



Beck Burn Wind Farm, Solway Moss Cumbria

Palaeoenvironmental Analysis Report



April 2018

OpenSpace for EDF Energy Renewables

Issue No: 2017-18/1899

OA North Job No: L10975PX

NGR: NY 34567 68902

Document Title: BECK BURN, SOLWAY MOSS, CUMBRIA
Document Type: Palaeoenvironmental Analysis Report
Client Name: OpenSpace (Cumbria) Ltd for EDF Energy Renewables Ltd
Issue Number: 2017-18/1899
OA Job Number: L10975PX
National Grid Reference: NY 34567 68902

Prepared by: Mairead Rutherford
Position: Project Officer - Environmental
Date: February 2018

Checked by: Karl Taylor
Position: Project Manger
Date: February 2018

Signed.....

Approved by: Rachel Newman
Position: Senior Executive Officer –
Research and Publications
Date: April 2018

Signed.....

Oxford Archaeology North
Mill 3, Moor Lane Mills
Moor Lane
Lancaster
LA1 1QD
t: (0044) 01524 541000
f: (0044) 01524 848606

w: www.oxfordarch.co.uk
e: info@oxfordarch.co.uk

© Oxford Archaeology Ltd (2018)
Janus House
Osney Mead
Oxford
OX2 0EA
t: (0044) 01865 263800
f: (0044) 01865 793496

Oxford Archaeology Limited is a Registered Charity No: 285627

Disclaimer:

This document has been prepared for the titled project or named part thereof and should not be relied upon or used for any other project without an independent check being carried out as to its suitability and prior written authority of Oxford Archaeology being obtained. Oxford Archaeology accepts no responsibility or liability for the consequences of this document being used for a purpose other than the purposes for which it was commissioned. Any person/party using or relying on the document for such other purposes agrees, and will by such use or reliance be taken to confirm their agreement to indemnify Oxford Archaeology for all loss or damage resulting therefrom. Oxford Archaeology accepts no responsibility or liability for this document to any party other than the person/party by whom it was commissioned.

CONTENTS

SUMMARY	2
ACKNOWLEDGEMENTS.....	3
1. INTRODUCTION	4
1.1 Circumstances of the Project.....	4
1.2 Previous Palaeoenvironmental Work.....	5
2. METHODOLOGY	6
2.1 Sampling Methodology	6
2.2 Sample Counting	6
2.3 Radiocarbon Dating	6
3. RESULTS: RADIOCARBON DATING AND PALYNOLOGY	7
3.1 AMS Dating	7
3.2 Pollen Zone Descriptions	7
3.3 Interpretation	10
4. RESULTS: LANDSCAPE EVOLUTION AND HUMAN IMPACT.....	17
4.1 Introduction	17
4.2 Discussion	17
5. CONCLUSIONS	21
BIBLIOGRAPHY	23
LIST OF FIGURES	26
TABLES	
Table 1: Radiocarbon AMS dates from Solway Moss.....	7

SUMMARY

EDF Energy Renewables Ltd was granted planning permission (Planning Ref 13/0866) to develop a wind farm (to be known as 'Beck Burn Wind Farm') on Solway Moss near Carlisle (NY 34567 68902). The planning permission was subject to several conditions, one of which (Condition 19) stated that a programme of archaeological work should be carried out in advance of the development. As part of this work, Jonathan Rook of OpenSpace (Cumbria) Ltd, on behalf of EDF Energy Renewables Ltd, and Peter Cardwell, archaeological consultant for EDF Energy Renewables Ltd, requested that Oxford Archaeology North (OA North) undertake an initial palaeoenvironmental assessment, and subsequent analysis work from cores collected from the site.

The initial assessment established that the cores had good pollen survival and that the sequence contained the earliest dated palaeoenvironmental record from Solway Moss. In addition, the sequence contained later medieval strata, which are rarely identified within cores in the region because of the widespread practice of peat cutting at that time. It was therefore agreed that a detailed dated pollen profile should be generated, taking into account how these new data could enhance previous palaeoenvironmental records for Solway Moss (Hodgkinson *et al* 2000).

Radiocarbon dating suggests that organic sediments began to accumulate within the early Holocene, in the early Mesolithic period (eighth millennium BC). The vegetational sequence records development of very early Holocene sedge-fen palaeoenvironments prior to colonisation by birch, and the subsequent establishment of mixed woodlands in the Mesolithic period. Such woodlands appear to have persisted for some time, but with expansion of heather moorland and the development of *Sphagnum*-moss communities. Previous work from Solway Moss has suggested disturbance caused by fire during the Mesolithic period (Hodgkinson *et al* 2000). A pollen diagram from the southern part of the Moss records occurrences of cereal-type pollen both during the late Mesolithic and early Neolithic periods (*ibid*). The current study provides indications of further disturbance events during the Bronze Age, and there is also new evidence to suggest small-scale continuous arable cultivation, between the late Iron Age to the early Roman period, and the early medieval period (with a break in arable agriculture between a little after cal AD 878-989 (1122±24 BP; SUERC 76308) and prior to cal AD 1444-1634 (377±24 BP; SUERC 68406)).

ACKNOWLEDGEMENTS

Oxford Archaeology North (OA North) would like to thank OpenSpace (Cumbria) Ltd, acting on behalf of EDF Energy Renewables Ltd, for commissioning the report, and particularly, for the assistance during fieldwork, Jonathan Rook and Paul Hayton. We would also like to thank Peter Cardwell, archaeological consultant for EDF Energy Renewables Ltd, for discussions concerning the project. Mairead Rutherford selected sub-samples for pollen analysis and radiocarbon dating, while Sandra Bonsall processed the pollen samples and Denise Druce identified plant macrofossils suitable for radiocarbon dating, and also fragments of wood to species. OA North is grateful to Lancaster University for the use of laboratory space for pollen processing. Mairead Rutherford analysed the sub-samples for pollen and wrote the report, Mark Tidmarsh and Marie Rowland producing the illustrations for the report. Radiocarbon dating was undertaken by the Scottish Universities Radiocarbon Dating Laboratory (SUERC). Karl Taylor managed the project and the report was edited by Rachel Newman.

1. INTRODUCTION

1.1 CIRCUMSTANCES OF THE PROJECT

- 1.1.1 EDF Energy Renewables Ltd was granted planning permission (Planning Ref 13/0866) to develop a wind farm (to be known as 'Beck Burn Wind Farm') on Solway Moss near Carlisle. The planning permission was subject to several conditions, one of which (Condition 19) stated that a programme of archaeological work be carried out in advance of the development. A written scheme of investigation (WSI) outlining the nature of the work was produced in November 2015 by Jacobs (Jacobs UK Limited 2015) and subsequently approved by the Local Planning Authority (Carlisle City Council).
- 1.1.2 Oxford Archaeology North (OA North) was commissioned by OpenSpace (Cumbria) Ltd (*via* Peter Cardwell, consultant archaeologist, on behalf of EDF Energy Renewables Ltd) in May 2016, to collect four peat cores from the proposed wind-farm site at Beck Burn, Solway Moss, Cumbria (NGR NY 34567 68902; Fig 1) and to undertake an initial palaeoenvironmental assessment, followed by selected analysis, of the collected sediments (OA North 2016).
- 1.1.3 The assessment recommended (as agreed with the Cumbria Historic Environment Service) that a section from the oldest material recorded at the site, from core 3 (Fig 2), should be subjected to pollen analysis, to detail the transition through initial sedge-fen development, and interpret any possible human impact on this development, prior to and possibly inclusive of Mesolithic woodland development. The latter utilised data from the assessment phase, as well as previously published regional data (Hodgkinson *et al* 2000).
- 1.1.4 An interpretation of previously published plant macrofossil and pollen data, from a core taken from the southern part of Solway Moss, adjacent to the site of the 'Solway Sheep' (Fig 2) is included in the current study (*Sections 3.2.4; 4.2.11; Hodgkinson et al 2000*). This permitted a fuller understanding of the palaeoenvironmental history of the late Mesolithic and Neolithic periods to be integrated into a detailed palaeoenvironmental history for both before and after this time period on Solway Moss.
- 1.1.5 In addition, pollen analysis was undertaken on samples from core 4, which formed the main element of the present study. This core was taken from an area beyond the footprint of the windfarm development, but where the deepest peat deposits had been identified (SKM Enviro 2010). The time interval represented in these sediments spans the early Bronze Age to post-medieval period, and the results permit a detailed record of land-use to be established for Solway Moss. Furthermore, these data provide a palaeoenvironmental context for the animal remains found during previous archaeological investigations (Hodgkinson *et al* 2000).
- 1.1.6 It was necessary to obtain further radiocarbon AMS (Accelerator Mass Spectrometer) dates to support this analysis. Multiple phases of disturbance linked to anthropogenic activity, during the Bronze Age, late Iron Age to early

Roman period, the medieval and post-medieval periods, have therefore been dated.

1.2 PREVIOUS PALAEOENVIRONMENTAL WORK

- 1.2.1 Previous work to 2000 has been summarised in the Cumbria volume of the North West Wetlands Survey (Hodgkinson *et al* 2000). This includes data on core retrieval, lithostratigraphic data and landscape evolution, as well as a review of previous palaeoecological work from Solway Moss and adjacent mosses (Fig 3). This was briefly reviewed during the assessment phase of the present project (OA North 2016).

2. METHODOLOGY

2.1 SAMPLING METHODOLOGY

2.1.1 In all, 70 sub-samples were taken, all at a standard sampling interval of 0.04m. Seven sub-samples from core 3, from depths of 3.54-3.75m, were analysed, with the aim of examining early Holocene material, and a further 63 sub-samples were analysed from core 4, at 2.48m-0.04m, to examine the Bronze Age to post-medieval deposits. In the event, however, the prevalence of *Sphagnum* moss precluded statistically significant pollen counts within the interval 0.40-0.32m in core 4. The palynological results from a core from the Moss, that was previously analysed in detail to provide a vegetational history of the late Mesolithic to Neolithic period (Hodgkinson *et al* 2000, fig 88), together with vegetational data, interpreted from assessed sub-samples during the initial phase of the current study, have also been incorporated, where appropriate. Therefore, a complete vegetational history from the earliest Holocene to the post-medieval period can be put forward, from which a cultural sequence can be drawn.

2.2 SAMPLE COUNTING

2.2.1 Pollen counts of 300-500 grains were achieved for all but 11 of the samples analysed, these latter yielding insufficient pollen for quantitative analysis. Percentage diagrams have been compiled, using the computer programs TILIA and TGView (Grimm 2011). The percentage values are based on a total land pollen (TLP) sum, including pollen of trees, shrubs, herbs and fern spores. Pollen of aquatic plants, non-pollen palynomorphs (NPP) and microscopic charcoal are expressed as percentages of TLP plus the respective sum to which they belong. Rare pollen types (single occurrences of taxa) are marked on the diagrams using a cross symbol. Pollen assemblage zones were placed through visual examination of the data.

2.3 RADIOCARBON DATING

2.3.1 All radiocarbon dating undertaken was carried out by the Scottish Universities' Environmental Research Centre (SUERC). Full details may be obtained from Dr Gordon Cook of SUERC. Dates have been calculated using OxCal v4.3.2 (Bronk Ramsey 2009), and the current internationally agreed atmospheric calibration dataset for the northern hemisphere, IntCal13 (Reimer *et al* 2013). All radiocarbon determinations are cited as calibrated ranges, cited as cal BC/AD, at a two-sigma confidence level (95.4%), followed by the radiocarbon age quoted in conventional years BP (before 1950; Stuiver and Polach 1977), plus the standard error and laboratory code. Tabulated and textual expressions of the posterior density estimates (modelled dates) are conventionally *italicised*, to distinguish them from simple radiocarbon dates, which are set out in standard text (Bayliss *et al* 2011, 20).

3. RESULTS: RADIOCARBON DATING AND PALYNOLOGY

3.1 AMS DATING

3.1.1 An initial six dates were obtained from cores 3 and 4 during the assessment phase of this project (OA North 2016), with a further eight during the analysis phase. In all but two samples, both the humin and humic acid fractions of the sediments were dated (Table 1).

SUERC code	Sample	Sample depth (m)	Fraction	$\delta^{13}\text{C}$	Age BP	Age cal BC/AD (95.4% confidence)	Period
68404	Core 4	4.97-4.99	Humic	-28.3	8725±34	7936-7605 cal BC	early Mesolithic
68405	Core 4	4.97-4.99	Humin	-26.6	8870±34	8222-7842 cal BC	early Mesolithic
68406	Core 4	0.24-0.25	Twigs	-29.4	377±34	cal AD 1444-1634	late medieval / early post-medieval
68407	Core 3	3.60-3.61	Humic	-27.8	9293±45	8697-8347 cal BC	early Mesolithic
68408	Core 3	3.60-3.61	Humin	-28	9538±34	9131-8758 cal BC	early Mesolithic
68943	Core 3	0.11-0.12	Leaves	-26.4	3016±25	1386-1132 cal BC	late Bronze Age
76308	Core 4	0.72-0.73	Humic	-27.7	1122±24	cal AD 878-989	early medieval
76309	Core 4	0.72-0.73	Humin	-27.8	1172±21	cal AD 773-942	early medieval
76310	Core 4	1.53-1.54	Humic	-28.4	1916±24	cal AD 27-132	late Iron Age to early Roman
76311	Core 4	1.53-1.54	Humin	-27.9	1894±24	cal AD 56-211	early Roman
76315	Core 4	2.24-2.25	Humic	-28	3267±24	1616-1497 cal BC	middle Bronze Age
76316	Core 4	2.24-2.25	Humin	-27.7	3276±24	1616-1502 cal BC	middle Bronze Age
76317	Core 4	2.46-2.47	Humic	-27	3478±24	1884-1701 cal BC	early Bronze Age
76318	Core 4	2.46-2.47	Humin	-26.9	3565±24	2013-1782	early Bronze Age

Table 1: Radiocarbon AMS dates from Solway Moss

3.2 POLLEN ZONE DESCRIPTIONS

3.2.1 The pollen data have been divided into a number of zones, defined by changes in the palynological record. The lowest two zones describe pollen from the oldest, early Holocene, sediments analysed (from core 3, labelled *BB3*); those from core 4 represent sediments that range in age from the later part of the early Bronze Age to the post-medieval period (labelled *BB4*).

- 3.2.2 **Zone BB3(a) 3.75-3.62m:** four sub-samples in sandy clay and silt deposits revealed an abundance of the fresh-water algal type, *Pediastrum* (HdV-760), and rare occurrences of the fresh-water algal type *Botryococcus* (HdV-761), along with abundant pollen of sedges (Cyperaceae) and commonly occurring grasses (Poaceae; Fig 4). Tree and shrub taxa were relatively poorly represented, comprising birch (*Betula*), hazel-type (*Corylus avellana*-type), willow (*Salix*) and pine (*Pinus*). Rare occurrences of juniper (*Juniperus*), crowberry (*Empetrum*) and heaths/heathers (*Ericales*-type) were also recorded. Herb taxa included meadow-sweets (*Filipendula*), cinquefoils (*Potentilla*-type), bedstraws (Rubiaceae), docks/sorrels (*Rumex*-type), meadow-rues (*Thalictrum*), dandelion-type (*Taraxacum*-type), pollen of the carrot family (Apiaceae), pinks family (Caryophyllaceae), cabbage family (Brassicaceae) and pea family (Fabaceae). Fern spores were represented by the occurrence of bracken (*Pteridium*), monolete ferns (Pteropsida) and horsetails (*Equisetum*). Pollen from aquatic plants was represented by commonly occurring grains of alternate water-milfoil (*Myriophyllum alterniflorum*), and rare pondweed (*Potamogeton*) and lesser bulrush (*Typha angustifolia*). Pollen of bog-bean (*Menyanthes*) was also recorded. Non-pollen palynomorphs comprised a sparse assemblage, assigned to type HdV-128, and *Closterium* (HdV-80). Microcharcoal was present in relatively low quantities.
- 3.2.3 **Zone BB3(b) 3.62-3.52m:** this zone also contains most of the taxa present in Zone BB3(a), but is distinguished by a dramatic initial decline from 80% to 30% abundance, and then to absence, in values for *Pediastrum* (HdV-760) species, coincident with a shift from sandy silts and clays to peat deposits. The pollen spectrum shows a slight decline in numbers of grass pollen grains, along with slightly increasing numbers of sedge pollen. Pollen of the carrot and bedstraw families are more commonly recorded than in the underlying zone. Tree pollen is generally sparse but includes evidence for the presence of birch, hazel-type, juniper, pine, willow and oak. The fungal spore type, *Clasterosporium caricinum* (HdV-25), is commonly recorded.
- 3.2.4 **Zone BB4(a) 2.48-2.30m:** tree pollen is well represented (Fig 5) throughout the zone and comprises pollen of hazel-type, alder, oak, and birch, as well as sporadic occurrences of pine, ivy (*Hedera*) and ash (*Fraxinus*). Heather (*Calluna*) pollen is consistently recorded, but in relatively small numbers. Grass pollen is present in relatively low numbers and values for pollen of sedges decrease through the zone. Pollen of herbs, such as ribwort plantain (*Plantago lanceolata*), docks/sorrels, buttercup-type (*Ranunculus*-type) and spores of bracken, are recorded. The numbers of *Sphagnum* moss spores fluctuate throughout the zone. Of the fungal spores and other non-pollen palynomorphs, the most significant is perhaps the presence of *Gelasinospora* (HdV-1; Fig 6); HdV-10 is also present towards the top of the zone, and microcharcoal is present in small amounts throughout. This zone can be placed stratigraphically above Zone SM-c, identified in pollen analysis in association with the findings of the 'Solway Sheep' (Hodgkinson *et al* 2000; Fig 7).
- 3.2.5 **Zone BB4(b) 2.30-2.14m:** this zone is distinguished by a gradual decrease in the pollen of the main tree types (alder, birch, hazel-type, oak) and an increase in values for heather and sedges, as well as consistent (but relatively low) counts for grasses. Pollen of beech (*Fagus*) is recorded for the first time. Also present in consistent but low numbers are pollen grains of ribwort plantain,

docks/sorrels and bracken spores. Cereal-type pollen / large grass pollen is recorded within the upper part of the zone (Fig 5). Counts for *Sphagnum* moss spores are low, as are microcharcoal values through the zone. *Gelasinospora* (HdV-1) and HdV-10, are present (Fig 6).

- 3.2.6 **Zone BB4(c) 2.14-1.74m:** tree pollen appears to show a varying but overall slight recovery (especially of birch and oak), but counts for heather decline, as do sedges, and grass pollen values remain low (Fig 5). Values for *Sphagnum* moss spores fluctuate from initially high counts to consistently lower counts. Microcharcoal counts are generally low, but values for testate amoebae (micro-organisms belonging to the Phylum Protozoa: Rhizopoda, in particular, *Amphitrema flavum*) begin to increase.
- 3.2.7 **Zone BB4(d) 1.74-1.16m:** this is the main pollen zone defined, distinguished by decreasing tree pollen and a major expansion of grasses and heather. The zone has been divided into three sub-zones, so that the rise, peak occurrence and gradual decline in grass pollen can be clearly distinguished, as pollen of the major tree types decline and then show slight recovery through the zone.
- 3.2.8 **Sub-Zone BB4(d)(i) 1.74-1.58m:** a major decrease in the pollen of the main tree types can be discerned, in particular oak and birch, followed by alder and hazel-type; conversely, values for heather begin to increase, as do counts for grasses. Pollen of herbs, such as mugworts, docks/sorrels and ribwort plantain, and spores of bracken are all consistently recorded. *Sphagnum* moss spores are present in small numbers and counts for microcharcoal are low.
- 3.2.9 **Sub-Zone BB4(d)(ii) 1.58-1.34m:** this sub-zone is distinguished by low counts for tree pollen, although these do increase slightly towards the top of the zone, and there is a major expansion of grasses, as well as lesser increases in sedges and a significant presence of ribwort plantain. Values of heather rise initially but then decrease. Cereal-type pollen is present, including the occurrence of grains that can be assigned to rye (*Secale*). Significant numbers of testate amoebae are present within this sub-zone, and microcharcoal particles are recorded in higher numbers than previously.
- 3.2.10 **Sub-Zone BB4(d)(iii) 1.34-1.16m:** values for tree pollen show slight increases (eg birch), but generally remain consistent and low. Counts for grasses and sedges dip a little towards the top of the zone as counts for heather increase slightly. Cereal-type pollen is present in small numbers. Of significance is a substantial increase in *Sphagnum* moss spores.
- 3.2.11 **Zone BB4(e) 1.16-0.80m:** this zone is distinguished from the underlying BB4(d) by a reduction in grass pollen, an intra-zone spike in sedge pollen, and increasing values for heather towards the upper part of the zone. Tree pollen counts remain generally low, with slight fluctuations (eg hazel-type). Grass pollen counts are lower than in the previous zone, but records are consistent for ribwort plantain, docks/sorrels and bracken spores. Cereal-type pollen is present in small numbers, and microcharcoal counts are very low. Fungal spores HdV-10 and HdV-18 are recorded in relative abundance (Fig 6) and values for testate amoebae decrease.
- 3.2.12 **Zone BB4(f) 0.80-0.30m:** this zone is characterised by the rise of heather moorland and *Sphagnum* moss, spores of the latter dominating the assemblage such that there is little or no recovery of other pollen within the interval 0.32-

0.40m. Rare cereal-type pollen grains are restricted to the lower part of the zone and these include those that can be assigned to rye. Counts for microcharcoal are slightly higher than in the previous zone and the fungal spore, *Gelasinospora* (HdV-1), is again recorded, but in low numbers.

- 3.2.13 **Zone BB4(g) 0.30-0.04m:** a gradual increase in pollen of pine, but decrease in all other tree types, characterises this zone. In addition, cereal-type pollen is strong through the zone, but numbers decrease within the upper part. The incidence of pollen grains of ribwort plantain, docks/sorrels, bedstraws, dandelion-types and bracken spores also remains important within the zone. Counts for heather and *Sphagnum* moss spores drop back towards the top of the zone, and microcharcoal particles are present in relatively strong numbers throughout, but particularly towards the top of the zone.

3.3 INTERPRETATION

- 3.3.1 **The beginning of the Holocene, early Mesolithic period: Pollen Zones BB3(a)-BB3(b):** the deepest deposits in core 3 comprise organic silty clays and sandy silts, overlain by pale to dark brown humified peat sequences (Fig 4). Radiocarbon assays from the lower part of the peat confirm an early Mesolithic date of 8697-8347 cal BC (9293±45 BP; SUERC 68407, humic acid fraction) and 9131-8758 cal BC (9538±34 BP; SUERC 68408, humin fraction). The sub-samples analysed for pollen within the deepest Zone BB3(a) contain abundant fresh-water algae, suggesting probable development of an algal-rich, fresh-water pond, surrounded predominantly by sedge fen, but also with grasses and other herbs, and possibly a little willow, nearby. Further away from the pond, there is some evidence for possible scrub development, indicated by the pollen of plants such as birch, crowberry, hazel-type and juniper. The whole assemblage is typical of the early Holocene, prior to the development of woodland vegetation.
- 3.3.2 Pollen Zone BB3(b) records a transitional change from an algal-rich pond to predominantly sedge-fen, coinciding with a lithostratigraphic change from clays to peat. This corresponds to the gradual filling in of the pond and initial peat development. Within the upper part of this zone, spores attributed to *Clasterosporium caricinum* (HdV-25) represent a fungus found on leaves of various sedges, growing in marshes and fens that are subject to periodic flooding (van Geel 1978).
- 3.3.3 The data collected during the assessment (OA North 2016) suggest that, in addition to sedge-fen, which appeared to become sufficiently acid for *Sphagnum* moss to develop, birch (possibly dwarf birch) also later colonised the area, along with other scrub vegetation, such as crowberry, hazel-type and willow. This is particularly apparent from the vegetational record present in core 4, where birch and hazel-type dominate the deepest sub-samples between 4.9m and 5m; this assemblage has been dated, at 4.97-4.99m in core 4, to the early Mesolithic period (humic acid date of 7936-7605 cal BC (8725±34 BP; SUERC 68404) and humin fraction date of 8222-7842 cal BC (8870±34 BP; SUERC 68405)). At 4.72m, in core 4, hazel-type becomes dominant, suggesting the development of dense hazel-type woodlands. Regionally, at Scaleby Moss (Fig 3), the hazel rise is dated to 8425-7576 cal BC (9009±194 BP, Q-161; Walker, 1966; Hodgkinson *et al* 2000), and at Burnfoothill Moss,

to 7737-7579 cal BC (8625±145 BP SRR-3758; Tipping 1995a), which are broadly in agreement with the dates obtained from the Beck Burn cores. Other tree types present at this time include elm, pine and oak; values for heather and ericaceous pollen are also significant.

- 3.3.4 The pollen data may be interpreted as suggesting that a mosaic of open water, sedge-fen and birch woodland existed at Solway Moss during the early Mesolithic period. Such wetland areas may have been attractive to hunter-gatherer groups as areas of potential food sources. However, as hydrosere succession and sedimentation progressed towards the development of acid mire in the later Mesolithic period (Fig 7; zone *SM-a*), parts of the area would have become less resource-rich. Nevertheless, people would have interacted with terrestrial habitats, dominantly birch and willow scrub, and later, birch woodlands and then hazel-type woodlands.
- 3.3.5 Although only low counts for microscopic charcoal have been recorded through pollen zones *BB3(a)* and *BB3(b)* (Fig 4), there are two slightly higher counts that may be correlated with slight declines in values for sedges and grasses. It is possible that these values provide evidence of disturbance by fire of the local vegetation at the wetland edge. Controlled burning would have improved productivity at the water's edge as well as clearing routes. However, although the charcoal records burning locally or within the wider environment, it may have had a natural origin (for instance, lightning strikes) rather than a purely human origin (Innes *et al* 2011).
- 3.3.6 The vegetational record at Beck Burn suggests that, at the beginning of the Holocene, algal-rich ponds surrounded by sedge fen existed in the palaeo-landscape. As sedge swamps developed in these waterlogged pools, dwarf shrubs of juniper and willow, followed by birch and hazel-type vegetation, produced an open landscape, with small shrubby copses isolated amongst grassland and herbaceous communities. This correlates with similar pollen profiles described from early Mesolithic sites on the North Cumbrian Plain (Hodgkinson *et al* 2000). The litho- and palynostratigraphic data, and new dates from the Beck Burn site, push back the start of the development of peat at Solway Moss, which previously was thought to have occurred shortly after 6500-6000 cal BC (*c* 7700-7200 BP; Hodgkinson *et al* 2000), to between 8697-8347 cal BC (9293±45BP; SUERC 68407, humic acid fraction) and 9131-8758 cal BC (9538±34 BP; SUERC 68408, humin fraction).
- 3.3.7 **Late Mesolithic - Neolithic palaeoenvironments: Pollen Zones *SMa-c*:** assessment data from Beck Burn, and previous work on Solway Moss (Hodgkinson *et al* 2000; Fig 7), as well as established regional vegetational patterns, appear to suggest that, following the rise of hazel-type vegetation, a mixed woodland community developed, including trees such as oak, elm and pine. Colonisation by oak and elm has been dated at Burnfoothill Moss (Fig 3) to 6231-6060 cal BC (7285±45BP; SRR-3757a; Tipping 1995a). This mixed assemblage was joined by alder, a further distinctive event in the succession of trees during the early Mesolithic period, the beginning of the alder rise having been dated at Scaleby Moss to 6457-5888 cal BC (7361±146 BP, Q-167; Godwin and Willis 1959). The rise to dominance of alder at Burnfoothill Moss has been interpolated as occurring between *c* 5984-5806 cal BC (*c* 6950-7050 BP) and *c* 5469-5321 cal BC (*c* 6350-6450 BP; Tipping 1995b).

- 3.3.8 Previous pollen work from the southern part of Solway Moss, in addition to the identification of burnt plant macrofossils and charred wood fragments, has suggested almost continuous fire disturbance during the late Mesolithic period, reaching a peak around 5000 cal BC (*c* 6100 BP; Hodgkinson *et al* 2000; Fig 7, zone *SM-a*). Both plant macrofossil and pollen data from this site suggest the possibility that birch carr woodland was subject to burning during the Mesolithic period and that this resulted in the local spread of heather on the Moss (*ibid*). This interpretation is evident on the pollen diagram, which shows the incidence of microcharcoal increasing significantly as birch decreases (zone *SM-b*). The pollen data also suggest that extensive areas of woodland were present regionally, with alder occupying damper valley areas, with drier ground being occupied by mixed, possibly open, woodlands of oak, elm, ash and lime. Scrubby hazel-type copses may also have been prevalent on the Moss. On the diagram, pollen of hazel-type increases following a peak in microcharcoal counts (the latter indicative of fire; zones *SM-b*, *SM-c*); fire disturbance by Mesolithic people could have encouraged renewed hazel growth (Innes *et al* 2011). Furthermore, microscopic charcoal and slightly elevated counts of the pollen of grasses and bracken have been interpreted as evidence to suggest the possible management of the landscape on Solway Moss during the late Mesolithic period (Hodgkinson *et al* 2000).
- 3.3.9 Open spaces in woodlands, created through burning, may have been a deliberate activity to provide areas for pasturing animals, but there may also have been social and ritual reasons for creating cleared areas (Innes *et al* 2011). Similar pollen profiles to those produced solely through human interference with the landscape could also result from disease and trampling/browsing by animals (*ibid*). Interpretation of the data from Burnfoothill Moss, favours an anthropogenic origin for microcharcoal, whilst also recognising possible natural origins (Tipping 1995b). At this site, two possible clearance phases were noted during the late Mesolithic period, dating between *c* 5750 BC and *c* 5250 BC, and initially, deforestation was through the use of fire, with cleared areas perhaps being maintained through grazing (Tipping 1997). Also on the northern side of the Solway, evidence for late Mesolithic anthropogenic woodland disturbance includes sites such as The Dod in upper Teviotdale, where a disturbance event has been dated to *c* 5600 BC, and Catherine Hill, Annandale, where small-scale human disturbance is dated to *c* 5500 BC (*ibid*).
- 3.3.10 This typically Mesolithic vegetation persisted until the start of the Neolithic period, at which point the values for pollen of elm decrease (the Elm Decline), dated at Solway Moss to 4036-3780 cal BC (5110±60 BP; GU-5275; Fig 7; *SM-c*; Hodgkinson *et al* 2000). Of interest is the occurrence of rare cereal-type pollen grains, dated to 3350-2890 cal BC (4400±80 BP; GU-5313), just above the Elm Decline, which, although the separation of cereal-type pollen from wild grasses is problematic (Andersen 1979), may provide support for possible Neolithic cereal cultivation on Solway Moss (Hodgkinson *et al* 2000). However, at Burnfoothill Moss, an Elm Decline date of 3700-3510 cal BC (4820±45 BP; SRR-3755) has been obtained, but appears not to show an association with anthropogenic activity until *c* 3515-3104 cal BC (*c* 4590 BP; Tipping 1995b; Parker *et al* 2002). Detailed pollen profiles from a palaeochannel of the River Eden near Carlisle show a very gradual elm

decline, associated with probable anthropogenic activity and early cereal cultivation, that has been chronologically modelled to start at 3940-3730 cal BC (95% probability) and to end at 3640-3510 cal BC (95% probability; Brown *et al* in prep).

- 3.3.11 **Early Bronze Age: BB4(a):** at a regional level, pollen data have shown that a phase of clearance occurred from c 2300 cal BC, across the lowland landscape of the inner Solway Firth, which is detectable in the pollen sequences from Burnfoothill Moss, Scaleby Moss, and Bolton Fell Moss (Tipping 1997). Following this, much of the early Bronze Age was characterised by phases of woodland regeneration, and it has been suggested that this may relate to a reduction in the intensity of land-use across the area (*ibid*).
- 3.3.12 The bottom of the pollen sequence obtained from core 4 at Beck Burn is dated to the later part of the early Bronze Age (1884-1701 cal BC (3478±24 BP; SUERC 76317; humic acid fraction) and 2013-1782 cal BC (3565±24 BP; SUERC 76318; humin acid fraction) at 2.46-2.47m). The pollen data seem to suggest little disturbance, based on continuous records of the pollen of herbs such as docks/sorrels and ribwort plantain, and the incidence of open-canopy trees such as ash. Records for the continuous occurrence of spores of bracken also support the presence of clearings or open-canopy woodland (Tipping 1995b). It is possible that open areas on the Moss or clearings in the woodland may have been used for pasturing animals; there is no evidence for crop cultivation.
- 3.3.13 Interestingly, although counts of microscopic charcoal particles decrease through the zone, rare fungal spores of *Gelasinospora* (HdV-1) provide evidence for the presence of charred plant matter, which may be indicative of local fires. Other fungal spores that occur consistently through the zone, such as HdV-10 and *Meliola* (HdV-14), are known to host on green plants and are particularly associated with heather (van Geel 1978). Both may be used as an indicator for local dry conditions on a bog or moss (*ibid*). It is likely that, locally, the Moss was colonised by scrubby heather and hazel-type plants, with some sedge fen-carr in wetter areas.
- 3.3.14 **Middle Bronze Age: BB4(b):** the pollen data in Zone *BB4(b)* are very similar to those in Zone *BB4(a)*, but are distinguished by the presence of probable cereal-type pollen grains, although it is difficult to be absolutely certain regarding the identifications, as the dimensions of cereal-types overlap with those of wild grasses (Andersen 1979). Slight increases in pollen of ribwort plantain and docks/sorrels, and occurrences of other open-ground and arable types, such as mugwort and pollen of the goosefoot family, may support an interpretation of limited arable cultivation at this time. The dimensions of the cereal-type grains suggest that possibly barley (*Hordeum*), as well as wheat/oats (*Triticum/Avena*), may have been cultivated. This event has been dated at 2.24-2.25m to 1616-1497 cal BC (3267±24 BP; SUERC 76315; humic acid fraction) and 1616-1502 cal BC (3276±24 BP; SUERC 76316; humin acid fraction).
- 3.3.15 At a regional level, this period appears to equate with more sustained clearance, as part of a prolonged period of agricultural activity in the Solway area (Tipping 1997). Cereal-type pollen is consistently recorded at pollen sites across the inner Solway Firth and adjacent areas after c 1800 cal BC, implying

the presence of arable agriculture with, for example, substantial cereal-pollen records dating from the Middle Bronze Age from lowland areas (Walker 1966; Tipping 1997). It also has been argued that, after *c* 1800 cal BC, there was no dramatic increase in clearances and that the levels of land-use remained fairly static throughout the remainder of the Bronze Age (*ibid*).

- 3.3.16 **Middle/Late Bronze Age to Iron Age: BB4(c):** the pollen data from Zone BB4(c) suggest a period of reduced cultivation, coincident with slight increases in pollen of oak, birch and alder, and an absence of cereal-type pollen. The consistent occurrence of ash suggests continuation of an open woodland canopy, although there is also evidence for regrowth of birch, and possibly slight increases, towards the top of the zone, of oak and hazel-type. No expansion of grasses is visible, although continuous records of pollen of ribwort plantain and docks/sorrels, and sporadic occurrences of mugworts and pollen of the goosefoot family, do suggest possible land utilisation for pasturing animals. Pollen data from the northern part of the Solway Plain, at Burnfoothill Moss, suggest that areas of the lowland plains were not abandoned during the late Bronze Age and there is pollen evidence indicative of pastoral farming (Tipping 1995b). Work on several sites around Morecambe Bay suggests that there was a regeneration of woodland associated with a decline in agricultural activity dating to the later Bronze Age and early Iron Age (Wimble *et al* 2000; Coombes *et al* 2009).
- 3.3.17 There is evidence for the spread of *Sphagnum* moss at Beck Burn during this time, and a general recession in the quantity of heather. Interestingly, values for testate amoebae begin to increase through this zone (Fig 6, BB4(c)). These are abundant and diverse within *Sphagnum* mosses, and forms assigned to *Amphitrema flavum* and *Assulina muscorum* are known from acid, hummocky, wet areas, and *Amphitrema wrightanum* may be indicative of boggy pools (Heal 2008). These data would imply increased wetness.
- 3.3.18 **Late Iron Age - Roman to early medieval periods: BB4(d) and BB4(e):** a phase of grass, and to a lesser extent, sedge, expansion is coincident with a major assault on the woodland, with decreases evident in pollen of the main tree types (oak, birch and alder; Sub-Zone BB4(d)(i-ii)). Counts for hazel-type show an initial increase in sub-zone BB4(d)(i), but then decrease through the rest of the zone. As the grasses became established, probable cereal-type pollen, including potential cultivation of rye (*Secale*-type), is indicative of renewed arable cultivation on Solway Moss, dated to the late Iron Age - early Roman period, at 1.53-1.54m (cal AD 27-132 (1916±24 BP; SUERC 76310; humic acid fraction) and cal AD 56-211 (1894±24 BP; SUERC 76311; humin acid fraction)). Values for open-ground indicators, including ribwort plantain and docks/sorrels, as well as mugworts, and pollen of the goosefoot family, suggest pastoral farming was also undertaken during this time.
- 3.3.19 The extension of grasslands and woodland clearance may have provided wood for fuel and buildings and extended grazing areas for animals, such as sheep, cattle, horses and pigs. During this time, at Beck Burn, there is further evidence of burning on or near the site, based on an increase in microcharcoal particles (BB4(d)(ii)), and records for the fungal spore associated with charred plant matter, *Gelasinospora* (HdV-1). These data testify to an intensive phase of activity on the Moss. As well as evidence for agricultural activity on drier

parts, areas of wet *Sphagnum* moss still also existed and possibly wet pools, around which sedges may have grown, and within which aquatic plants and testate amoebae may have lived (sub-zone *BB4(d)(ii)*).

- 3.3.20 Richard Tipping (1995b) found evidence on Burnfoothill Moss (Fig 3) for cereal-type pollen, along with a major grass and sedge expansion, dated to the late Iron Age and early Roman period, very similar to that at Beck Burn. Pollen profiles and radiocarbon dating from Walton Moss (Dumayne 1992) and Glasson Moss (Dumayne and Barber 1994) provide evidence for the start of clearance there during the late Iron Age. This time period also saw renewed extensive woodland clearance throughout Cumbria, including the lowland valleys and coastal fringes (Coombes *et al* 2009). This clearance may also have led to the expansion of acid moorland (*ie* spread of heather), which may have prevented widespread regeneration of the woodland (Dumayne-Peaty and Barber 1998; Wimble *et al* 2000). The evidence from numerous pollen sites throughout the region indicates that extensive and concerted woodland clearance occurred in the Iron Age (from *c* 500 cal BC onwards) and, in some places, into the early Roman period (Tipping 1997; Hodgkinson *et al* 2000; Wilmott 2009). The purpose of this clearance appears to have been to convert larger areas of the landscape into agricultural land and, across the region, pollen evidence exists for both arable and pastoral farming (Tipping 1997; Hodgkinson *et al* 2000; Forster 2010).
- 3.3.21 At Beck Burn, pollen data from Zone *BB4(e)*, of later Roman to early medieval age (dates inferred), show a drop in pollen of grass and slight regeneration of tree pollen, including hazel-type, birch and alder. Partial woodland regeneration has been interpreted after about cal AD 300 (*c* 1750 BP; Tipping 1995b) from Burnfoothill Moss, and may be linked to reduced Roman control in the area.
- 3.3.22 **Medieval period *BB4(f)*:** the most striking feature of the later elements of the pollen diagram is the expansion of heather moorland. At first, counts for *Sphagnum*-moss spores show peak values but then decline, as heather moorland spread. At Beck Burn, low-level cereal cultivation, including rye, is dated, at 0.72-0.73m, to the early medieval period, cal AD 878-989 (1122±24 BP; SUERC 76308; humic acid fraction) and cal AD 773-942 (1172±21 BP; SUERC 76309; humin acid fraction). Pollen diagrams from nearby Bolton Fell Moss (Fig 3) suggest similar, low-level agricultural activity, dating to cal AD 714-980 (1170±50 BP, Hv-3084; Barber 1981; Hodgkinson *et al* 2000). This evidence for cultivation accords well with documented accounts of agricultural exploitation of the Cumbrian lowlands during the early medieval period (*c* AD 700-1000; Wimble *et al* 2000; Coombes *et al* 2009; Quartermaine and Leech 2012), although there is a lack of consistency in pollen records within Cumbria throughout the early medieval and later periods (Forster 2010).
- 3.3.23 At Beck Burn, the record for cereal cultivation ceases from some time after the early medieval period until the later medieval/post-medieval period (upper part of Zone *BB4(f)*). This is again consistent with pollen records from Bolton Fell Moss, which imply that, during the later medieval period, there was a reduction or even abandonment of cereal cultivation (dated to between cal AD 1258-1395 (680±50 BP; Hv-3078) and cal AD 1298-1429 (560±35 BP; Hv-3081; Hodgkinson *et al* 2000).

3.3.24 **Late medieval to post-medieval period BB4(g):** renewed use of the Moss for cereal cultivation is evident from the pollen record, although the values decrease towards the top of Zone BB4(g). A reduction in heather pollen coincident with initially increased, but gradually reducing, values of grasses, ribwort plantain, docks/sorrels, mugworts, thistles, and other herb taxa, suggests the area around Beck Burn may also have been used for pastoral agriculture during this period. Of interest is the further reduction in tree cover of oak, hazel-type, birch and alder, but there is a rise in pine pollen, possibly indicative of pine plantations, dated after cal AD 1444-1634 (377 ± 34 BP; SUERC 68406). Pine woods are known to have been planted from the eighteenth century (for example, from Coniston Water; Pennington 1997). An increase in microcharcoal may signify the burning of heather on the Moss. Throughout this time period, the Moss may have been used for subsistence farming, including possible increased coppicing of the woodland for charcoal production.

4. RESULTS: LANDSCAPE EVOLUTION AND HUMAN IMPACT

4.1 INTRODUCTION

- 4.1.1 New pollen data from cores (cores 3 and 4) collected from Solway Moss permit interpretation of a series of changes in the local and regional vegetation, dating back to the early Mesolithic period (8697-8347 cal BC (9293±45 BP; SUERC 68407, humic acid fraction; core 3) and 9131-8758 cal BC (9538±34 BP; SUERC 68408, humin fraction); core 3). These data, in combination with earlier palaeoenvironmental data for the later Mesolithic to Neolithic period (Hodgkinson *et al* 2000) allow a vegetational reconstruction spanning from the very early Mesolithic to the post-medieval periods, a time interval of approximately 9000 years. The pollen record is representative of its catchment area and is generally smaller for bogs than for lakes. In raised peat bogs, the catchment area includes pollen produced by plants growing on the peat surface as well as those derived from a more distant, regional source (Jacobson and Bradshaw 1981).
- 4.1.2 The vegetational history of Solway Moss reflects, in part, the impact of people on the vegetational succession, and therefore provides a proxy record of human activity at and adjacent to the site. The data suggest a landscape modified by man from the early Mesolithic period onwards.
- 4.1.3 The effects of changing weather patterns through the Mesolithic to post-medieval periods are likely to have had an impact on local populations and consequently, on the interaction of people with the landscape. The end of the early Neolithic period, the late Bronze Age and early Iron Age, as well as the late medieval period, are all associated with relatively rapid changes towards more unstable weather conditions in Britain and Europe, with colder winters and wetter summers (Bevan *et al* 2017). Such downturns in climate could have resulted, for example, in reduced food production and fewer growing days for cereal agriculture, as well as increased risk of crop loss and food insecurity due to storms (*ibid*).

4.2 DISCUSSION

- 4.2.1 **Mesolithic period:** the pollen data (Fig 4) may be interpreted as indicative of the existence of a shallow pond with stabilised soils around it, leading to typical plant communities, with aquatics, mainly water-milfoils, and later, bog-bean and herbs like docks/sorrels and meadow-rues, and typical wetland plants such as meadowsweets. In the first few thousand years of the Holocene, conditions were generally warm and dry, causing falling groundwater conditions and terrestriation of small water bodies (Tipping 1995b). The early Holocene vegetation comprised species-rich grassland with a few herbs like meadow-rues and meadowsweets, the latter a classic indicator of the warm, early-succession herbaceous phase of the early Holocene (Bridgland *et al* 2011). These early Holocene wetland successions are an important part of the environmental history, with the aquatic, algal and marsh taxa all characteristic of the early stages of hydrosereal succession (*ibid*). The aquatic taxa, such as water-milfoil, bulrushes and bog-beans, underline the open-water

nature of wetlands in this early Holocene phase. The pollen diagram also identifies data relevant to the dryland, showing development of shrub communities including crowberry, willow and birch. The establishment of a closed birch woodland marks the first stage in the development of mixed-species full-interglacial forest (Birks 1989), that took place over the next 3-4000 years. This event, followed by the immigration of hazel-type, pine, elm, oak, alder and lime, in the first half of the Holocene, is well-documented regionally and locally (Walker 1966; Hibbert and Switsur 1976; Hodgkinson *et al* 2000).

- 4.2.2 Previous work at Solway Moss indicated that the onset of peat accumulation began shortly after 6500-6000 cal BC (*c* 7700-7200 BP), when birch fen-carr became established (Hodgkinson *et al* 2000); however, the current study shows that peat accumulation had already begun shortly after 8697-8347 cal BC (9293±45 BP; SUERC 68407, humic acid fraction) and 9131-8758 cal BC (9538±34 BP; SUERC 68408, humin fraction), with the establishment of sedge fen-carr and the reduction in algal taxa indicative of open water.
- 4.2.3 Evidence from plant macrofossils and pollen analysis (including microcharcoal) for the later Mesolithic period suggests that birch carr may have been selectively subjected to burning, reflecting possible management of the landscape, and probably contributing to the local spread of an open heather-dominated community (Fig 7; Hodgkinson *et al* 2000). Pollen data (from the same site; *ibid*) provide evidence for the continued presence of regional mixed woodland, comprising mainly oak, alder and elm at this time.
- 4.2.4 **Neolithic period:** the Elm Decline, interpreted as resulting from clearance activity, has been dated to 4040-3780 cal BC (5110±60 BP; GU-5275) at Solway Moss (Hodgkinson *et al* 2000). Cereal-type pollen from the Moss was dated to 3350-2890 cal BC (4400±80 BP; GU-5313), and another grain, from an adjacent sample, was dated to 4040-3780 cal BC (5110±60 BP; GU-5275), which, tentatively, might also be indicative of early cereal cultivation (*ibid*). The pollen data suggest the landscape may have been used for pasturing animals, as well as possible cultivation of cereals, perhaps in openings in wooded areas. Recent research, based on radiocarbon dates being used to reconstruct past population dynamics, has suggested that the first arrival of early Neolithic cereal cultivation in Britain and Ireland may have coincided with migrant farmers from the European mainland (Bevan *et al* 2017), although, for the Solway area, this should perhaps be treated with some caution, as the evidence from Stainton West, near Carlisle (Brown *et al* in prep), suggests agriculture was introduced between 3800 cal BC and 3700 cal BC, and it is far from clear that this was directly linked to a major influx of migrants. At the end of the early Neolithic period, it is likely that poor climatic conditions led to the abandonment of cereal cultivation (Bevan *et al* 2017).
- 4.2.5 **Bronze Age:** the pollen diagrams (core 4, Figs 5, 6) for Beck Burn add considerably to knowledge and an understanding of vegetational change, and the impact of people on the environment of Solway Moss during the Bronze Age. The data show that, during the early Bronze Age (*BB4(a)*), there was little disturbance of a generally wooded palaeoenvironment, but during the middle Bronze Age (*BB4(b)*; 1616-1497 cal BC (3267±24 BP; SUERC 76315; humic acid fraction) and 1616-1502 cal BC (3276±24 BP; SUERC 76316;

humic acid fraction)), there is evidence for a greater impact, including limited tree clearance, as well as slight increases in open-ground indicators (grasses, ribwort plantain) and the incidence of cereal-type pollen. This renewed clearance may correlate with the movement of arable farmers across Solway Moss towards upland areas after the early Bronze Age (Tipping 1995a). A radiocarbon-dated pollen diagram relating to human impact, from Bolton Fell Moss (Fig 3), suggests that, during the Bronze Age, the landscape remained well wooded, with temporary clearings being created for small-scale agriculture (Dumayne 1995). Pollen evidence from Glasson Moss and Walton Moss (Fig 3) also supports this interpretation (*ibid*).

- 4.2.6 During the later Bronze Age to Iron Age (dates inferred; *BB4(c)*), there is evidence from the Beck Burn pollen diagram for forest regeneration, accompanied by a slight reduction in grass pollen, and the near absence of cereal-types, suggesting less human impact at the site. Climatic deterioration during the later middle to late Bronze Age (*c* 1200-1600 cal BC) resulted in colder and wetter conditions and mean temperatures may have dropped by up to 2°C (Lamb 1981). Such shifts to colder and wetter conditions may have had a negative impact on the viability of the Moss for arable agriculture. Palaeoclimatic data, based on mire-surface wetness, from nearby Walton Moss and Bolton Fell Mosses, support a shift to wetter conditions during the late Bronze Age, *c* 1200-800 cal BC (Hughes *et al* 2000). The work of Barber *et al* (1994) and Bevan *et al* (2017) has suggested that the climatic deterioration at the end of the Bronze Age or in the early Iron Age was one of the most severe events of climatic downturn in the entire Holocene, and occurred at *c* 800 cal BC (*c* 2650 BP), leading to population stagnation.
- 4.2.7 **Late Iron Age and Roman period:** until the current study, there were no known palynological data available for Solway Moss for the later prehistoric period, although limited data have come from Burnfoothill Moss (Tipping 1995a; 1995b; Fig 3); therefore, the new data from Beck Burn (*BB4(d)*) are an important contribution to an understanding of land-use during this time. With the exception of the early medieval and post-medieval periods, the clearance of woodland at Beck Burn is most significant during the late Iron Age and early Roman periods (*BB4(d)*), pollen evidence for both arable cultivation and pastoral farming at Beck Burn being dated, at 1.53-1.54m, to cal AD 27-132 (1916±24 BP; SUERC 76310; humic acid fraction) and cal AD 56-211 (1894±24 BP; SUERC 76311; humin fraction). The later Iron Age to Roman period witnessed a dry and warm phase, which began *c* 500 cal BC (*c* 2400 BP) and lasted for several centuries, with climatic deterioration occurring around AD 650 (*c* 1480 BP; Barber *et al* 1993; 1994).
- 4.2.8 At Beck Burn (*BB4(e)*), during the Roman period, partial woodland regeneration appears to have taken place, with a reduction in grasses, and only sporadic occurrences of cereal-type pollen. However, the consistent curve for ribwort plantain and docks/sorrels, together with sporadic records for mugworts and the pollen of the goosefoot family, suggest that disturbance for pastoralism may still have been active on the Moss. Pollen data from Burnfoothill, north of Solway Moss, have shown that deforestation began before 157 cal BC - cal AD 76 (2015±45 BP; SRR-3752), and that partial woodland regeneration occurred after about cal AD 300 (*c* 1750 BP; Tipping 1995b), perhaps linked to reduced Roman control in the area.

- 4.2.9 **Early medieval and post-medieval periods:** until the current study, no palynological record is known to exist for the relatively recent past at Solway Moss. The remains of two cattle excavated from the Moss have been radiocarbon dated to the early medieval period, providing dates of cal AD 660-980 (1220±75 BP; OxA-3642); cal AD 660-1056 (1210±80 BP; OxA-3641); and cal AD 670-1056 (1185±70 BP; OxA-3640; Hodgkinson *et al* 2000). New data from Beck Burn now provide a palaeoenvironmental context for these faunal remains. Cereal cultivation, including rye, is dated on the Moss, at 0.72-0.73m, to cal AD 878-989 (1122±24 BP; SUERC 76308; humic acid fraction) and cal AD 773-942 (1172±21 BP; SUERC 76309; humin acid fraction), providing overlapping age spans to those obtained from the cattle remains. The palaeoenvironmental evidence from Beck Burn at this time suggests mixed-economy subsistence farming, including low-level cereal cultivation, of rye as well as other cereal types, with pollen evidence also for pastoral farming. Proxy climate data derived from changes in peat-bog surface wetness reveal a shift to a drier, warmer climate from around AD 900-1300, known as the 'Medieval Warm Period' (Chiverrell 2001; Chiverrell and Menuge 2003; Hughes *et al* 2000). Turner *et al* (2014) suggest the Medieval Warm Period occurred in the North of England in *c* AD 926-1190.
- 4.2.10 At some point during the medieval period on Solway Moss (prior to *c* AD 1450), arable cultivation ceased, but the regeneration of trees was almost insignificant, though heather moorland and *Sphagnum* moss spread across the site. Pollen evidence supports the continuation of pastoralism on the Moss during this time. The late medieval period was marked by a climatic deterioration, the 'Little Ice Age', with colder and wetter conditions established *c* AD 1200-1700 (Lamb 1977). An apparent reduction in agricultural activity at Beck Burn may coincide with a reduced population as a result of colder and wetter conditions, but may also reflect the impact of historical events such as the Great Famine and the Black Death (*c* AD 1270-1450; Bevan *et al* 2017).
- 4.2.11 The remains of the 'Solway Sheep' have been dated to cal AD 1440-1955 (265±95 BP; OxA-4215) and cal AD 1470-1955 (230±75 BP; OxA-4216; Hodgkinson *et al* 2000). These dates overlap in part with a date from the upper 0.25m of peat at Beck Burn, of cal AD 1444-1634 (377±34 BP; SUERC 68406), pollen evidence above this suggesting a largely deforested landscape, apart from pine plantations, with heather moorland and grassy areas increasingly used for pastoral farming and with initially significant, but then reducing, evidence for cereal cultivation.

5. CONCLUSIONS

- 5.1 Pollen analysis of the selected cores from Beck Burn on Solway Moss, when added to earlier palaeoenvironmental analysis of material from the Moss (Hodgkinson *et al* 2000), identified vegetational changes (both locally and regionally), as well as the recognition of human impacts on the environment.
- 5.2 These changes and impacts can be summarised as:
- peat accumulation had begun as early as *c* 8697-8347 cal BC, substantially older than the previous record of *c* 6500-6000 cal BC;
 - possible early water-edge activity/sedge burning dating to the early Mesolithic period;
 - woodland management (clearing of birch/burning) dating to the late Mesolithic period;
 - anthropogenic activity associated with clearance and small-scale cultivation, dating to the early Neolithic period;
 - low-level disturbance for pastoral farming, dating to the early Bronze Age;
 - more significant forest disturbance and cereal cultivation, dating to the middle Bronze Age, and possibly associated with people moving across the Moss to upland sites;
 - evidence for regeneration of woodlands and reduced human impact, the implication being that this dates to the late Bronze Age to the Iron Age;
 - significant woodland clearance for arable and pastoral agriculture, dating to the late Iron Age or early Roman period;
 - possible slight woodland regeneration, as well as evidence for sporadic arable farming, but consistent evidence for pastoral farming during the later Roman period;
 - a period of mixed subsistence economy, with evidence for both arable and pastoral agriculture during the early medieval period, possibly coincident with the ‘Medieval Warm Period’;
 - a period of limited activity on the Moss, possibly related to demographic collapse during the period of the Great Famine and Black Death in the fourteenth century, as well as coincident with the Little Ice Age;
 - renewed activity, with cereal cultivation, pastoral farming and tree clearances, dating to the late medieval to early post-medieval period;
 - development of pine plantations, possibly in place since the eighteenth century or later.
- 5.3 The palynological data from Beck Burn thus provide a wealth of data concerning human impact on the landscape spanning the early Mesolithic to post-medieval periods. Importantly, this study demonstrates the need to collect

peat cores even from areas with limited archaeological features and/or artefacts, as the palaeoenvironmental record will provide information on activity both from the moss and its vicinity, thus creating a vital link with the past.

BIBLIOGRAPHY

- Andersen, S Th, 1979 Identification of wild grasses and cereal pollen, *Danm Geol Unders*, **1978**, 69-92
- Barber, K E, 1981 *Peat stratigraphy and climatic change: a palaeoecological test of the theory of cyclic peat bog regeneration*, Rotterdam
- Barber, K E, Chambers, F M, Maddy, D, Stoneman, R, and Brew, J S, 1994 A sensitive high-resolution record of late-Holocene climatic change from a raised bog in northern England, *Holocene*, **4(2)**, 198-205
- Barber, K E, Dumayne, L, and Stoneman, R, 1993 Climate change and human impact during the late Holocene in northern Britain, in F M Chambers (ed), *Climate change and human impact on the landscape*, London, 225-36
- Bayliss, A, van der Plicht, J, Bronk Ramsey, C, McCormack, G, Healy, F, and Whittle, A, 2011 Towards generational times-scales: the quantitative interpretation of archaeological chronologies, in A W R Whittle, F M A Healy, and A Bayliss, *Gathering time: dating the Early Neolithic enclosures of southern Britain and Ireland*, Oxford, 17-59
- Bevan, A, Colledge, S, Fuller, D, Fyfe, R, Shennan, S, and Stevens, C, 2017 Holocene fluctuations in human population demonstrate repeated links to food and climate, *Proc Nat Acad Sci*, **114** (49) E10524-E10531 [Online] Available at: <https://doi.org/10.1073/pnas.1709190114> (accessed 15 February 2018)
- Birks, H J B, 1989 Holocene isochrone maps and patterns of tree spreading in the British Isles, *J Biogeog*, **16**, 503-40
- Bridgland, D, Innes, J, Long, A, and Mitchell, W, 2011 *Late Quaternary landscape evolution of the Swale-Ure Washlands, North Yorkshire*, Oxford
- Bronk Ramsey, C, 2009 Bayesian analysis of radiocarbon dates, *Radiocarbon*, **51**, 337-60
- Brown, F, Clark, P, Dickson, A, Gregory, R A, and Zant, J, in prep *From an ancient Eden to a new frontier: archaeological investigations along the Carlisle Northern Development Route*, Lancaster Imprints
- Chiverrell, R C, 2001 A proxy record of late Holocene climate change from May Moss, northeast England, *J Quat Sci*, **16(1)**, 9-29
- Chiverrell, R C, and Menuge, N, 2003 Climate change, in R A Butlin (ed), *Historical atlas of North Yorkshire*, Otley, 22-5
- Coombes, P V M, Chiverrell, R C, and Barber, K E, 2009 A high-resolution pollen and geochemical analysis of late Holocene human impact and vegetation history in southern Cumbria, England, *J Quat Sci*, **24(3)**, 224-36
- Dumayne, L, 1992 *The Late Holocene palaeoecology and human impact on the environment of northern Britain*, unpubl PhD thesis, Univ Southampton
- Dumayne, L, 1995 Human impact on vegetation in northern Cumbria since the Bronze Age: relating palynological and archaeological evidence, *Trans Cumberland Westmorland Antiq Archaeol Soc*, n ser, **95**, 23-33

- Dumayne, L, and Barber, K E, 1994 The effect of the Romans on the environment of northern Britain: pollen data from three sites close to Hadrian's Wall, *Holocene*, **4(2)**, 165-73
- Dumayne-Peaty, L, and Barber, K E, 1998 Late Holocene vegetational history, human impact and pollen representativity variations in northern Cumbria, England, *J Quat Sci*, **13**, 147-64
- Forster, E, 2010 *Palaeoecology of human impact in Northwest England during the medieval period: investigating 'cultural decline' in the Dark Ages*, unpubl PhD thesis, Univ Southampton
- Godwin, H, and Willis, E H, 1959 Cambridge University natural radiocarbon measurements II, *Amer J Sci Radiocarbon suppl*, **2**, 62
- Grimm, E C, 2011 *Tilia, TiliaGraph and TG-View*, Illinois, Illinois State Museum, [Online] Available at: <http://intra.museum.state.il.us/pub/grimm/tilia> (accessed 10 January 2018)
- Heal, O W, 2008 The distribution of testate amoebae (Rhizopoda: Testaceae) in some fens and bogs in Northern England, *Zool J Linnean Soc*, **44(298)**, 369-82
- Hibbert, F A, and Switsur, V R, 1976 Radiocarbon dating of Flandrian pollen zones in Wales and Northern England, *New Phytol*, **77**, 793-807
- Hodgkinson, D, Huckerby, E, Middleton, R, and Wells, C E, 2000 *The lowland wetlands of Cumbria*, North West Wetlands Survey, **6**, Lancaster Imprints, **8**, Lancaster
- Hughes, P D, Mauquoy, D, Barber, K E, and Langdon, P G, 2000 Mire development pathways and palaeoclimatic records from a full Holocene peat archive at Walton Moss, Cumbria, *Holocene*, **10**, 465-79
- Innes, J B, Blackford, J, and Simmons, I G, 2011 Mesolithic environments at Star Carr, the eastern Vale of Pickering and environs: local and regional contexts, *J Wetland Archaeol*, **11**, 85-108
- Jacobs UK Limited, 2015 *Written scheme of investigation: archaeological watching brief and palaeoenvironmental assessment*, unpubl doc for EDF Energy Renewables
- Jacobson, G L, and Bradshaw, R H W, 1981 The selection of sites for palaeovegetational studies 1, *Quat Res*, **16**, 80-96
- Lamb, H H, 1977 *Climate past, present, and future, 2: climatic history and the modern world*, Cambridge
- Lamb, H H, 1981 Climate from 1000BC to 1000AD, in M Jones, and G Dimbleby (eds), *The environment of man: the Iron Age to the Anglo-Saxon period*, BAR Brit ser, **87**, Oxford, 53-65
- Mook, W G, 1986 Business meeting: recommendation/resolutions adopted by the Twelfth International Radiocarbon conference, *Radiocarbon*, **26**, 799
- Oxford Archaeology North, 2016 *Beck Burn Wind Farm, Solway Moss, Cumbria, palaeoenvironmental assessment report, 2016-17/1764*, unpubl rep
- Parker, A G, Goudie, A S, Anderson, D E, Robinson, M A, and Bonsall, C, 2002 A review of the mid-Holocene Elm Decline in the British Isles, *Prog Phys Geog*, **26(1)**, 1-45

- Pennington, W, 1997 Vegetational history, in G Halliday, *A flora of Cumbria*, Lancaster, 42-50
- Quartermaine, J, and Leech, R H, 2012 *Cairns, fields and cultivation: archaeological landscapes of the Lake District uplands*, Lancaster Imprints, **19**, Lancaster
- Reimer, P J, Bard, E, Bayliss, A, Beck, J W, Blackwell, P, Bronk Ramsey, C, Buck, C E, Cheng, H, Edwards, R L, Friedrich, M, Grootes, P M, Guilderson, T P, Haflidason, H, Hajdas, I, Hatté, C, Heaton, T J, Hoffmann, D L, Hogg, A G, Hughen, K A, Kaiser, K F, Kromer, B, Manning, S W, Niu, M, Reimer, R W, Richards, D A, Scott, E M, Southon, J R, Staff, R A, Turney, C S M, and van der Plicht, J, 2013 IntCal13 and Marine13 radiocarbon age calibration curves 0-50,000 years cal BP, *Radiocarbon*, **55**, 1869-87
- SKM Enviros, 2010 *Beck Burn Wind Farm environmental statement*, unpubl rep
- Stuiver, M, and Polach, H A, 1977 Discussion: reporting on 14C data, *Radiocarbon*, **19** (3), 355-63
- Tipping, R M, 1995a Holocene evolution of a lowland Scottish landscape: Kirkpatrick Fleming. Part I, peat and pollen stratigraphic evidence for raised bog development and climate change, *Holocene*, **5**(1), 69-81
- Tipping, R M, 1995b Holocene evolution of a lowland Scottish landscape: Kirkpatrick Fleming. Part II, regional vegetation and land-use change, *Holocene*, **5**(1), 83-96
- Tipping, R M, 1997 Holocene evolution of a lowland Scottish landscape, in R Mercer, *Kirkpatrick Fleming, Dumfriesshire: an anatomy of a parish in south west Scotland*, Dumfries Galloway Natur Hist Antiq Soc Ann Hill Bequest, **6**, Dumfries, 5-12
- Turner, T, Swindles, G, and Roucoux, K, 2014 Late Holocene ecohydrological and carbon dynamics of a UK raised bog: impact of human activity and climate change, *Quat Sci Rev*, **84**, 65-85
- van Geel, B, 1978 A palaeoecological study of Holocene peat bog sections in Germany and the Netherlands based on the analysis of pollen, spores and macro- and microscopic remains of fungi, algae, cormophytes and animals, *Rev Palaeobot Palynol*, **25** 1-120
- Walker, D, 1966 The late Quaternary history of the Cumberland lowland, *Phil Trans Royal Soc, B*, **251**, 1-120
- Wilmott, T, 2009 *Hadrian's Wall: archaeological research by English Heritage 1976-2000*, Swindon
- Wimble, G, Wells, C E, and Hodgkinson, D, 2000 Human impact on mid-late Holocene vegetation in south Cumbria, UK, *Vegetation Hist Archaeobot*, **9**, 17-30

LIST OF FIGURES

- Figure 1: Site location
- Figure 2: Coring location plan
- Figure 3: Location of mosses and previous coring sites in the vicinity of Solway Moss
- Figure 4: Core 3: pollen analysis diagram
- Figure 5: Core 4: pollen analysis diagram
- Figure 6: Core 4: non-pollen and aquatic pollen percentage diagram
- Figure 7: Pollen analysis diagram adjacent to Solway Moss ‘sheep’ location, reproduced from Hodgkinson *et al* 2000

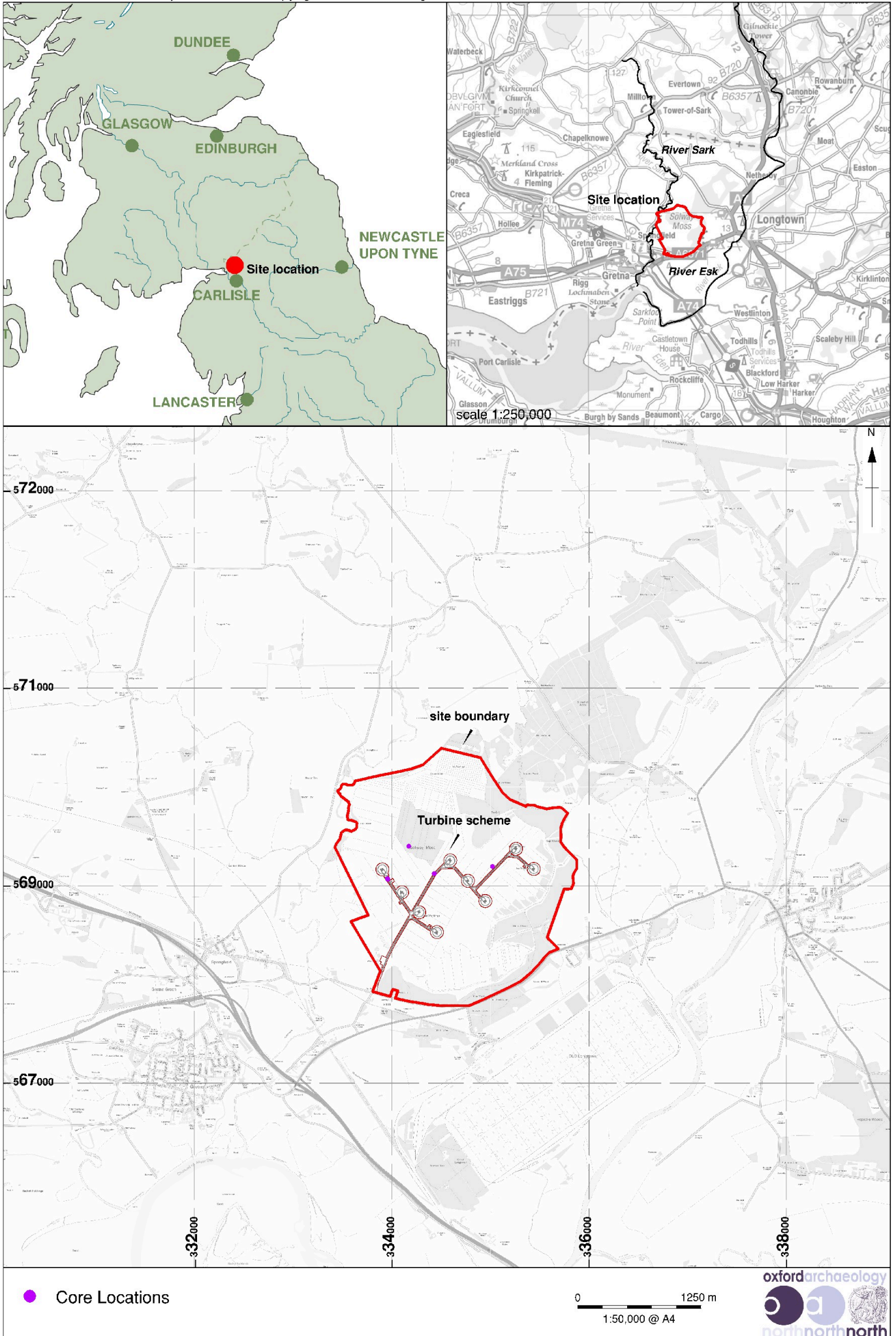
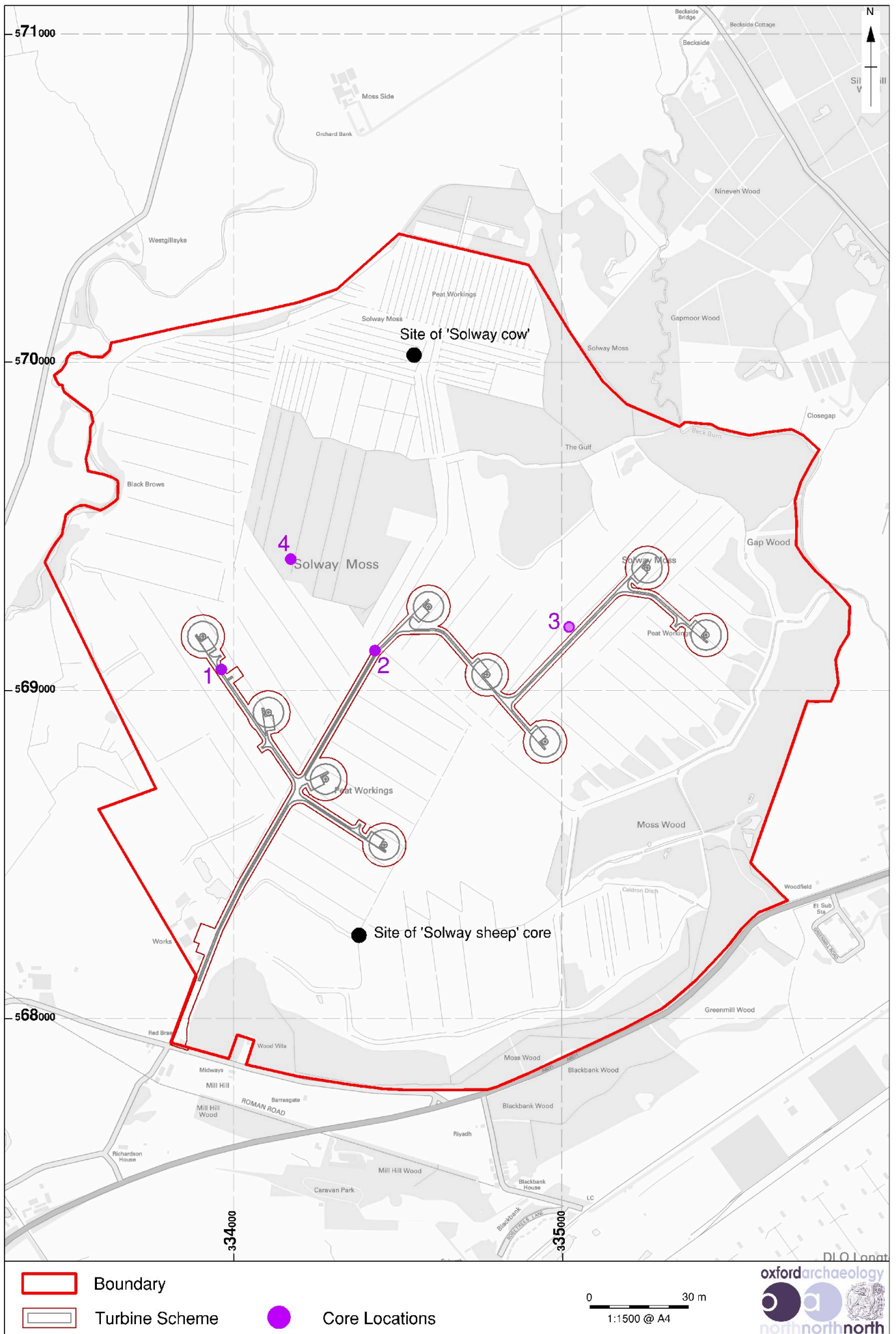


Figure 1: Site location



KTL10975PX*MAT*Mar 2018

Figure 2: Coring location plan

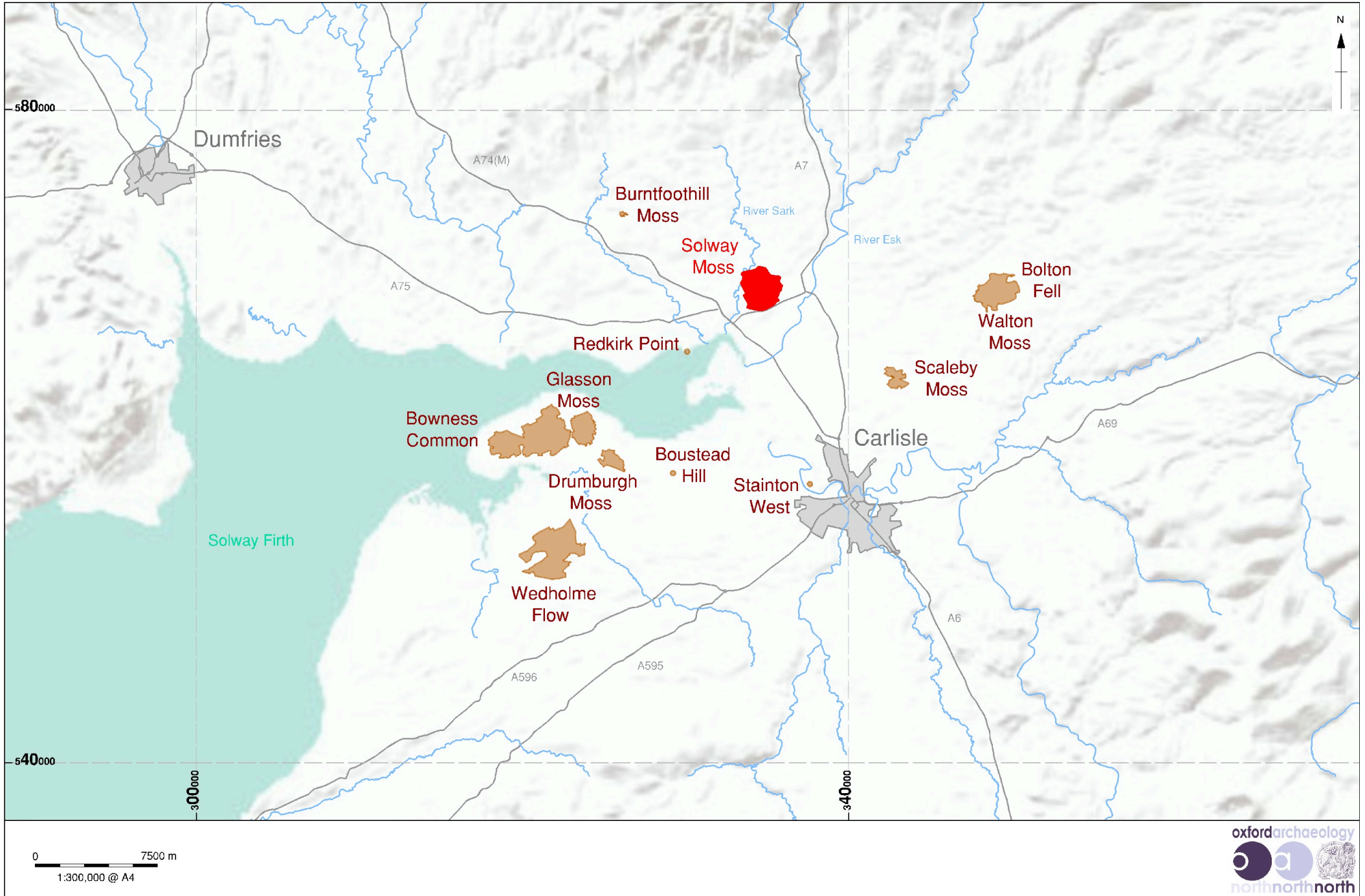
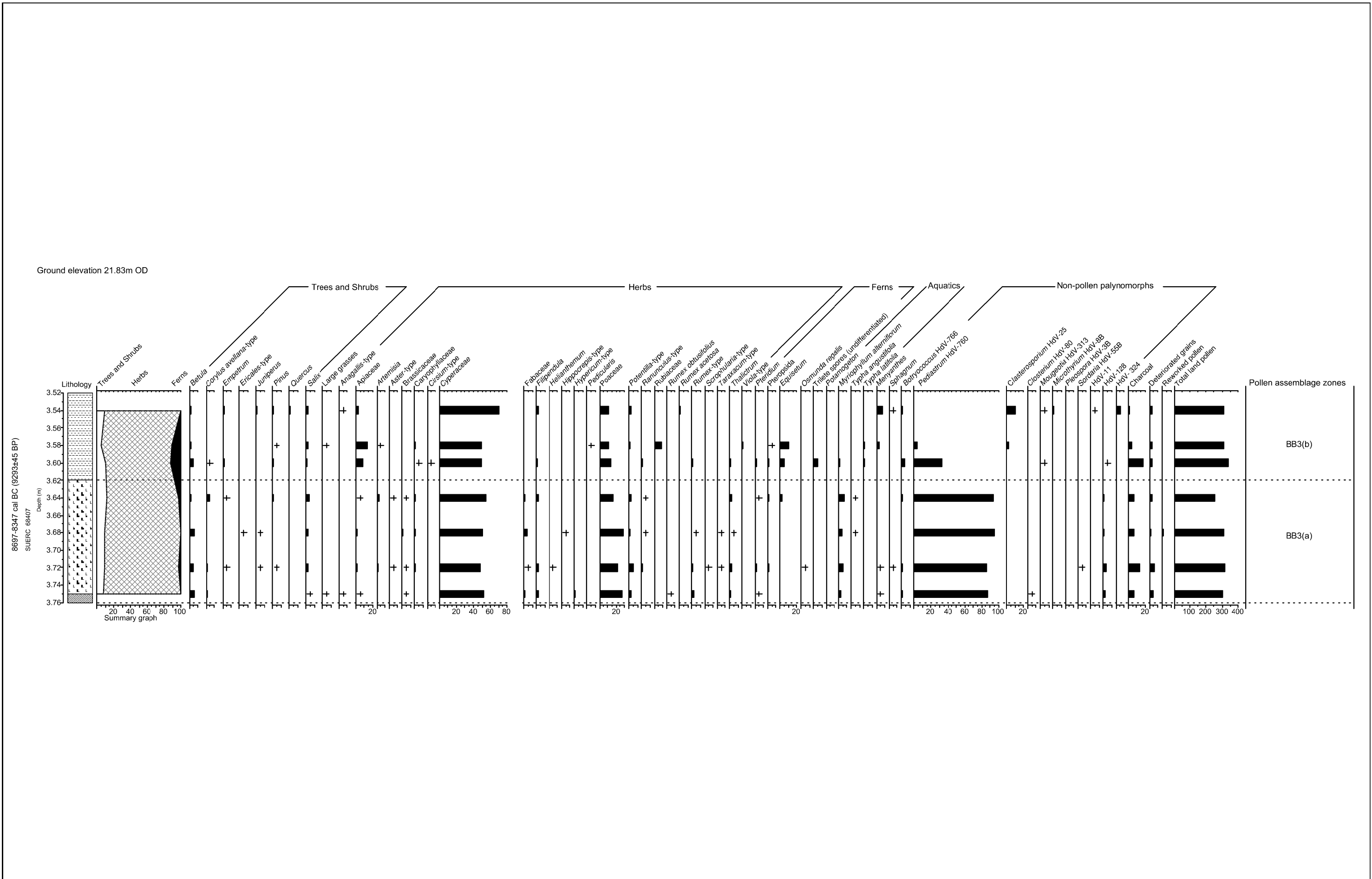


Figure 3: Location of mosses and previous coring sites in the vicinity of Solway Moss



KT-L10975PX-MAT-March 2018

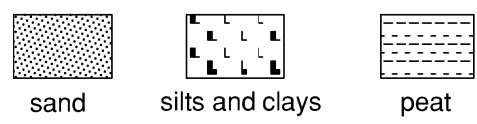
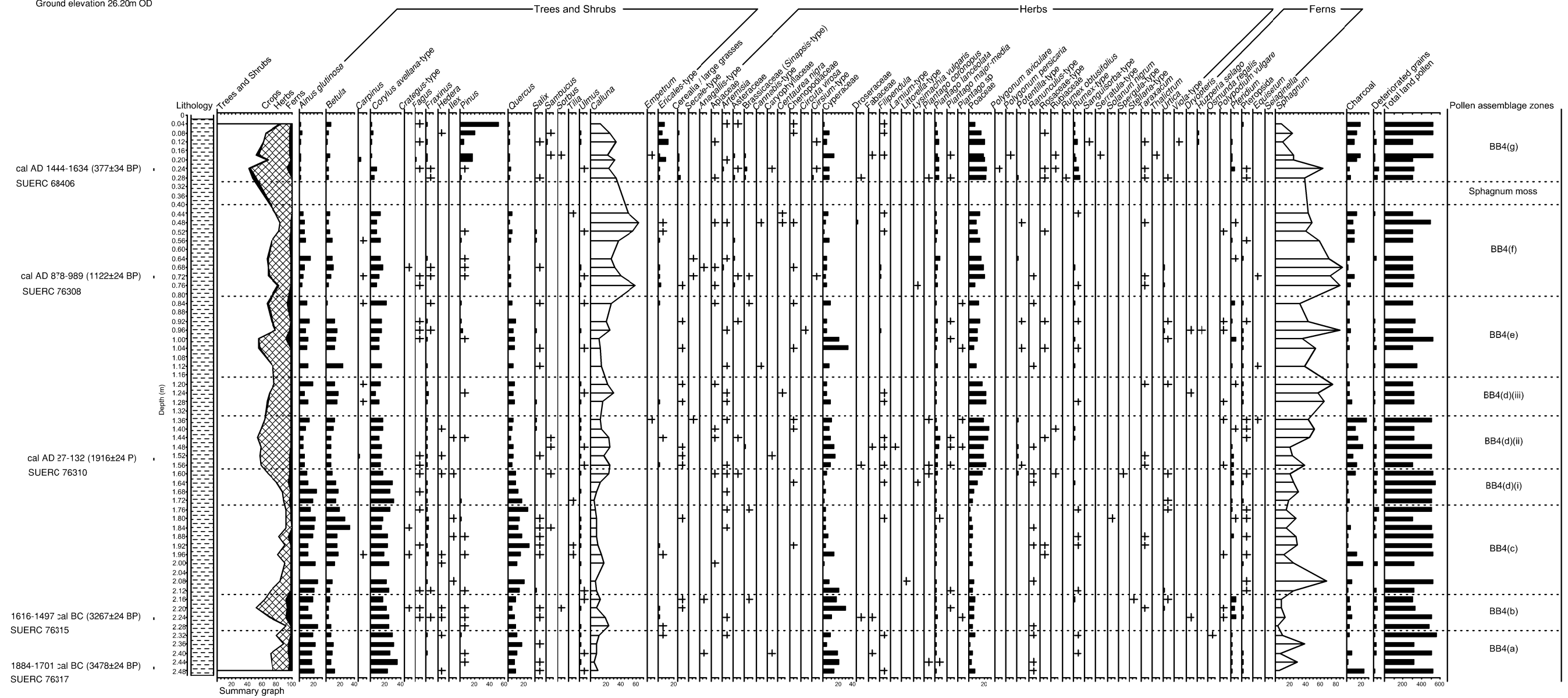


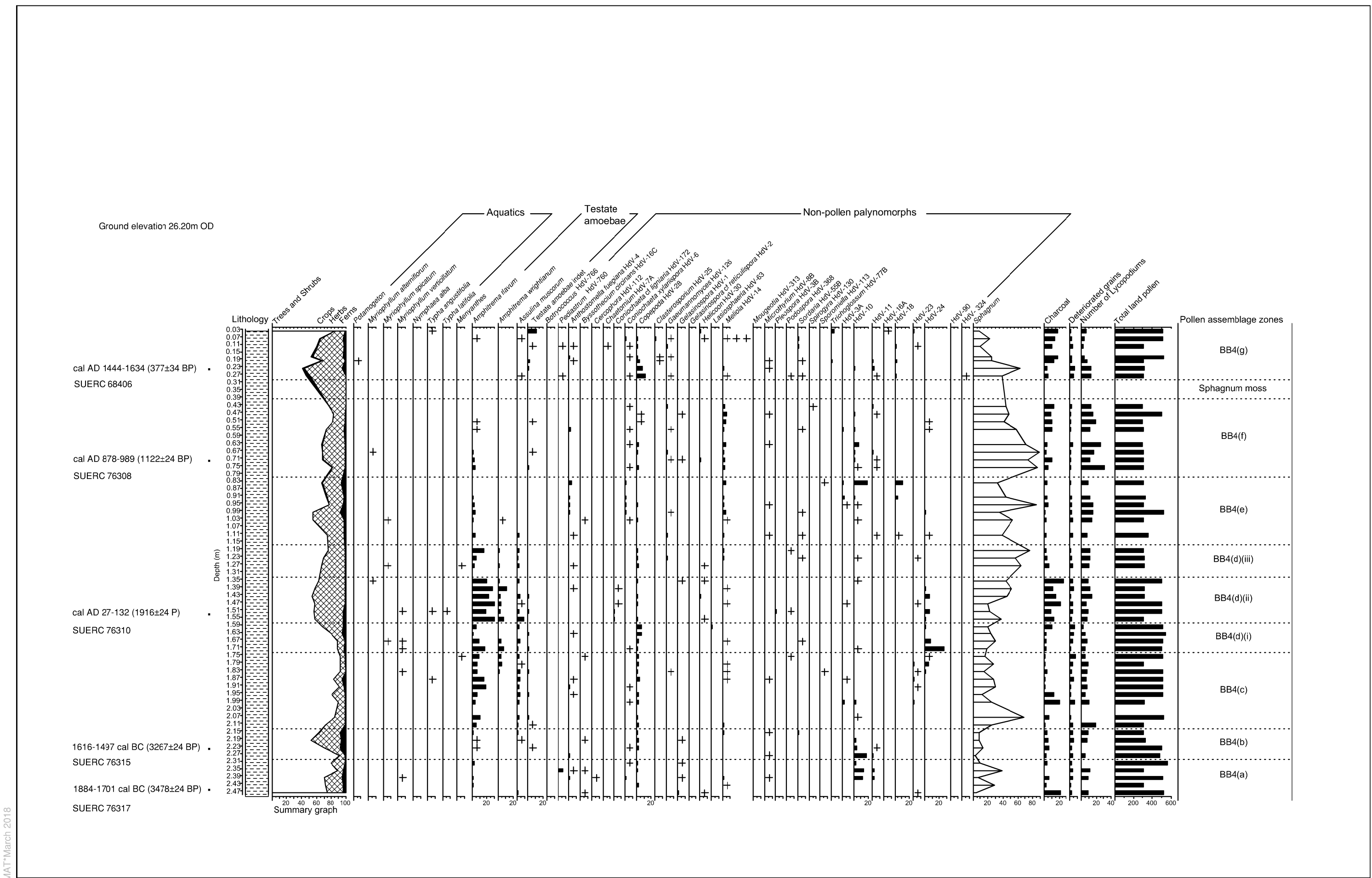
Figure 4: Core 3: pollen analysis diagram

Ground elevation 26.20m OD



peat

Figure 5: Core 4: pollen analysis diagram



KT-L10975PX-MAT-March 2018

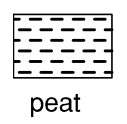
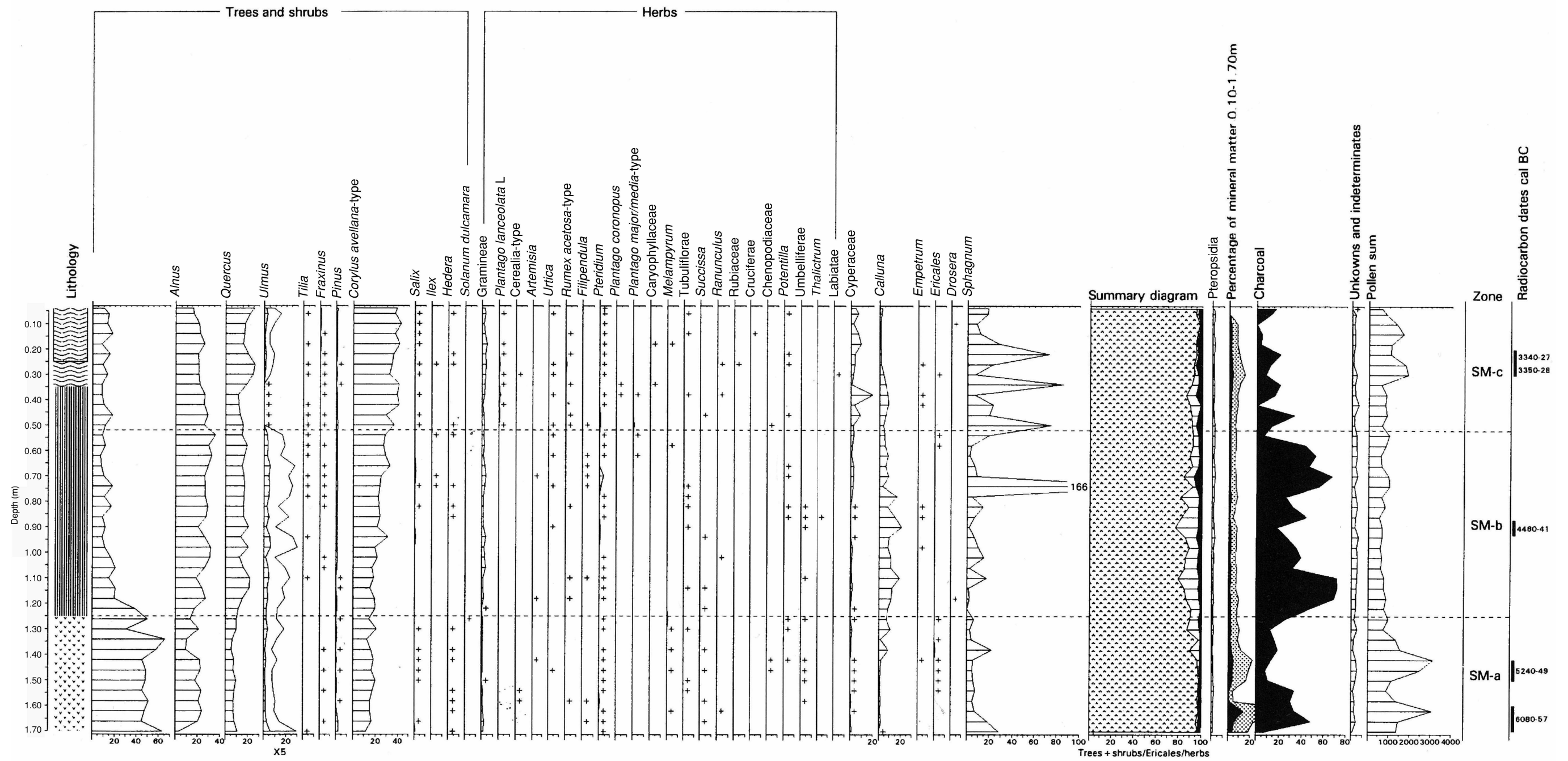


Figure 6: Core 4: Non-pollen palynomorphs and aquatic pollen percentage diagram



E.Huckerby 2000



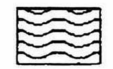
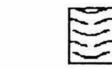
-  Wood peat
-  *Eriophorum* / *Calluna*
-  *Sphagnum cuspidata*
-  *Sphagnum acutifolia* / *imbricatum*



Figure 7: Pollen analysis diagram adjacent to Solway Moss 'sheep' location, reproduced from Hodgkinson *et al* 2000



Mill 3
Moor Lane Mills
Moor Lane
Lancaster
LA1 1QD
t: (01524 541000
f: (01524) 848606
e: oanorth@oxfordarch.co.uk
w: www.oxfordarch.co.uk

Director and Chief Executive:
Gill Hey BA PhD MifA FSA

Private Limited Company Number: 1618597

Registered Charity Number: 285627

Registered Office: Oxford Archaeology Ltd.
Janus House, Osney Mead, Oxford, OX2 0ES