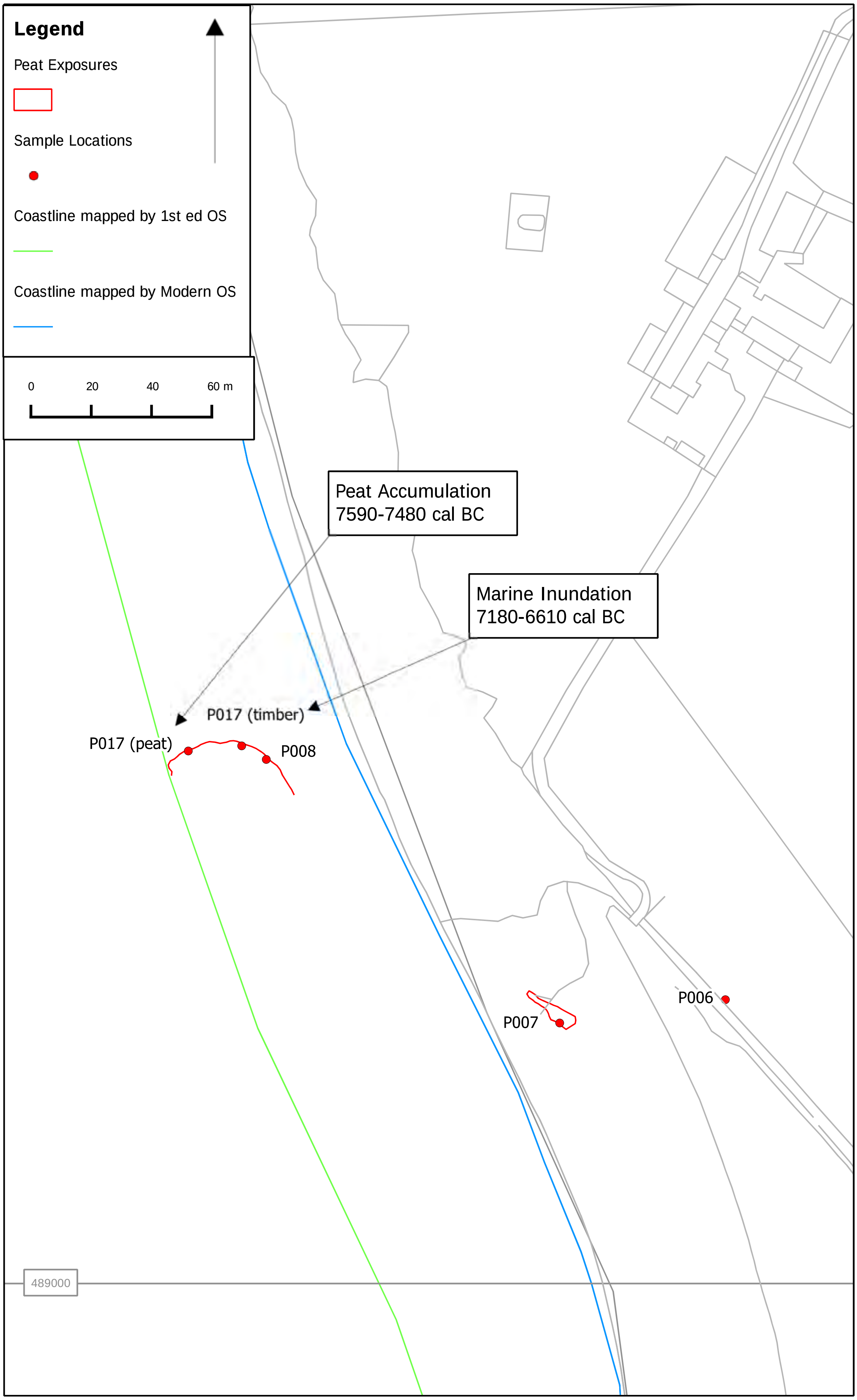

Figure 6.28 Location and radiocarbon dates of samples taken at Annas Mouth

6.15 Eskmeals / Bootle (SD 07944 90925)

Although no formal record exists on the peat database, there are both published (e.g. Bonsall *et al.*, 1989) and unpublished (Andy Howard, *pers. comm.*) records of a 'submerged forest' in the foreshore at Eskmeals. Access to this part of the coastline is arranged through the MoD as this foreshore forms part of the Eskmeals firing range. Despite extensive recent records of exposed Holocene sediments in this area, no exposures could be identified during a total of three visits in Spring 2012. Hand augering of up to 0.9m at the grid reference above did not reveal any silts or peats near the modern inter-tidal surface. This is an example of the highly mobile nature of the inter-tidal sediments and the ease with which significant thicknesses of inter-tidal sand can be deposited in a very short space of time. The mid-lower inter-tidal zone did yield some *in situ* reddish diamicton at the surface.

6.15.1 Radiocarbon Analysis

Despite the deposit not being exposed at the time of survey, two samples of hazelnut shells obtained by Sue Stallibrass during an exposure in 2002-2003 were sent for radiocarbon dating as part of this project.

Samples submitted from the upper 5–10cm of this peat exposure are statistically consistent (T'=0.9; ν=1; T'(5%)=3.8; Table 5; Fig 6) and could be of the same actual age. The results suggest the upper peat formed in the first quarter of the sixth millennium cal BC.

Laboratory number	Sample	Material	$\delta^{13}C$ (‰)	Radiocarbon Age (BP)	Calibrated Date (95% confidence)
UBA-22193	BO1 – sample A	Hazelnut shell from the upper 5–10cm of peat exposure	-22.9	7027±38	6000–5830 cal BC
SUERC-44439	BO1 – sample A	As UBA-22193 [different hazelnut]	-24.9	6984±27	5980–5780 cal BC

Table 6.8: Bootle/Eskmeals – North West Rapid Coastal Zone Assessment – radiocarbon results

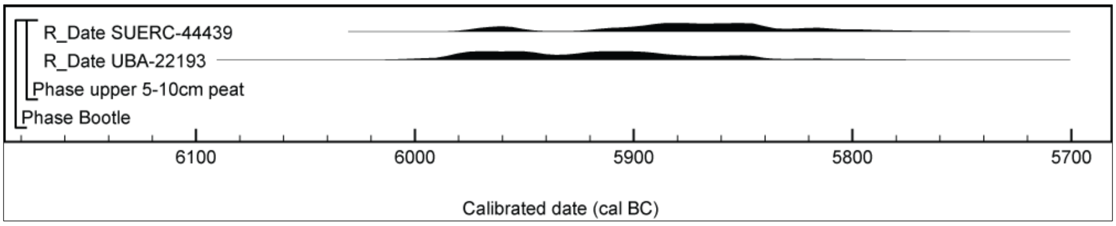

Figure 6.29: Probability distributions of dates from Bootle.

6.16 **Ravenglass** (SD 08523 96141)

The small tidal harbour at Ravenglass has significant mud-covered flats and channels, some limited saltmarsh extends to south of the village. Small streams dissecting the saltmarsh area reveal possible tidally-controlled clastic sediments to about 70-80cm, but no peats were observed at the time of survey. Reconnaissance of the inter-tidal zone at low tide also yielded no visible evidence of peat remains. Previous records of a kettle hole exposed at Ravenglass during excavation engineering works for the installation of local sewerage system (Clifford Jones, *pers. comm.*).

6.17 **Drigg** (SD 04694 98563 Map Figure 6.34)

Drigg beach forms the western boundary of the Drigg Coast SSSI and a vegetated dune system marks the high beach line immediately north of the beach access path. The inter-tidal zone is dominated by a relatively compressed (steep) sandy environment with occasional cobbles. During a visit in March 2012 no inter-tidal deposits were observed on the foreshore, but significant exposures of peat and clays/silts were recorded in the dune sections (Figure 6.30). Similar sediments have been recorded on the foreshore in recent months (Clifford Jones, *pers. comm.*). Around 100m to the north, the cliff line is replaced by a red-brown sandy diamicton (Till). This glacigenic unit can also be observed as an irregular surface at the base of the dune systems.

The sequence shows distinctive lateral variability in thickness and sedimentology and almost certainly relates to marine flooding of an uneven late-glacial sequence, and subsequent infill of what was probably a kettle-hole or similar depositional feature under freshwater depositional setting (Figure 6.31), resulting in a significant thickness of peat.

At present, the relatively cohesive nature of the diamicton at the base of the sequence, often covered by cobble armouring, combined with the clear presence of established vegetation (Marram) across much of the cliff face suggests that lateral erosion rates are relatively low along this part of the coastline.

Figure 6.30 above left, Dune section at Drigg showing grey silts left foreground and overlying peats to the right; above right, Detail of main peat sequence overlying till at this point, rather than silts (scale = 1m).

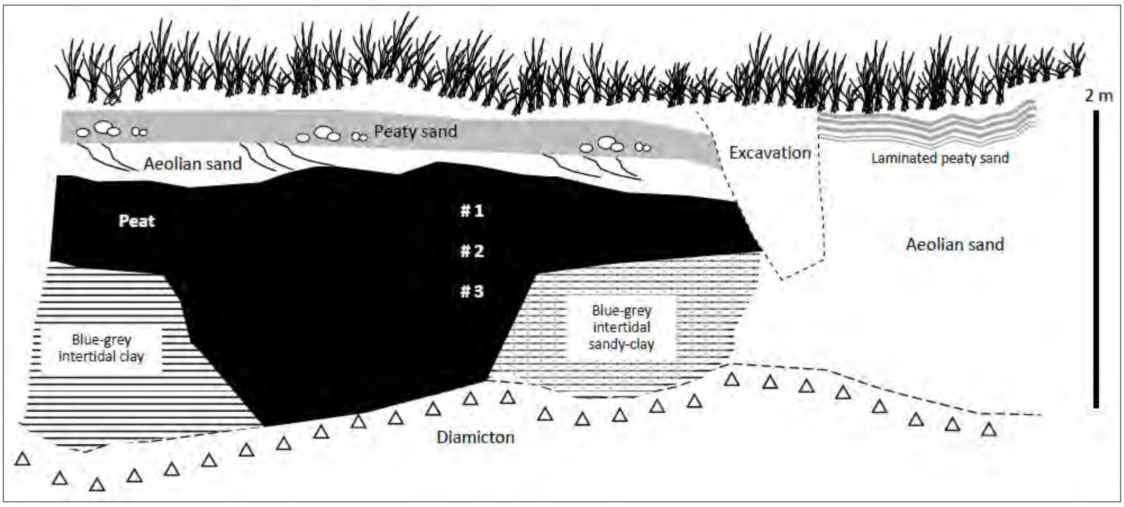

Figure 6.31 Summary section through dune sequence at Drigg, Cumbria (site P011), based on composite of a number of adjacent sections, much of the area covered by vegetation often making precise relationship between separate units difficult to establish laterally.

6.17.1 Pollen Analysis

The three samples from the peat deposits at Drigg (P001 - 60-65cm, 35-40cm and 15-20cm) displayed very good concentrations and preservation of palynomorphs sufficient for palaeoenvironmental interpretation (Figure 6.32). A marked decline in *Alnus* from *c.*60% at the base to *c.*10% at the top of the sequence is apparent. This is paralleled by a rise in Salix and Cyperaceae to 35% and 20% respectively. Other trees and shrubs including *Corylus*, *Betula, Ulmus* and *Quercus* are also recorded but show little variation. This sequence thus demonstrates accumulation of peat within an alder fen, with the subsequent rise in willow probably related to autogenic processes within the wetland system. Mixed hazel-oak-birch-elm deciduous woodland was apparently established on the dryland soils beyond the peatland edge. This range of taxa, specifically the presence of elm, may suggest a mid-Holocene, pre-Neolithic timeframe for the sampled sediments.

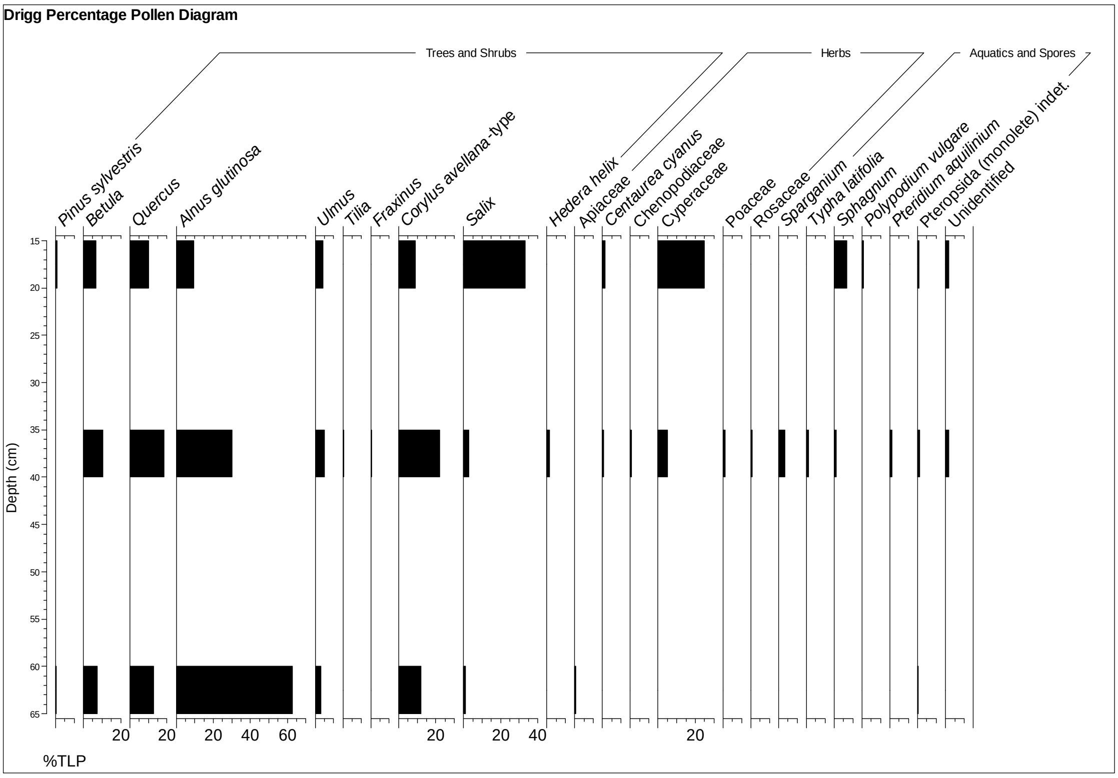

Figure 6.32 Pollen record through the Drigg coastal section.

6.17.2 Radiocarbon Analysis

Samples were submitted from a peat deposit exposed in the dune face. A hazelnut shell (UBA-22187) and small piece of *Alnus* roundwood (SUERC-44438) from a 2cm thick bulk sample taken 5cm up from the uneven base of the peat deposit are of different ages (Table 6.9; Figure 6.33). The latest of these therefore provides the best estimate for the formation of the peat of 5230–5040 cal BC.

A sample of *salix/populus* from the middle of the peat deposit returned a date of 4690-4450 cal BC (UBA-22186). Measurements on the humic and humin fractions of the peat sample from the top 2cm of the peat are not statistically consistent (T'=19.9; ν=1; T'(5%)=3.8; Ward and Wilson 1978). As outlined above the humin fraction probably provides the best estimate for the top of the peat at 3630–3360 cal BC (Wk-35921).

Laboratory number	Sample	Material	δ13C (‰)	Radiocarbon Age (BP)	Calibrated Date (95% confidence)
Wk-35927	D1	Peat (243g) humic acid fraction, from 0–2cm from the top of the eroding face	-29.4	4451±35	3340–2930 cal BC
Wk-35921	D1	Peat (243g) humin, from 0–2cm from the top of the eroding face	-29.0	4672±35	3630–3360 cal BC
UBA-22186	D2 38–40cm	*Salix/Populus* roundwood including final growth ring	-25.2	5701±35	4690–4450 cal BC
UBA-22187	D3 5cm from base	Nut (unidentified) from 2cm spit at 5cm up from the uneven base of the peat	-31.0	6936±35	5900–5730 cal BC
SUERC-44438	D3 5cm from base	Alnus, small roundwood from 2cm spit at 5cm up from the uneven base of the peat	-29.7	6189±29	5230–5040 cal BC

Table 6.9 Drigg – North West Rapid Coastal Zone Assessment – radiocarbon results

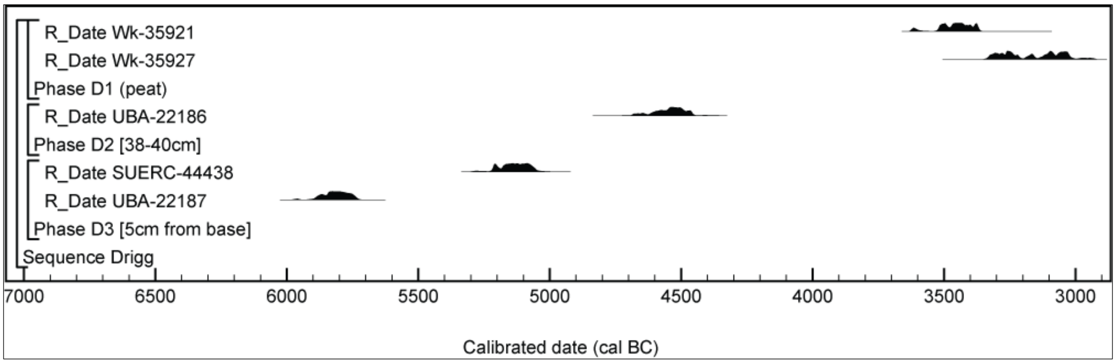

Figure 6.33 Probability distributions of dates from Drigg. The distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993)

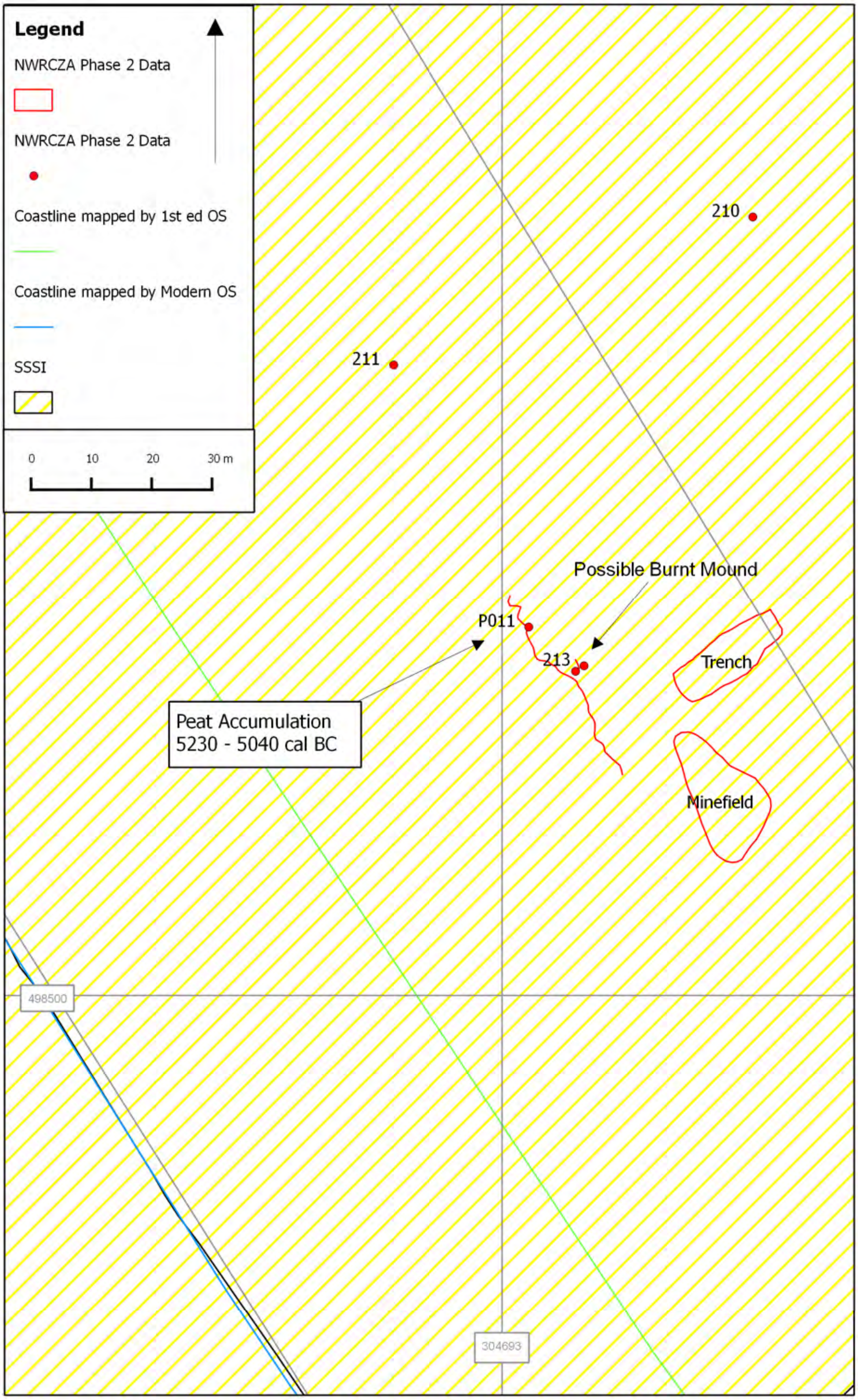

Figure 6.34 Location and radiocarbon dates of samples taken at Drigg

6.18 St Bees, Cumbria (NX 96177 11537 Map Figure 6.40)
The St. Bees coastline is dominated by tall (>10m) cliffs of either glacial diamicton to the south or Permo-Triassic sandstone (>15m) to the north.

The upper tidal zone is dominated by gravel & cobble grade material which is managed through a series of groynes. Immediately below this mobile, storm and wave dominated material is a sand-dominated zone which includes small boulders and exposures of presumed Holocene peats lying within a small coast parallel channel (Figure 6.35).

The mid inter-tidal zone is dominated by a berm of medium-grained sand which separates a lower inter-tidal zone of medium sand with exposures of eroding blue-grey clays. The geometry of the surface exposures of peats and clays, confirmed by coring, suggests the peat to be younger than the clays (Figure 6.36). The peats appear to be steeply dipping seaward at their most inland extent although this may be a local effect.

The seaward exposure of blue-grey clay is eroding into a series of coast-normal crests, probably due to the effect of backwash draining from the large landward inter-tidal area. The clays are permeated by significant amounts of fine organic material, possibly rootlet remains.

Figure 6.35 Top left, view to north following main exposure of inter-tidal peats; top right, example of large surface timber; bottom left, inter-tidal silts eroding in the lower zone; bottom right, small section cut through the St Bees peat horizon for pollen, macrofossil and ^{14}C sampling.

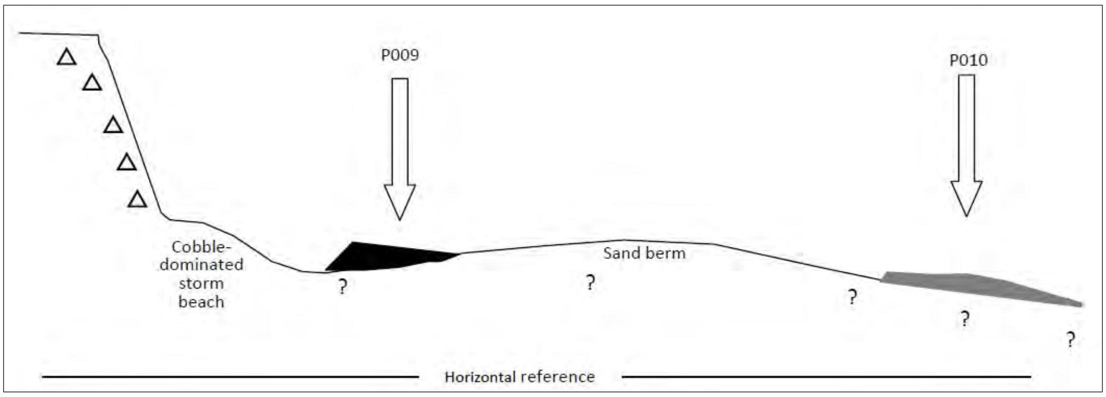

Figure 6.36 Section shows the relative position of the organic and clastic sediments exposed on the foreshore at St Bees, Cumbria in March 2012. The Holocene peat and silt exposures occur along relatively extensive coast-parallel strips of up to 30 m. The top surface of the peat bears a number of *in situ* tree-stumps, prostrate tree trunks and branches (3 m long by <80 cm diameter). "?" indicates uncertainty of subsurface relationship between units.

6.18.1 Pollen Analysis

The peat sequence was determined to be at least 44cm thick (Figure 6.37). The upper surface contained a very large number of flattened tree trunks and occasional *in-situ* tree boles. A total of four peat samples were recovered from this thick sequence and were found to contain only low pollen concentrations which are presented in Table 6.10.

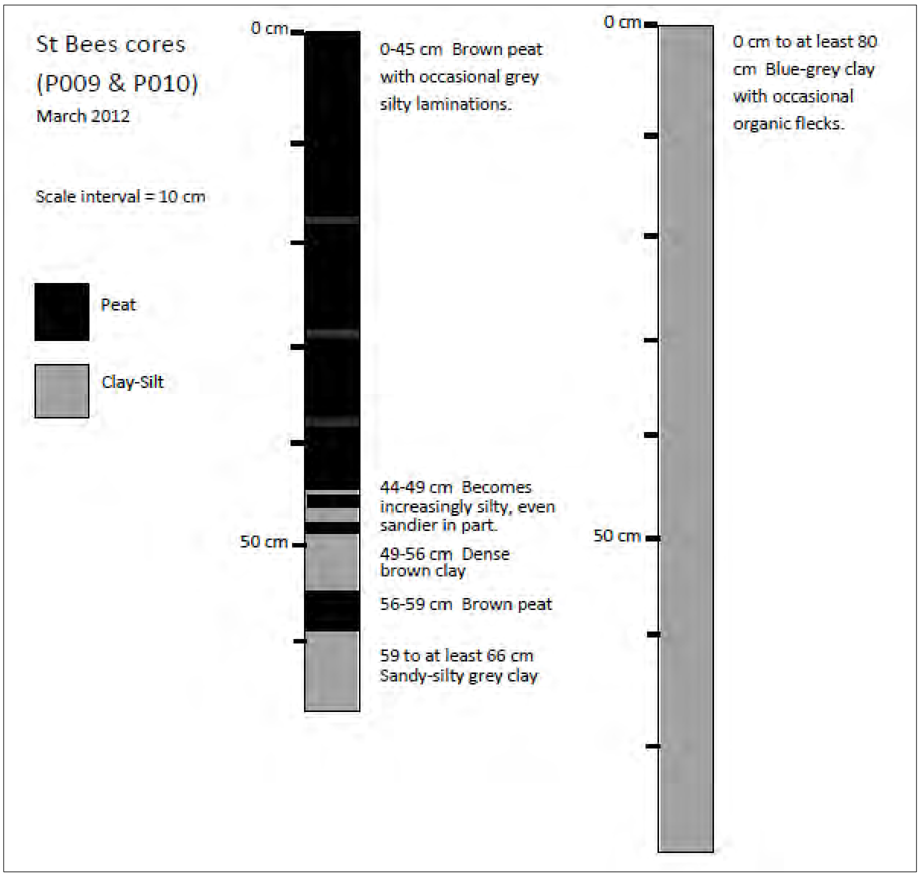

Figure 6.37Cores through the foreshore at St Bees.

P009	#A	#B	#C	#D	#E
	8-12 cm	16-20 cm	30-34 cm	56-59 cm	42-46 cm
	Very Low Conc.	No Pollen	Very Low Conc.	Very Low Conc.	Very Low Conc..
Betula			1		
Corylus avellana-type	5			1	1
Salix	9		4		
Hedera helix			1		
Filipendula			2		
Pre-Quaternary Spores				1	1
Unidentified				2	

Table 6.10 Pollen record through peat at St Bees.

6.18.2 Radiocarbon Analysis

Five samples from an exposure of peat (P009) in the coast-parallel channel, which contained a large number of flattened tree-trunks and occasional *in situ* tree boles, were submitted for radiocarbon dating.

The results and Bayesian analysis (Table 6.11; Figures 6.38 and 6.39) indicate that rapid peat accumulation took place in the mid-ninth millennium cal BC. The small roundwood sample taken from 3-4cm from the top of the peat appears to be intrusive and provided a date of 3940-3700cal BC.

Laboratory number	Sample	Material	δ¹³C (‰)	Radiocarbon Age (BP)	Calibrated Date (95% confidence)
UBA-22188	SB3 [3–4cm] sample A	Nut (unidentified) from 1cm spit 3–4cm below the top of the peat	-28.1	9078±58	8430–8230 cal BC
SUERC-44446	SB3 [3–4cm] sample A	Small roundwood, including bark (unidentified) from 1cm spit 3–4cm below the top of the peat	-28.7	5001±29	3940–3700 cal BC
UBA-22189	SB2 [18–20cm] sample A	Nut (unidentified) from 2cm spit 18–20cm below the top of the peat	-25.6	9270±49	8640–8310 cal BC
SUERC-44445	SB2 [18–20cm] sample B	*Salix/Populus*, fragment of roundwood, 4mm diameter, one ring. From 2cm spit 18–20cm below the top of the peat	-28.4	9200±29	8550–8300 cal BC
UBA-22190	SB1 [33–35cm]	*Salix/Populus* sapwood from 2cm spit 33–35cm below the top of the peat	-30.4	9229±43	8610–8300 cal BC

Table 6.11 St Bees – North West Rapid Coastal Zone Assessment – radiocarbon results

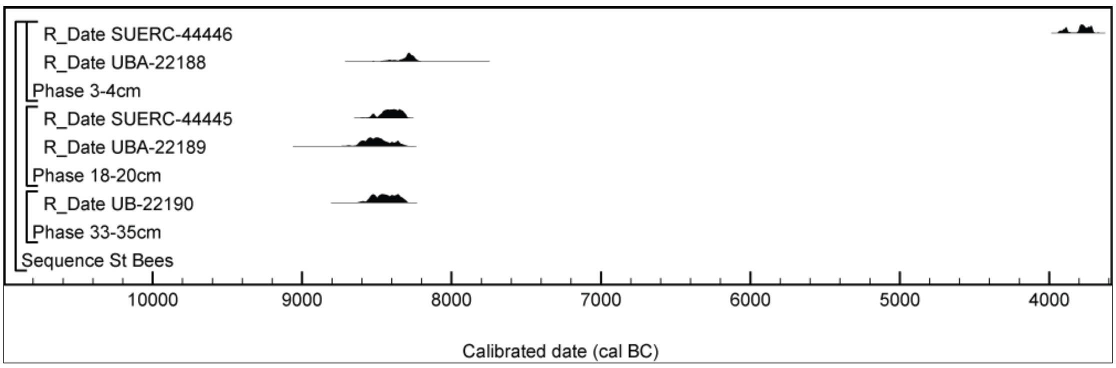

Figure 6.38 Probability distributions of dates from St Bees. The distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993)

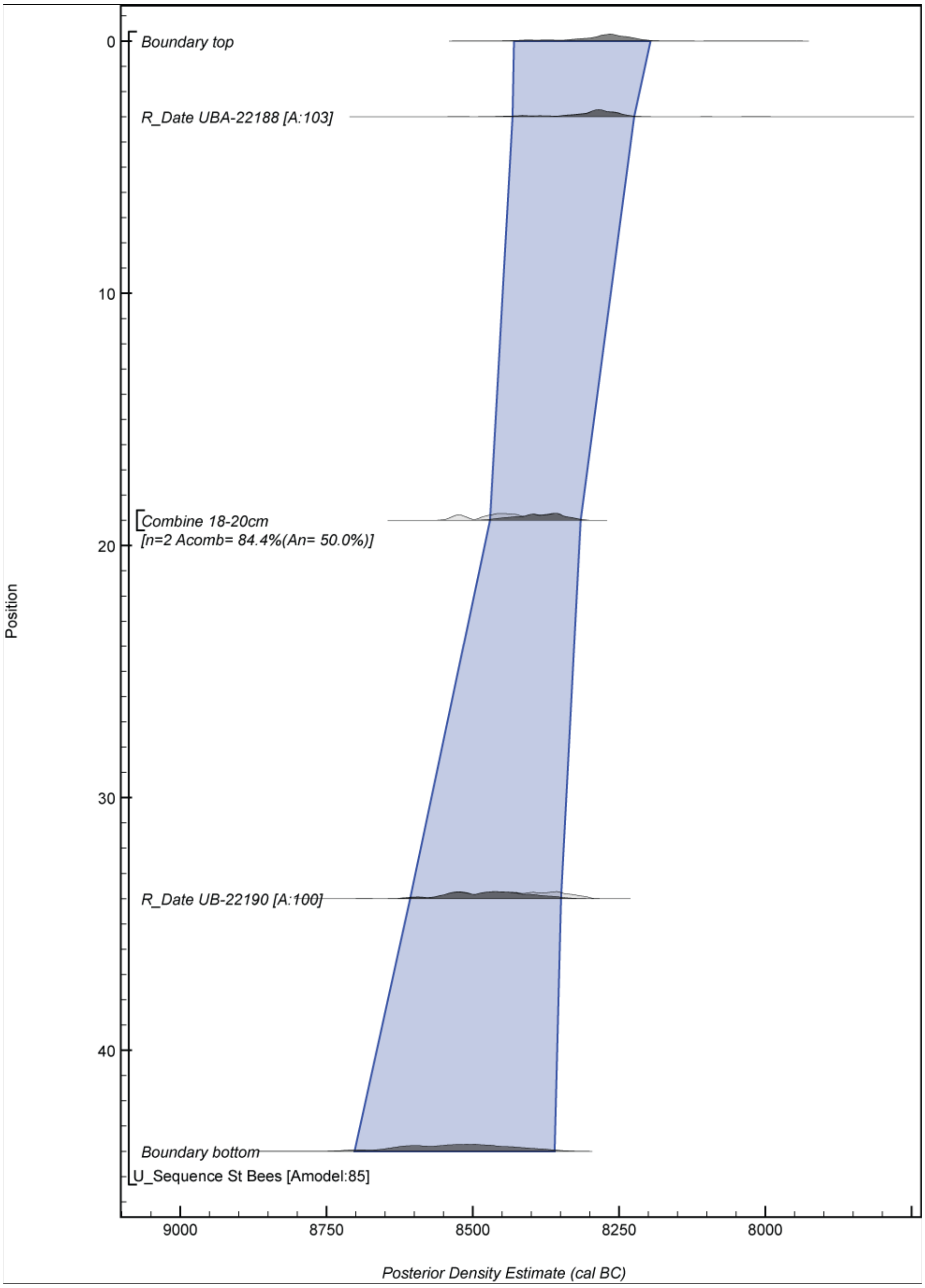

Figure 6.39: Bayesian age-depth model of the chronology of the sediment sequence at St Bees (U_Sequence model; Bronk Ramsey 2008). The coloured band show the estimated date of the sediment at the corresponding depth, at 95% probability. For radiocarbon dates, the lighter distribution is the result of simple calibration and the darker distribution is the posterior density estimate provided by the model.

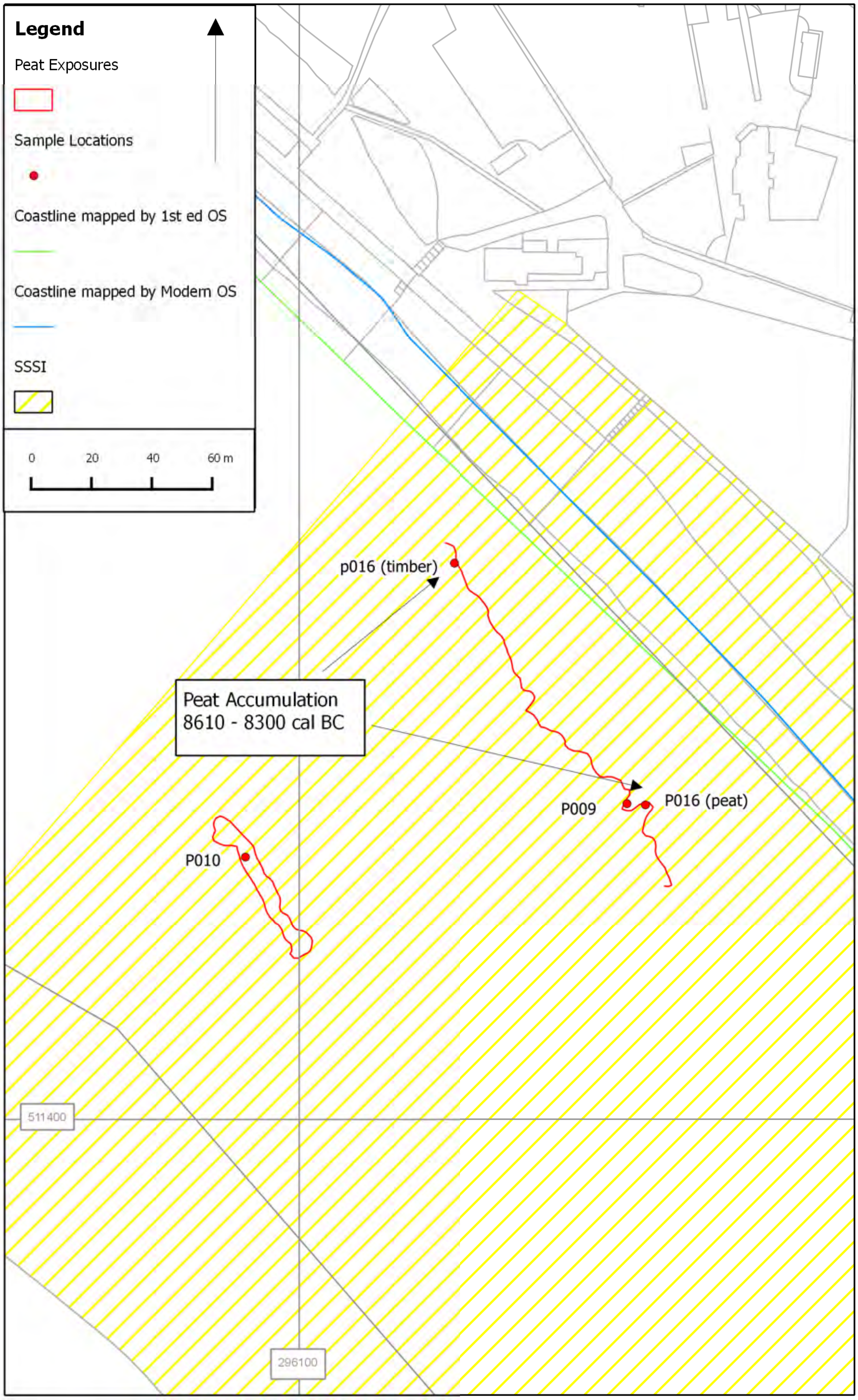

Figure 6.40 Location and radiocarbon dates of samples taken at St Bees

6.19 **Allonby** (NY 07422 42035)

Peat database record 528 refers to the record of 'moor log', but no grid reference was given. Having visited the site, no inter-tidal sediments were exposed and the record almost certainly relates to an inland, rather than a coastal location.

6.20 **Beckfoot** (NY 08523 49772 Map Figure 6.44)

A low gradient beach comprising sand-cobble mix dominating the inter-tidal zone. The top of the beach is formed by a 3-5m cliff of poorly consolidated sands and gravels (Figure 6.41) which are presumably of fluvio-glacial outwash. Engineering works are currently in progress as the retreating cliff line is threatening the existing coast road. The locality is recorded in the peat database (record 646) as having 'an exposure of forest soil, containing peat and recognisable organic fragments' on the foreshore (Bullen Consultants Ltd, 1998).

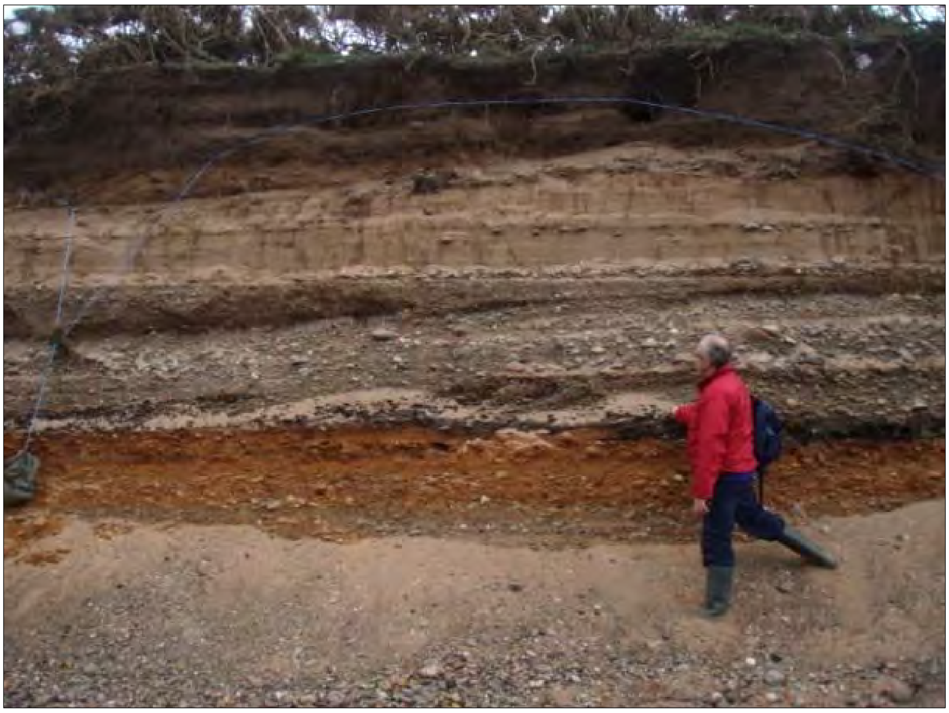

Figure 6.41 Interbedded sands and gravels forming cliffline at Beckfoot

Amongst the foreshore cobbles and boulders, *c.*60m seaward of the cliff line, a rather indistinct exposure of clays is observed, exposed in an arc trending broadly NE-SW (Figure 6.42). The clay (a maximum of 30cm) is draped on a thin peat which rests on an uneven surface of clast to matrix-supported glacial outwash with a coarse-sand matrix and pebble to boulder size, rounded dominantly granitic clasts.

6.20.1 Pollen Analysis

The peat (<5cm) contains abundant plant macrofossils (*Typha* or *Phragmites* type). The upper surface of the clay currently exhibits a significant number of both fallen trees (max. thickness ~30cm) and significant *in situ* tree boles (trunks <40cm diameter).

The sample at this location (P014) contained only low pollen concentrations, these are presented in Table 6.12.

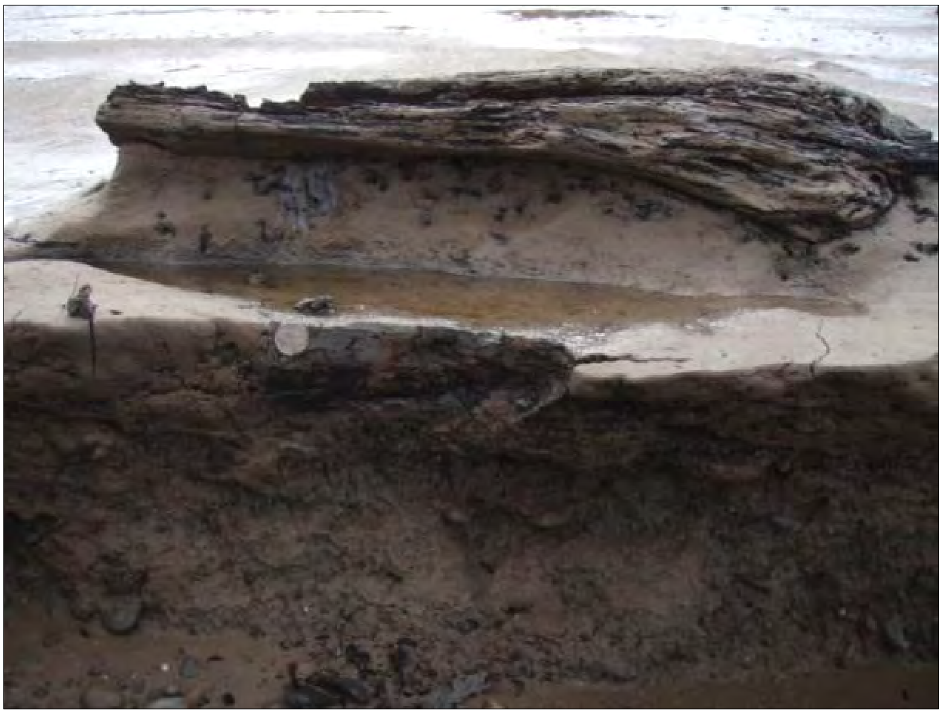

Figure 6.42 thin 2-4 cm peat (immediately below 10pence coin) on Beckfoot foreshore, with inter-tidal clays above forming a pedestal protected by an overlying tree trunk.

Pollen Sample P014	#A
	Raw pollen counts
Pinus sylvestris	8
Betula	6
Quercus	6
Alnus glutinosa	1
Ulmus	5
Corylus avellana-type	29
Chenopodiaceae	1
Cyperaceae	9
Cirsuim-type	2
Poaceae	15
Menyanthes	1
Typha latifolia	2
Sphagnum	2
Polypodium vulgare	10
Pteridium aquilinium	63
TLP	82

Table 6.12 Pollen counts for Beckfoot sample P014

6.20.2 Radiocarbon Analysis

A bulk sample of the complete depth of peat, <5cm, produced statistically consistent radiocarbon determinations (T'=1.9; ν=1; T'(5%)=3.8; Table 6.13; Figure 6.43) and the weighted mean (8278±32 BP) provides the best estimate for the age of the peat at 7470–7180 cal BC. The remains of a prostrate tree exposed on the upper surface of the exposed peat-bed date to 7030–6640 cal BC.

Laboratory number	Sample	Material	$\delta^{13}C$ (‰)	Radiocarbon Age (BP)	Calibrated Date (95% confidence)
Wk-35926	B1	Peat (358g) humic acid fraction, from sample of the total peat bed which was less than 5cm thick above diamicton	-28.3	8324±46	
Wk-35920	B1	Peat (358g) humin fraction, from sample of the total peat bed which was less than 5cm thick above diamicton	-28.3	8338±43	
	B1	T'=1.9; ν=1; T'(1%)=3.8		8278±32	7470–7180 cal BC
UBA-22192	B2	*Quercus*. Last 5 rings including final growth ring from sample of prostrate tree on the upper surface of exposed peat bed	-27.4	7896±45	7030–6640 cal BC

Table 6.13: Beckfoot – North West Rapid Coastal Zone Assessment – radiocarbon results

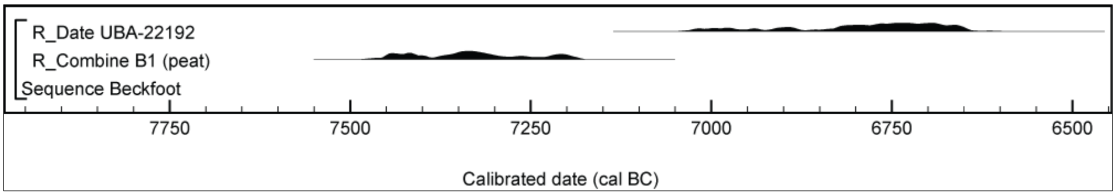

Figure 6.43: Probability distributions of dates from Beckfoot. The distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993)

6.21 **Glasson** (NY 24407 61302)

Peat database records 529 and 611 relates to a 'submerged forest' based upon an account from the early 19th century. The details suggest the occurrence of large trees, both fallen and *in situ*, set in a blue clay. During the field visit, no such deposits could be seen, the modern environment being dominated by a sandy inter-tidal zone which becomes slightly silty towards 1.2m depth. The uppermost part of the inter-tidal zone is formed by a 1m high cliff of eroding, laminated saltmarsh sediments.

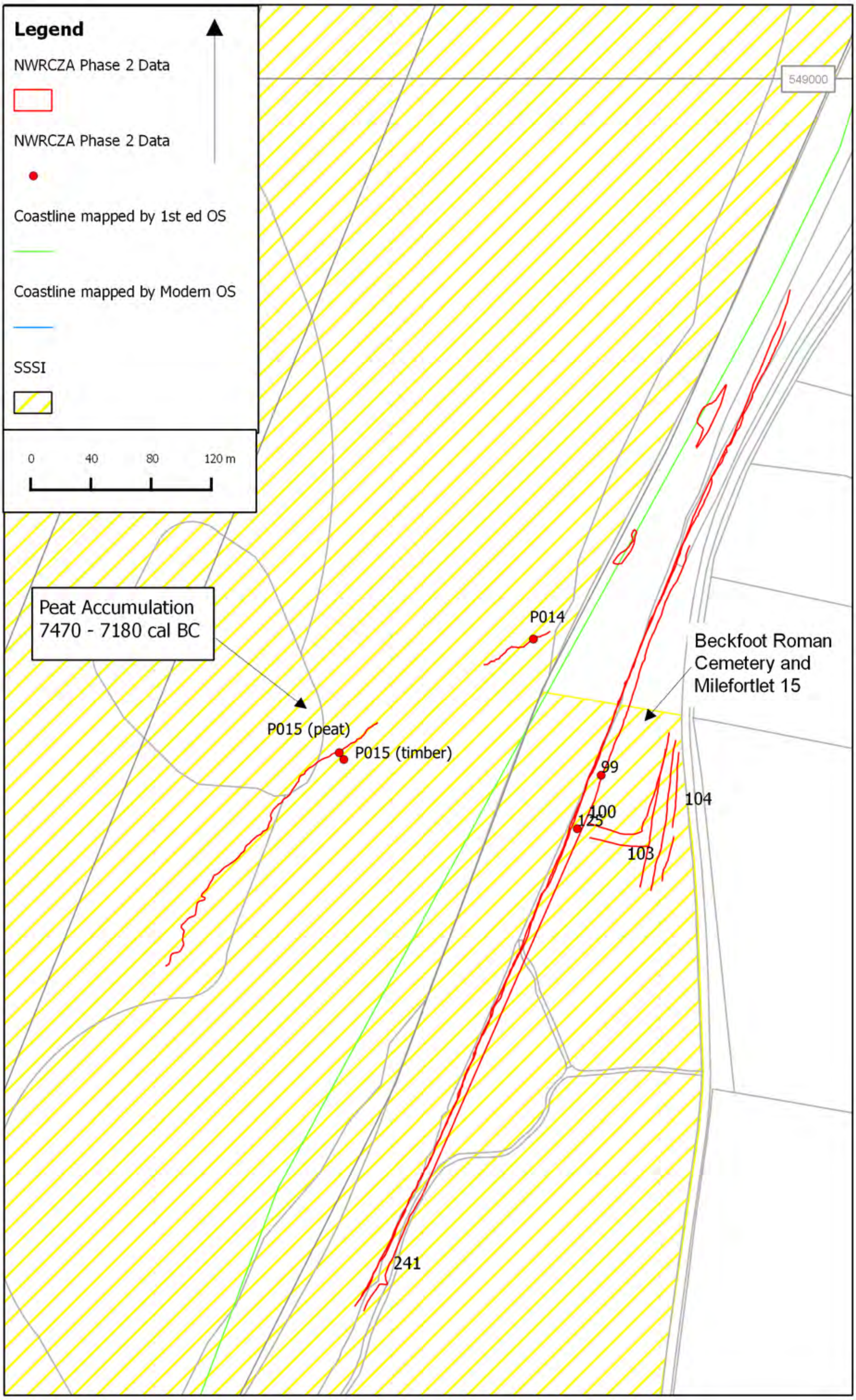

Figure 6.44 Location and radiocarbon dates of samples taken at Beckfoot

6.22 Discussion

The palaeoenvironmental analysis of coastal and inter-tidal peat sites within the study area has added a significant quantity of new data to the knowledge base for this region. Figure 6.45 provides a summary of the radiocarbon dates obtained as part of the NWRCZA palaeoenvironmental survey and the pollen assessments have provided information on the potential for full palnological analysis to be undertaken at these sites. Of particular note is the survival of a peat bed at Cleveleys, Lancashire, dating from the Windermere Interstadial. This is the only known exposed inter-tidal peat of this age on the North West coast and it is undergoing active and ongoing erosion. Although the potential for pollen analysis at this site is low, there are certainly other techniques which could be used to provide an environmental reconstruction from this significant palaeoenvironmental resource.

The dating analysis has also provided the earliest recorded dates for exposed inter-tidal peat beds in Cumbria, and has identified significantly earlier deposits along the North West coast more generally. Figure 6.46 shows the location and dates of peat beds sampled as part of NWRCZA Phase 2 alongside previously known dates for this region. Aside from demonstrating the contribution that the NWRCZA Phase 2 has made, it serves to highlight the geographical spread of dated information. This identifies a tentative date range of 7180-6090 Cal BC for marine inundation on the central north west coast with a marine inundation of 5895-5740 Cal BC within Morecambe Bay. The assessment has provided a number of key dates that can be used as Sea-Level Index Points to assist in reconstructing past sea levels.

All of the peat beds that were sampled and dated as part of this phase of work are exposed and the majority are in the inter-tidal zone, where they will be affected by every tide. Only the Drigg peat bed lies in the dune face, but it too is in a very exposed location where it will be affected by the majority of high tides. None of these peat beds will be protected by any 'Hold the Line' SMP2 policies, as they lie in the inter-tidal zone, beyond the scope of these schemes. There is also scope for these peat beds to be adversely affected by shoreline management policies in the near vicinity, or for some distance along the coast, as these will affect tidal conditions and levels of sediment transport within the system.

Aside from the dated and sampled sites, the NWRCZA Phase 2 has provided up-to-date condition statements on other known coastal and inter-tidal peat sites within the project area. It is important to note that whilst these were not exposed at the time of the present survey, these peat beds may also contain significant palaeoenvironmental information and should be routinely monitored for any change in their status.

There is significant potential for further 'rescue' work to be undertaken on the most threatened inter-tidal and foreshore peats.

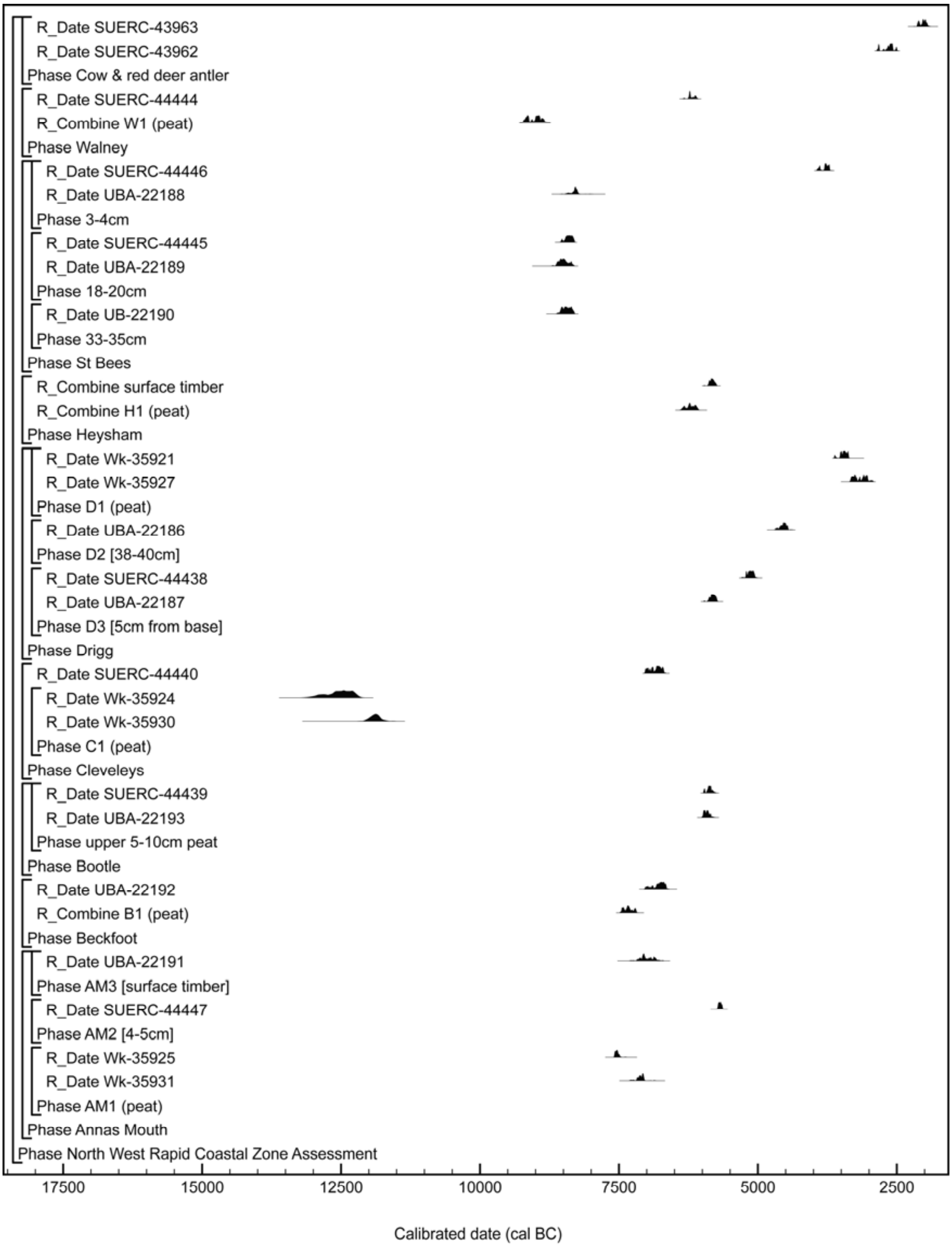

Figure 6.45 Radiocarbon dates obtained as part of the NWRCZA Phase 2 project.

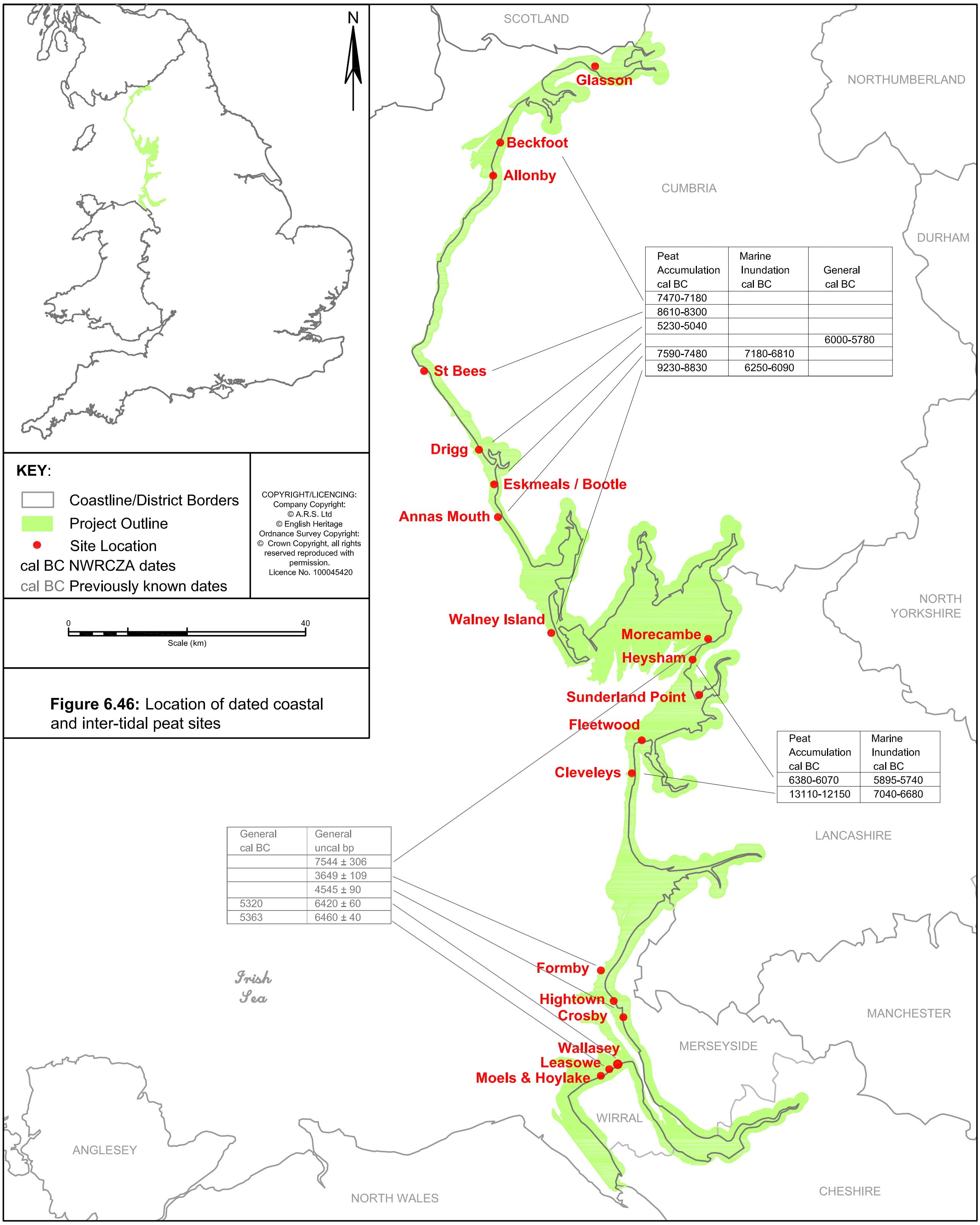

Figure 6.46: Location of dated coastal and inter-tidal peat sites

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