Must Farm, Whittlesey, Cambridgeshire Dendrochronological and radiocarbon dating

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SUMMARY
The Must Farm pile-dwelling site is an extraordinarily well-preserved Late Bronze Age settlement in Cambridgeshire built over a freshwater palaeochannel that was destroyed by a catastrophic fire shortly after its construction. Predating the settlement was a double-alignment of massive oak piles. This technical archive report on the tree-ring and radiocarbon analysis of samples from the site provides full details of the dendrochronological and radiocarbon dating programmes. The significance of the results is discussed more fully in Tyers *et al* (2024) and Knight *et al* (2024).

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INTRODUCTION

The Must Farm pile-dwelling site is an extraordinarily well-preserved Late Bronze Age settlement in Cambridgeshire (Fig 1) built over a freshwater palaeochannel that was destroyed by a catastrophic fire shortly after its construction. Predating the settlement was a double-alignment of massive oak piles.

The Must Farm excavations revealed 935 structural timbers from the Causeway, the Pile-dwelling Structures and their Palisade. The Causeway material was a conventional assemblage of dendrochronologically datable large oaks and other non-datable material. The Pile-dwelling structural assemblage comprised no long-lived material, instead it comprised mostly 20–60-year-old ash trees, and 20–40-year-old oaks, used in the round, or as split halves. Almost all of this material was intact from pith to bark-edge. Relative dating has been successful within this material, providing evidence for a site-wide single year construction phase, but without identifying a calendar date for this. The longest lived of these timbers has provided the sub-samples for a radiocarbon wiggle matching programme aimed at providing a construction date for the Pile-dwelling.

This document is a technical archive report on the tree-ring and radiocarbon analysis of samples from Must Farm. An accompanying chapter (Tyers *et al* 2024) provides a context for the challenges of working with the Must Farm dendrochronological material, illustrated with other British tree-ring results for late Bronze Age and early Iron Age data sets. It also incorporates the results from this report in a wider discussion of the chronology of the Must Farm Pile-dwelling settlement, Causeway and palaeochannel. Full details on the Must Farm excavations and post-excavation analysis can be found in Knight *et al* (2024).

DENDROCHRONOLOGY

Sampling

There are *c*. 5500 wood records from the Must Farm site. The bulk of this material comprised wood chips, debris and small roundwood of no dendrochronological potential, but 935 were larger timbers from the Pile-dwelling Structures and Palisade, and the Causeway. Tree-ring dating samples were collected from select groups of structural timbers from the Structures and Palisade during the early stages of the excavations, several further groups were collected as the excavations proceeded, and in the final days the tops of all the uprights were cut down to enable the site to be covered. All this material was visually assessed on site for dendrochronological potential. Around 250 samples were taken from the MUS15 site in total. These were prepared for analysis and re-assessed for potential, 132 of these were subjected to full dendrochronological analysis. Combined with 14 from MUS06 (and a further 5 MUS06 samples duplicated by further samples of the same timber during MUS15), 1 analysed timber from MUS10, 2 from MUS11, and 1 from nearby site MAP08, these provide an assemblage of 150 tree-ring series (Table 1; Appendix 1) that probably include all the suitable material from the Must Farm excavations.

Mike Bamforth and Iona Robinson Zeki reviewed all the timbers on site during excavation and lifting. They became aware early on that there were visually distinctive characteristics in the ash upright cross-sections that enabled them to be confident when material was part of the dominant group of timbers. Assessment of potential on site was undertaken by visually assessing fresh breaks or sections for wood type, and ring counts. Material considered to have some potential was sampled or set aside for sampling. Off-site, cross-sections from these were frozen and a clean-cut surface made through them revealing the rings sequences in sufficient detail for analysis. These sections were then reviewed again for ring counts, with those with more than 30 rings prioritised for analysis. Amongst this material priority was also given to timbers with intact bark-edge and displaying undistorted anatomies.

The initial analytical results identified the presence of a group of oak and ash with a single identical felling date spread across the Pile-dwelling. This early study also identified that this material would probably not prove datable by dendrochronological methods. The assessment methodology was subsequently split into two separate strands; first it was modified to seek out all the longest-lived material from the Palisade and Pile-dwelling structures. This was in order to identify the best possible samples for the radiocarbon wiggle-matching. Second, we sought out all the material that was clearly not part of this dominant group in the hope that these would either provide longer ring series to which the Pile-dwelling sequences could be matched, or that they would themselves be datable.

Analysis

Standard dendrochronological methods, following English Heritage guidelines (English Heritage 1998), were applied to the Causeway assemblage, and to the material identified from the pile dwelling structures The Causeway timbers were primarily oaks, derived from divided parts of larger trees, and often missing sapwood and bark. A range of these provide absolute dating evidence for the Causeway. A small number of oaks from the Pile-dwelling also provided some dating evidence.

The much larger Palisade and Pile-dwelling structural assemblage was intrinsically less suitable for dendrochronological analysis. Dendrochronological analysis could only be undertaken here because the assemblage comprised timbers primarily intact to bark surfaces. The Palisade and Pile-dwelling dendrochronological process was reversed from the usual 'what is the date of this timber?' and instead was 'can these bark-edges be proven to be co-eval or not?'. This approach exploited this unique resource to provide scientifically robust information of interpretative archaeological value to the excavation.

RESULTS

Causeway

Dendrochronology

The causeway (Fig 2) comprised an assemblage of large oaks posts composed primarily of two distinct styles of pile: converted oak piles and massive 'in the round' oak piles with carved lugs (Fig 3). Forty-two samples were selected for analysis from this assemblage (Table 2; Fig 4). The selected samples comprised 41 oaks (*Quercus* spp.) and one ash (*Fraxinus* sp.) timber. These were found to contain between 35 and 174 annual rings. The selected assemblage was relatively short lived for dendrochronological analysis with a median of 56 rings. The unselected timbers had even fewer rings. The selected material included timbers with a wide range of cross-section sizes, from WD7122 which was 105 x 55mm up to WD2933 which was 330 x 285mm. The tree-ring width sequences from ten of these oak timbers were dated by reference to each other and to a small number of contemporaneous reference data sets, principally the Flag Fen/Fengate master sequence that spans 1363–937 BC (Neve 1999; Tables 3–4). The causeway dated timbers produced a composite sequence spanning 1373–1285 BC (Fig 5). Amongst these WD2853 retained bark and was felled in spring 1284 BC. WD6423 had the onset of sapwood at 1307 BC and its interpretation, felled between 1297–61 BC, is broadly compatible either with the felling date of WD2853, or with WD39, which also had sapwood and was potentially felled at the same time or slightly later, 1283–47 BC. The other seven datable sequences retained only oak heartwood, the latest of these, WD5825, ended at 1286 BC and thus likely dates from after 1276 BC.

Radiocarbon dating and wiggle matching

Following the failure of ring-width dendrochronology to provide absolute dating for any of the 'in-the-round' piles from the Causeway, two undated short-lived oak timbers from this group were sampled for radiocarbon dating and wiggle-matching (see Appendix 2); WD2944 (53 heartwood rings) and WD3249 (41 rings (?H/S)). In addition, samples were also submitted from the 7.8 m+ long horizontal 'bridge' WD6430 (53 heartwood rings) that could also not be dated by dendrochronology.

Twenty-one radiocarbon measurements have been obtained from single annual tree-rings from timbers WD2944, WD3249, and WD6430 (Tables 5–7), including from six rings where replicate samples were dated at two different laboratories (Centre for Isotope Research, University of Groningen (GrM-), the Netherlands and the Laboratory of Ion Beam Physics, ETH Zürich (ETH-), Switzerland; Appendix 2).

Figure 6 illustrates the chronological model for the WD2944 sequence (the CQL2 code is given in Appendix 3). This model incorporates the gaps between each dated annual ring known from tree-ring counting (eg that the carbon in ring 1 of the measured tree-ring series (WD2944_ring_1) was laid down 13 years before the carbon in ring 14 of the series (ETH-106010), with the radiocarbon measurements

(Table 5) calibrated using the internationally agreed radiocarbon calibration data for the northern hemisphere, IntCal20 (Reimer *et al* 2020).

The model has good overall agreement (Acomb: 108.2, An: 31.6, n:5), with all five dates on single rings having good individual agreement (A > 60) with their positions in the sequence. It suggests that the final ring of the WD2944 sequence formed in *1470–1420 cal BC* (*95% probability*; *ETH-106012*; Fig 6), probably in *1465–1445 cal BC* (*68% probability*).

Figure 7 illustrates the chronological model for the WD3249 sequence (the CQL2 code is given in Appendix 3). This model incorporates the gaps between each dated annual ring known from tree-ring counting (eg that the carbon in ring 1 of the measured tree-ring series (GrM-22282) was laid down ten years before the carbon in ring 11 of the series (ETH-106006)), with the radiocarbon measurements (Table 6) calibrated using the internationally agreed radiocarbon calibration data for the northern hemisphere, IntCal20 (Reimer *et al* 2020).

The model has good overall agreement (Acomb: 160.6, An: 31.6, n:5), with all five dates on single rings having good individual agreement (A > 60) with their positions in the sequence. It suggests that the final ring of the WD3249 sequence formed in *1425–1395 cal BC* (*95% probability*; *WD3249_ring_41*; Fig 7), probably in *1420–1400 cal BC* (*68% probability*).

Figure 8 illustrates the chronological model for the WD6430 sequence (the CQL2 code is given in Appendix 3). This model incorporates the gaps between each dated annual ring known from tree-ring counting (eg that the carbon in ring 40 of the measured tree-ring series (GrM-22280) was laid down 13 years before the carbon in ring 53 of the series (ETH-106005), with the radiocarbon measurements (Table 7) calibrated using the internationally agreed radiocarbon calibration data for the northern hemisphere, IntCal20 (Reimer *et al* 2020).

The model, that excludes the clearly anomalously earlier date on ring 1 (ETH-106002) has good overall agreement (Acomb: 56.2, An: 35.4, n:4), with all but one (GrM-22280; A=31) of the four dates on single rings having good individual agreement (A > 60) with their positions in the sequence. It suggests that the final ring of the WD6430 sequence formed in *1425–1400 cal BC* (*95% probability*; *ETH-106005*; Fig 8), probably in *1420–1400 cal BC* (*68% probability*).

Interpretation of Causeway timbers wiggle matching

As the ?heartwood/sapwood boundary was apparent on timber WD3249 a felling date range of *1410–1360 cal BC* (95% probability; *WD3249_felling*; Fig. 9) could be estimated by the addition of a sapwood estimate (Arnold *et al* 2019). The other two timbers only retained the oak heartwood and thus the estimates for the date of their final rings; WD2944: *1470–1420 cal BC* (*95% probability*; *ETH-106012*; Fig 6) and WD6430: *1425–1395 cal BC* (*95% probability*; *ETH-106005*; Fig 8) only provide *terminus post quos* (or dates after) for their felling.

There is clear evidence therefore that the Causeway is a multi-phase group of timbers. The radiocarbon wiggle-matching suggests that some of the material ('in-the-round' piles and the long horizontal timber) in the Causeway dates from the late fifteenth or early fourteenth century cal BC (Fig 9), whilst the dendrochronology indicates that the Causeway was probably subject to several repair events (using converted piles) during the early half of the thirteenth century BC (Fig 8).

Pile-dwelling settlement

Dendrochronology

Sampling

The pile-dwelling (Fig 10) structural assemblage comprised no long-lived material at all, instead it comprised mostly 20–60-year-old ash trees (*Fraxinus* sp.) and 20–40 year old oaks (*Quercus* spp.), both used mostly either in the round, or as split halves. All 746 timbers from the pile-dwelling were reviewed for their potential usefulness for dendrochronological analysis by Iona Robinson Zeki and Michael Bamforth. The best material was sampled. These samples were then collected, prepared for analysis and re-assessed for potential.

Analysis

In total 86 of these timbers were then subjected to standard dendrochronological analysis, with the palisade contributing 45 ash and one oak (Table 8; Figs 11–12), and Structures 1–5 contributing 30 oaks and six ash (Tables 9–13; Figs 13–15). The latter group can be subdivided into 17 samples from Structure 1 (Table 9), four each from Structures 2 (Table 10) and 3 (Table 11), five from Structure 4 (Table 12), and six from Structure 5 (Table 13). The final component of this assemblage were a group of four oak samples from the pile-dwelling not attributed to specific structures (Table 14). This was an exceptionally uniform group of samples (with the reconstructed median diameters for different structural elements typically falling within 100–150mm). The analysis generally utilised single radii, recorded from single slices per timber, but included some sequences analysed from more than one slice of the same timber, and some sequences recorded along more than one radius of the same slice. The process of reviewing all the timbers on site, and sampling even the borderline material was intended to identify, and then analyse, all the most suitable material that was present within the Must Farm pile-dwelling excavation.

Almost all of the sampled material was intact from pith to bark-edge, some timbers had been crushed, some were charred, but most were intact. Almost all retained clear evidence for their final year of growth and their bark-edge. These timbers could therefore potentially identify the year, or years, that they were cut down.

Using a combination of standard cross-matching algorithms and visual comparisons it was possible to dendrochronologically cross-match 27 oak timbers to form a 43-year oak site chronology (Table 15) and to separately cross-match 46 ash timbers to form a 61-year ash site chronology (Table 16). These two series cross-match with each other, *t*-value 6.16 (Fig 16). This dendrochronological analysis indicates all 73 of these timbers were felled in the precisely same year, referred to as Year Zero, or YZ for the rest of this report (Figs 17–18). The remaining analysed samples from the pile-dwelling contain sequences cannot be matched. Most of these are visually similar material, but some were incomplete to bark-edge and several were crushed or otherwise distorted. There is no reason to suggest that these represent separate felling events, though undated oak WD5309, attributed to Structure 2, contained 139 rings and is clearly completely different.

Identifying that the final ring present in most of these timbers is precisely co-eval has allowed the relative dating analysis of this large assemblage of timber to provide strong evidence for a single site-wide year of construction. The palisade and Structures 1–5, as well as the group of other pile-dwelling structural material, contained oak felled in this year, whilst the palisade and Structures 1, 3 and 4 also contained ash felled in this year.

Unfortunately, due to the lack of contemporaneous local tree-ring chronologies for this period, dendrochronological methods cannot presently identify the absolute dates for these two site chronologies. We may never identify the actual date of this year since these very short tree-ring sequences will undoubtedly require very local datasets to be successfully cross-matched.

All of the oak and ash timbers from the pile-dwelling were assessed on site to identify the most suitable material for analysis. It was noted that there was a set of typical characteristics regarding the ring directly under the bark-edge, and what appeared to be a visibly common pattern for the last few rings. It was important to test as far as we could whether the shorter-lived oaks and ashes, not selected for analysis, were contemporary with those that had been analysed in a more conventional sense. The correlation algorithm we use does not search using sub-30 year material, but we can visually compare these sequences, and statistically check the correlations at these locations. A group of ten sub-30 ring samples were selected to be recorded in order to test this possibility (Table 17). These samples comprised two ash from the palisade, both with 19 rings, four oaks from Structure 1 with 27 and 28 rings, two ash from Structure 2 with 24 rings and 28 rings, a 28 ring oak from Structure 5, and a 28 ring oak from the other pile-dwelling structural material. It was concluded that both the palisade ashes, three of the Structure 1 oaks, one of the Structure 2 ashes, and the other structural oak appeared to be co-eval with the rest of the material (Figs 19–20; Tables 18–19). The remainder do not appear to be related to the others or anything else, again it is reasonable to assume they are simply further examples of undatable series contemporary with the rest. This is particularly the case given the limited usefulness of such short-lived sequences.

Interpretation

Figure 16 shows that the oak and ash terminal ring for relative year 0 is not significantly larger or smaller than the preceding five years. This suggests that this material was felled either close to the end of the growing season of year 0 or somewhere over the winter of years 0/1 but before the onset of spring growth in year 1 – this period covers approximately September–March inclusive. There were no obvious exceptions to this pattern amongst the entire assemblage of cross-matched material, nor as far as we are aware, was there any amongst the other settlement material assessed but not analysed from the site. The 41 matching palisade ash timbers can all be characterised as containing a complete terminal ring for year 0, the single matched palisade oak was too slow-grown to be certain whether its last ring was complete or not. Timbers from Structures 1–5 have the additional complexity of some charred surfaces. Sixteen of the 17 matched Structure 1 timbers were identified as having a final ring at the same year 0 as the palisade timbers. Six of the 17 timbers had a charred edge, of which three were definite bark-edge and three have a charred edge that may or may not be bark edge, with one of these latter three having a last complete measured ring ending a year earlier. The remaining 11 timbers from Structure 1 were not charred, or at least were not charred where we sampled them. These all end at the same year, with ten of them recorded as having bark-edge and one with a probable bark edge. Structures 2–5 similarly include a further 12 samples with a final ring for year 0, three of which were also charred, one of these three having bark-edge for the same year but of indeterminate completeness. The two non-structural oaks also have the same complete ring for year 0, one of which was also charred.

There is no doubt from the dendrochronological analysis, therefore, that the excavated part of the settlement used a large group of oak and ash timbers felled in a single campaign, a felling campaign that either lasted just a few weeks somewhere between autumn and spring or perhaps lasted throughout the autumn, winter and nearly through to the following spring. There are no parallels that we are aware of for such a large assemblage of contemporaneously felled timbers from any other excavation. Fiskerton (Field and Parker Pearson 2003) was a similarly well preserved and large assemblage which had a similar number of intact timbers with bark edges, these however comprised a series of discrete repairs to a structure spread across more than a century. A similar group of undated short-lived oaks was recovered from the excavation of a platform and causeway at Shinewater near Eastbourne (Hillam 2003), however their relative tree-ring dating identified a widespread construction event followed by a repair phase a decade later. Chronological modelling of the available radiocarbon dates from Shinewater (Appendix 4) provides an estimate for the construction of the platform of *810–745 cal BC* (*95% probability*) probably *800–770 cal BC* (*68% probability*), around half a century later than the Must Farm pile-dwelling.

Resolving the chronology of the pile-dwelling timbers?

The longest lived of the pile-dwelling timbers, that could be fully resolved, was an ash from the palisade with 61 rings, WD2759. This slice was sub-sampled into five-year blocks and these were used for the radiocarbon wiggle matching programme *(see below)*. When combined with the other radiocarbon dates from the pile-dwelling this has provided an estimate for its construction date of *865–840 cal BC* (*95% probability*). This dating indicates that the pile-dwelling tree-ring series most probably lie somewhere along the tree-ring sequence in the region between *c*. 915 BC at their older end and *c*. 845 BC at their younger end. The causeway discussion (above) illustrated that the chronological and geographical disposition of contemporaneous reference datasets is the key determinant for the likelihood of dating these sequences. Six oak timbers from Must Farm (Table 20; see below), contain a composite sequence that runs from 1065–907 BC. The nearby Flag Fen/Fengate sequence which used to end at 937 BC, now has two further oak timbers that cross-matched to Must Farm and other data such that it now runs through to 918 BC. Clearly neither Flag Fen/Fengate nor the Must Farm datasets can be expected to provide any significant overlap to either of the pile-dwelling oak and ash sequences. Virtually full overlaps to dated sequences will be required to date these series and the best either might achieve are overlaps of a decade or two to the ash sequence.

At greater distances from Must Farm, there are several more oak sequences that cover the same sort of period: Cambridge, St Clements Garden (1257–948 BC, *c*. 45km away (Tyers 2016)), Caldicot, southern Wales (1131–998 BC, *c*. 205km away (Hillam 1997)), Greylake, Somerset Levels (1108–952 BC, *c*. 245km away (Hillam pers. comm.)) and Skinners Wood, Somerset Levels (1162–983 BC, *c*. 240km away (Hillam 1993)). Each of these ends within the period 998–948 BC, just before the end of the Must Farm and Flag Fen/Fengate assemblages, and, just as with those sequences, they clearly cannot be expected to overlap with the pile-dwelling sequences. There are just three tree-ring series from the British Isles that give complete or almost complete overlaps across the target period. One of these is the Newington Quarry material (Tyers 2003; Tyers 2017), from *c*. 110km away, running to 835 BC, and a further English group is Swan Carr from County Durham, 1155–381 BC, *c*. 245km away (Baillie and Brown pers. comm.). Swan Carr has approximately ten timbers and Newington has approximately five that cover some of our period of interest. Both these sites are almost certainly too distant to be any help with the pile-dwelling. The third site is Ballymacombs More, Northern Ireland, running from 947–633 BC, which as well as being even further away (*c*. 490km), only includes one timber that covers the period of interest to us (Baillie and Brown pers. comm.). At the time of writing that is the entire British Isles data set for the first quarter of the first millennium BC, the weakest point in the 7000-year continuous tree-ring sequence. The Must Farm data has been run past all of this material, singly and in various combinations, and no statistically significant and replicated results have been noted. Various continental European datasets have also been examined with no evidence for the dating of these series.

Can this be resolved reliably? Perhaps not, these series are exceptionally short by normal British tree-ring standards, and it is not clear how nearby we would need to be to find matching data sets for these sequences. We could use short-lived modern oaks to model how close we might need contemporaneous data in order to get sufficiently high correlations to identify the date of the pile-dwelling sequences. That modelling process is not straightforward since the trees may have different sensitivities at different eras and may need to be growing with a similar stand density and soil substrate. The answer is probably not very far at all. There was undoubtedly more timber that was growing at the time that was utilised somewhere, but both its subsequent preservation and subsequent excavation are needed in order to find it. We have exhausted the potential of the Must Farm pile-dwelling site, and the potential of nearby excavations, but timbers excavated in the future that lie within the Late Bronze Age–Early Iron Age period and come from an area up to *c*. 50km from Must Farm could provide our answer. Datable tree-ring sequences of this period are evidently a very small resource. It has taken dendrochronologists 50 years to find just 15 contemporaneous and datable oak sequences, but these are from trees that grew on sites 100–500km away. It is clear that any potentially similar material from nearby sites should be prioritised for analysis.

As part of the process of searching through the timbers from Must Farm for datable sequences, a small group of timbers were identified where it seemed possible, they might have useful dating potential, even though each was of limited direct interpretative value to the excavation project. Simultaneously, a number of timbers from nearby earlier excavations were assessed and, where appropriate, these were analysed. Twelve oak samples containing between 36 and 126 rings were analysed (Table 20). Five of these timbers, derived from Must Farm, were dated by reference to Flag Fen/Fengate and other datasets (four from the pile-dwelling excavation (MUS15) and one from the Must Farm palaeochannel excavation (MUS11; Robinson *et al* 2015)) (Fig 21; Tables 21–22). These series have heartwood end dates of 969 BC, 933 BC, 933 BC, 928 BC and 907 BC. The latest of those may have been intact to heartwood-sapwood edge. WD1769 and WD2711 were derived from palaeochannel deposits outside the perimeter of the pile-dwelling. Their presence is difficult to interpret with any certainty, they perhaps suggest there was activity in the vicinity within the 900–850 BC period. WD7316, WD7324 and WD7325 were derived from the pile-dwelling settlement. None of these were charred and their precise relationship with the construction, occupation and conflagration of the pile-dwelling is unclear. Their recovery suggests we have successfully exploited the excavated assemblage for all its datable timbers. Together, these five timbers provided a composite tree-ring sequence spanning 1065–907 BC. This cross-matched to two hitherto undated timbers from Fengate and extended that sequence from 937–918 BC (Tables 23–24). A further oak heartwood timber from a pile-alignment at Horsey Hill (MAP08) (Gibson and Knight 2009) was found to date to 1004–924 BC (Fig 21).

Radiocarbon

Wiggle-matching the ash master sequence

Following the failure of the ring-width dendrochronology to provide conclusive calendar dating for the Pile-dwelling settlement a series of samples were submitted for radiocarbon wiggle-matching to the Oxford Radiocarbon Accelerator Unit (ORAU) and Scottish Universities Environmental Research Centre (SUERC) (Appendix 2). The samples derive from two timbers that form part of the undated 61-year ash site chronology and comprised 12 contiguous blocks of five tree-rings from WD2759 (Table 25) and from the final ring (year 0) from WD2882 (Table 26).

Figure 22 illustrates the chronological model for the undated ash site sequence (the CQL2 code is given in Appendix 3). This model incorporates the gaps between the dated samples known from tree-ring counting (eg that the carbon in ring 52 (the middle of the 54–50 block of rings) of the measured tree-ring series (OxA-36040)) was laid down five years before the carbon in ring 47 (the middle of the 49–45 block of rings of the series (SUERC-74906), with the radiocarbon measurements calibrated using the internationally agreed radiocarbon calibration data for the northern hemisphere, IntCal20 (Reimer *et al*. 2020).

The model, has good overall agreement (Acomb: 66.5, An: 19.6, n: 13), with all but two (rings 24–20; A=50 and OxA-36041; A=51)) of the 13 dates having good individual agreement (A > 60) with their positions in the sequence. It suggests that the final ring of the ash site chronology formed in *865–840 cal BC* (*95% probability*; *ash_ring_0*; Fig 22), probably in *860–845 cal BC* (*68% probability*).

Radiocarbon dates from the 2005–6 evaluation

Seven radiocarbon determinations were obtained following the 2005–6 evaluation from Beta Analytic (Table 27; Appendix 2). At the beginning of 2005, samples from two submerged posts were dated (Beta-201982–3). They both came from 'grab' samples retrieved from submerged timbers at the edge of the quarry pit and represented 'blind' tests of what was then an ambiguous feature. These samples have very limited contextual detail due to the circumstances of their retrieval (i.e. the samples were collected by scrabbling about underwater). In addition, the samples came from uprights that had intermittently been exposed to air with only their core or heartwood surviving; thus, they only provide *termini post quos* for the timbers felling.

Following the subsequent opening of two small machine-excavated trenches later in 2005 and the exposure of a short row of small-diameter timber posts in Trench 82 additional material for radiocarbon dating was taken from these newly revealed uprights. The samples came from identifiable structures: Palisade (Beta-202663) and internal uprights (Beta-202662 and Beta-202664) The dated material comprised sections of sapwood taken from small-medium diameter oak or ash uprights that were not more than 30 years old.

Finally, in 2006 an intensive site-specific evaluation revealed the discrete cultural horizon related to the Pile-dwelling settlement built over a partially choked water course. The bulk of the material encountered was fire-damaged and appeared to be the vestiges of a major conflagration event which destroyed the settlement. The carbonised food remains from the interior of a whole but burnt pottery vessel, Pot M, from the 'cultural horizon' was dated (Beta-243230) along with a piece of a large oak pile that had been stripped of its bark and sapwood (Beta-227132).

All six waterlogged wood samples dated from the 2005–6 evaluation were measured by conventional radiometric methods and lack precise information about the relationship of the dated material to the target event (in this case the felling of the timbers). Hence, although at the time of their submission they provided reliable samples to determine the age of the structures (Fig 23) they have been excluded from the analysis undertaken below due to the availability of the estimate derived from the wiggle-match of the ash master sequence.

The whole fire-damaged pottery vessel that contained carbonised food remains does, however, provides an important constraint on the date of construction of the Pile-dwelling settlement as it must post-date its building (see below).

Non-waterlogged wood samples from the 2015–6 excavations

Within the Pile-dwelling settlement the semi-articulated remains of a number, 15, of young lambs between the age of 3 and 6 months (Rajkovača 2024), were found within the footprints of the structures (Fig 24). The partial articulation is thought to be a product of the structure's collapse as in most cases all skeletal elements were present. The lambs provided the opportunity to date samples that must post-date the construction of the site and are therefore important for two reasons, firstly they provide an independent check on the accuracy of the estimate for year 0 obtained from the wiggle-match of the ash site sequence and secondly they allow us to determine how long the settlement might have been in use. Although a number of lines of evidence suggest the conflagration event happened very quickly following construction (Knight and Ballantyne 2024) independent scientific evidence to support this, even at the relatively 'coarse' resolution achievable by radiocarbon dating, is important.

Samples from three lambs were dated (Table 28; Appendix 2) and given the clear evidence that they all died at the same time the measurements have been combined using the OxCal function `Combine` (Fig 25) in the model described below.

Use

The model for the use of the Pile-dwelling settlement is shown in Figure 26. It has good overall agreement (Amodel: 123). The difference between the latest dated material (*last_pile_dwelling_settlement*; Fig 26) and the estimate for construction (*ash_year_0*; Fig 22) of the Pile-dwelling settlement suggest it was only in use was a couple of decades (median 10 years).

Curation of human remains

Recent research (Booth and Brück 2020, 15) has suggested that a high proportion of unburnt disarticulated human remains from British Bronze Age contexts were probably already 'old' when they were deposited, providing the first clear evidence for the systematic curation of human bones in this period. The recovery of human skull fragments from two different individuals from the Pile-dwelling settlement has allowed us to ascertain whether a similar practice was also taking place at Must Farm (Fig 27). The radiocarbon results (Table 28; Appendix 2) do not provide a conclusive answer to how much older than the settlement the human remains are (Fig 28); although they would not have been more than more than *c*. 100 years old when deposited.

The palaeochannel

In order to help understand the setting into which the Causeway and Pile-dwelling settlement were built an attempt was made to date the sequence of deposits found within the palaeochannel (Fig 29). Given the wealth of evidence for the local environment both within the channel and in its immediate vicinity understanding the chronology of the deposits it contained was a key aim of the radiocarbon dating programme. But understanding when different deposits formed within features such as the palaeochannel is far from straightforward. Although the palaeochannel contained a wealth of organic material suitable for radiocarbon dating evaluating its relationship to the formation of a deposit is far from straightforward. An active freshwater channel such as that at Must Farm is by its very nature a dynamic environment with material continually being washed in, transported, deposited, eroded, and redeposited. Thus, identifying suitable material that is close in age to when a deposit formed for radiocarbon dating requires a degree of trial and error.

Initially we obtained twelve radiocarbon determinations from six pairs of samples comprising waterlogged plant material and single twigs from six horizons (Table 29; Appendix 2). By dating two different types of material we hoped to evaluate whether they could be of the same actual age or not. We had hypothesised based on work in similar environments (Chiverrell *et al* 2009) that it was more likely that the fragile waterlogged plant material should be closer in age to the date when the deposit they were contained in formed than the more robust twigs that could have been eroded from further upstream and redeposited (and hence be older than the deposit they were recovered finally recovered from).

Three of the pairs of measurements are statistically consistent at the 5% significance level (Table 30) and thus the waterlogged plant material and twigs from these deposits could be of the same actual age, but for the other three pairs of measurements the twigs are considerably older (Fig 30). The fact that the twigs are in three cases many 100s of years older than the waterlogged plant remains suggests that our original hypothesis that due to their more robust nature they are more prone to being residual in the deposit they are recovered from has some basis.

Additional information on the chronology of the palaeochannel is also provided by a radiocarbon date on the 'disarticulated' remains of a large dog found immediately below the shell influx layer [367]. Although the dog was not found in articulation the skeletal elements recovered, seven ribs, two mandibles, tibia and femur) suggest it has not moved far from where it was originally buried. Finally, the estimated date for the construction of the pile-dwelling settlement (*ash_year_0*) can provide a constraint for the age of deposits above and below it.

The model for the chronology of the palaeochannel is shown in Figure 31 (the CQL2 code is given in Appendix 3) and has good overall agreement (Amodel=102). Apart from the two radiocarbon dates from the base of the freshwater water sequence (SUERC-76191 and OxA-36403; sample 2, context [378]) that have been combined using the OxCal function `Combine`, the dates on waterlogged plant material and single twigs from the remaining five dated horizons have been treated as only providing maximum ages for their contexts (OxCal function `After`).

The earliest dated sedimentary unit [378] in the palaeochannel is estimated to have been deposited in *1615–1505 cal BC* (*95% probability*; *2 [-3.25 to -3.26m OD]*; Fig 31) and probably *1610–1575 cal BC* (*34% probability*) or *1560–1515 cal BC* (*34% probability*).

The shell influx layer [367] was deposited sometime after *1290–1125 cal BC* (*95% probability*; *ETH-96047*; Fig 31) and probably *1265–1200 cal BC* (*63% probability*) or *1140–1130* cal BC (*5% probability*). The estimated date for the construction of the pile-dwelling settlement — *865–835 cal BC* (*95% probability*; *ash_year_zero*; Fig 31) and probably *860–845 cal BC* (*68% probability*) — provides a *terminus post quem* for the sediments deposited after its destruction.

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TABLES

Table 1. Dendrochronology analysis summary

Group	Total >=30yr analysed	>=30yr oak	dated	YZ	>=30yr ash	YZ	
causeway	42	41	10	-	1	-	Table 2
palisade	46	1	-	1	45	41	Table 8
str1	17	16	-	16	1	1	Table 9
str2	4	4	-	2	-	-	Table 10
str3	4	2	-	1	2	1	Table 11
str4	5	2	-	2	3	3	Table 12
str5	6	6	-	3	-	-	Table 13
other p–d	4	4	-	2	-	-	Table 14
other	12	12	6	-	-	-	Table 20
Total >=30yr	140	88	16	27	52	46	

Short series	Total <30yr analysed	<30yr oak	YZ	<30yr ash	YZ	
Total <30yr	10	6	4	4	3	Table 17

YZ, relatively dated series, each of these timbers was found to be felled in the precisely same year. This year is currently unidentified by dendrochronological methods.

Table 2. Causeway dendrochronology samples

Wood Number	Dimensions mm	Wood type	Rings	Sap/Bark	Result
20	180 x 100	Oak	52+*30*	-	1370–1319 BC
37/362	230 x 230	Oak	57	H/S?	undated
38	270 x 270	Oak	36	H/S?	undated
39	310 x 160	Oak	68	5	1355–1288 BC
42	290 x 105	Oak	74	-	1373–1300 BC
55	220 x 180	Oak	41	H/S?	undated
163	200 x 140	Oak	56	H/S?	undated
180	230 x 220	Oak	46	H/S?	undated
181	225 x 155	Oak	115	H/S?	undated
186	210 x 170	Oak	50	H/S?	undated
369	190 x 100	Oak	102	-	undated
2713	150 x 130	Oak	36	-	undated
2809	300 x 260	Oak	60	-	undated
2853	170 x 150	Oak	87	22+sB	1371–1285 BC
2933	330 x 285	Oak	42	-	undated
2935	185 x 160	Oak	43	-	1358–1316 BC
2936	210 x 170	Oak	48	-	1364–1317 BC
2940	275 x 260	Oak	60	H/S?	undated
2944	325 x 280	Oak	53	-	undated
2946	210 x 115	Oak	69	-	undated
2956	270 x 240	Oak	35	-	undated

Wood Number	Dimensions mm	Wood type	Rings	Sap/Bark	Result
2957	230 x 135	Oak	82	-	undated
3249	270 x 250	Oak	41	H/S?	undated
3250	215 x 175	Oak	174	15	undated
3251	145 x 140	Oak	88	-	undated
4225	225 x 145	Oak	42	18	undated
4227	250 x 195	Oak	36	-	undated
4231	160 x 105	Oak	68	-	undated
4233	220 x 200	Ash	36	-	undated
4242	250 x 130	Oak	50	16+sB	undated
5602	165 x 50	Oak	40	-	undated
5825	120 x 110	Oak	75	-	1360–1286 BC
6420	230 x 120	Oak	55	-	1365–1311 BC
6422	245 x 240	Oak	64	-	undated
6423	230 x 90	Oak	59	H/S	1365–1307 BC
6424	280 x 220	Oak	52	-	undated
6427	165 x 80	Oak	49	-	1351–1303 BC
6430	250 x 100	Oak	53	-	undated
6645	130 x 100	Oak	*30*+51	-	undated
6860/7490	165 x 160	Oak	65	-	undated
7122	105 x 55	Oak	62	-	undated
7360	140 x 115	Oak	80	22	undated

Key for Tables 2, 8-14, 17, 20: **Num** wood number. **Dimensions** to nearest 5mm on major and minor axes. **Wood**, oak is *Quercus robur* or *Q. petraea* which cannot be differentiated, ash is *Fraxinus excelsior*. **Ring** counts in italics, are unmeasurable bands, these are estimated additional rings, **Sap/Bark** H/S? onset of sapwood (not for ash), +sB additional partial spring growth ring under bark, +Bw apparently full years growth, probably autumn/winter felled, +B ring too narrow to determine season of felling, +?B possible bark, ch charred outer. Note ash does not normally have differentiated heartwood/sapwood and only one sample was observed amongst the ash samples here, this was undated ash MUS06 127, part of the Palisade. **Result**, BC absolute dates where given are for the dendrochronologically dated sequences, using a calendar scale where 1 BC immediately precedes AD 1, i.e. there is no 0 BC or AD 0. YZ, relatively dated series, each of these timbers was found to be felled in the precisely same year, given a datum Year Zero for the felling year. This year is currently unidentified by dendrochronological methods. Undated, series which were not matched to either the YZ sequences, or the absolute tree-ring chronologies.

Table 3. Causeway intra-t values

	39	42	2853	2935	2936	5825	6420	6423	6427
20	4.03	3.24	4.82	-	-	-	3.66	-	3.13
39		6.95	5.61	5.71	5.69	8.50	5.54	4.87	5.83
42			4.99	7.16	4.16	6.38	6.34	5.75	4.26
2853				4.69	3.46	5.17	5.95	5.77	10.07
2935					4.28	5.07	4.81	4.05	3.70
2936						4.46	3.57	-	6.59
5825							7.25	8.62	5.04
6420								9.86	7.23
6423									6.52

Table 4. Causeway inter-t values, in distance order

	20	39	42	2853	2935	2936	5825	6420	6423	6427
Cambs FF88T JN	5.72	10.07	7.23	8.74	5.03	3.96	6.81	6.36	5.10	5.92
Cambs FG137T	5.31	11.89	8.69	7.76	6.75	5.62	11.74	8.27	6.02	6.63
Notts NQ ALL	3.10	-	3.89	4.55	-	4.36	3.59	3.07	-	4.37
Yorks HAS_BOG	4.31	4.01	4.66	5.10	3.05	-	4.81	4.87	4.26	3.89
Kent SWALCLF	3.91	4.95	5.71	3.95	4.80	3.84	3.81	3.09	-	3.35

Table 5: Must Farm causeway 'in-the-round' pile timber WD2944 radiocarbon and stable isotope results. Replicate measurements have been tested for statistical consistency and combined by taking a weighted mean before calibration as described by Ward and Wilson (1978; T'(5%)=3.8, v=1 for all).

Laboratory reference	Sample ID, material & context	Radiocarbon Age (BP)	$\delta^{13}C_{IRMS}$ (‰)	$\delta^{13}C_{AMS}$ (‰)
ETH-106009	2944.1.1 Waterlogged wood, *Quercus* sp. heartwood ring 1, causeway 'in-the-round' pile timber 2944	3252±16		−23.5
GrM-22053	2944.1.2 Replicate of ETH-106009	3215±18	−23.5±0.15	
2944.1	^{14}C: 3236±12 BP, T′=2.4			
ETH-106010	2944.14 Waterlogged wood, *Quercus* sp. heartwood ring 14, causeway 'in-the-round' pile timber 2944	3214±16		−21.3
GrM-22054	2944.27 Waterlogged wood, *Quercus* sp. heartwood ring 27, causeway 'in-the-round' pile timber 2944	3190±18	−24.2±0.15	
ETH-106011	2944.40.1 Waterlogged wood, *Quercus* sp. heartwood ring 40, causeway 'in-the-round' pile timber 2944	3195±16		−23.9
GrM-22055	2944.40.2 Replicate of ETH-106011	3200±30	−27.1±0.15	
2944.40	^{14}C: 3196±15 BP, T′=0.0			
ETH-106012	2944.53 Waterlogged wood, *Quercus* sp. heartwood ring 53, causeway 'in-the-round' pile timber 2944	3210±26		−20.1

Table 6: Must Farm causeway 'in-the-round' pile timber 3249 radiocarbon and stable isotope results. Replicate measurements have been tested for statistical consistency and combined by taking a weighted mean before calibration as described by Ward and Wilson (1978; T'(5%)=3.8, ν=1 for all).

Laboratory reference	Sample ID, material & context	Radiocarbon Age (BP)	$\delta^{13}C_{IRMS}$ (‰)	$\delta^{13}C_{AMS}$ (‰)
GrM-22282	3249.1 Waterlogged wood, *Quercus* sp. heartwood ring 1, causeway 'in-the-round' pile timber 3249	3201±24	−26.2±0.15	
ETH-106006	3249.11 Waterlogged wood, *Quercus* sp. heartwood ring 11, causeway 'in-the-round' pile timber 3249	3173±16		−23.8
GrM-22051	3249.21 Waterlogged wood, *Quercus* sp. heartwood ring 21, causeway 'in-the-round' pile timber 3249	3154±18	−27.7±0.15	
GrM-22283	3249.31.1 Waterlogged wood, *Quercus* sp. heartwood ring 31, causeway 'in-the-round' pile timber 3249	3086±24	−28.8±0.15	
ETH-106007	3249.31.2 Replicate of GrM-22283	3163±26		−22.1
3249.31	^{14}C: 3122±18 BP, T′=4.7			
GrM-22052	3249.41.1 Waterlogged wood, *Quercus* sp. heartwood ring 41, causeway 'in-the-round' pile timber 3249	3147±18	−26.5±0.15	
ETH-106008	3249.41.2 Replicate of GrM-22052	3122±16		−26.6
3249.41	^{14}C: 3133±11 BP, T′=1.1			

Table 7: Must Farm causeway horizontal timber 6430 radiocarbon and stable isotope results. Replicate measurements have been tested for statistical consistency and combined by taking a weighted mean before calibration as described by Ward and Wilson (1978; T'(5%)=3.8, ν=1 for all).

Laboratory reference	Sample ID, material & context	Radiocarbon Age (BP)	$\delta^{13}C_{IRMS}$ (‰)	$\delta^{13}C_{AMS}$ (‰)
ETH-106002	6430.1 Waterlogged wood, *Quercus* sp. heartwood ring 1, from causeway horizontal timber 6430	3288±26	-	−20.2
ETH-106003	6430.14.1 Waterlogged wood, *Quercus* sp. heartwood ring 14, from causeway horizontal timber 6430	3206±16	-	−24.3
GrM-22048	6430.14.2 Replicate of ETH-106003	3190±20	−26.6±0.15	
6430.14	^{14}C: 3197±13 BP, T′=0.2			
ETH-106004	6430.27.1 Waterlogged wood, *Quercus* sp. heartwood ring 27, from causeway horizontal timber 6430	3182±16		−25.7
GrM-22281	6430.27.2 Replicate of ETH-106004	3070±45	−28.5±0.15	
6430.27	^{14}C: 3170±16 BP, T′=5.4			
GrM-22280	6430.40 Waterlogged wood, *Quercus* sp. heartwood ring 40, from causeway horizontal timber 6430	3088±23	−28.2±0.15	
ETH-106005	6430.53 Waterlogged wood, *Quercus* sp. heartwood ring 53, from causeway horizontal timber 6430	3143±16		−26.4

Table 8: Pile-dwelling Palisade dendrochronological samples

Num	Dimensions	Wood	Rings	Sap/Bark	Result
127	105 x 105	Ash	51	-	undated
128	90 x 90	Ash	37	-	undated
2717	105 x 105	Ash	40	+Bw	YZ
2719	120 x 120	Ash	47	+Bw	YZ
2731	90 x 90	Ash	43	+Bw	YZ
2735	125 x 125	Ash	*20*+55	+Bw	YZ
2737	95 x 85	Ash	45	+Bw	YZ
2738	115 x 110	Ash	48	+Bw	YZ
2743	125 x 125	Ash	49	+Bw	YZ
2748	115 x 115	Ash	42	+Bw	YZ
2753	115 x 115	Ash	43	+Bw	YZ
2755	110 x 110	Ash	46	+Bw	YZ
2759	120 x 120	Ash	61	+Bw	YZ
2760	100 x 95	Ash	44	+Bw	YZ
2762	95 x 90	Ash	49	+Bw	YZ
2770	145 x 135	Ash	45	+Bw	YZ
2774	140 x 135	Ash	46	+Bw	YZ
2777	135 x 120	Ash	43	+Bw	YZ
2781	125 x 120	Ash	50	+Bw	YZ
2806	145 x 135	Ash	40	+Bw	YZ
2815	130 x 130	Ash	42	+Bw	YZ
2819	115 x 110	Ash	46	+Bw	YZ
2820	110 x 110	Ash	43	+Bw	YZ
2821	115 x 105	Oak	33	13+B	YZ
2822	115 x 115	Ash	39	+Bw	YZ
2824	115 x 115	Ash	43	+Bw	YZ
2830	115 x 115	Ash	40	+Bw	YZ
2834	110 x 110	Ash	43	+Bw	YZ
2840	140 x 130	Ash	42	+Bw	YZ
2845	120 x 120	Ash	45	+Bw	YZ
2848	135 x 130	Ash	44	+Bw	YZ
2849	140 x 140	Ash	*12*+47	+Bw	YZ
2869	110 x 110	Ash	45	+Bw	YZ
2881	125 x 120	Ash	39	+Bw	YZ
2882	125 x 125	Ash	45	+Bw	YZ
2913	135 x 135	Ash	43	+Bw	YZ
2914	90 x 90	Ash	43	+Bw	YZ
2915	100 x 100	Ash	56	+Bw	YZ
2916	105 x 105	Ash	44	+Bw	YZ
2917	105 x 105	Ash	*17*+30	+Bw	undated
2918	115 x 115	Ash	44	+Bw	YZ
2921	115 x 115	Ash	41	+Bw	YZ
3008	140 x 140	Ash	47	+Bw	YZ
3020	150 x 145	Ash	45	+Bw	undated
6038	115 x 115	Ash	46	+Bw	YZ
6501	115 x 110	Ash	42	+Bw	YZ

2882 = MUS06 638, 2916 = MUS06 136, 2918 = MUS06 134

Table 9: Pile-dwelling Structure 1 dendrochronological samples

Num	Dimensions	Wood	Rings	Sap/Bark	Result
2772	145 x 145	Oak	30	10+Bw	YZ
2775	160 x 155	Oak	31	13+Bw	YZ
2780	160 x 155	Oak	40	14+Bw	YZ
2784	160 x 160	Oak	36	13+Bw	YZ
2785	160 x 150	Oak	36	18+Bw	YZ
2787	160 x 155	Oak	33	11+?B	YZ?
2803	155 x 155	Oak	32	14+Bw	YZ
3505	195 x 155	Oak	36	13 ch	YZ?
3526	130 x 70	Oak	33	14 ch	YZ?
3542	145 x 145	Ash	36	+Bw ch	YZ
3565	155 x 70	Oak	33	13+Bw	YZ
3600	140 x 80	Oak	40	21+Bw ch	YZ
3601	150 x 75	Oak	34	13+Bw	YZ
3626	145 x 70	Oak	33	17+Bw ch	YZ
3747	170 x 80	Oak	30	10+Bw	YZ
3916	190 x 105	Oak	35	12 ch	YZ?
3936	135 x 80	Oak	31	19+Bw	YZ

Table 10: Pile-dwelling Structure 2 dendrochronological samples

Num	Dimensions	Wood	Rings	Sap/Bark	Result
4777	195 x 90	Oak	43	17+Bw	YZ
5054	100 x 95	Oak	31	14+Bw	YZ
5309	160 x 45	Oak	139	7	Undated
5319	195 x 55	Oak	31	-	Undated

Table 11. Pile-dwelling Structure 3 dendrochronological samples

Num	Dimensions	Wood	Rings	Sap/Bark	Result
2804	160 x 155	Oak	30	12+Bw	YZ
3021	140 x 135	Ash	44	+Bw	undated
3022	170 x 145	Ash	40	+Bw	YZ
5679	160 x 80	Oak	33	15+Bw ch	undated

Table 12: Pile-dwelling Structure 4 dendrochronological samples

Num	Dimensions	Wood	Rings	Sap/Bark	Result
5148	115 x 60	Ash	34	+Bw ch	YZ
5243	170 x 80	Oak	33	14+Bw	YZ
5262	190 x 105	Oak	31	12+Bw	YZ
5272	145 x 50	Ash	39	+Bw	YZ
5702	165 x 75	Ash	33	+B ch	YZ

Table 13: Pile-dwelling Structure 5 dendrochronological samples

Num	Dimensions	Wood	Rings	Sap/Bark	Result
663	145 x 130	Oak	40	17+Bw	YZ
2945	150 x 140	Oak	39	14+Bw	YZ
2955	125 x 125	Oak	37	15+Bs	undated
4261	155 x 140	Oak	33	13+Bw ch	YZ

4266	170 x 145	Oak	31	9+Bw	undated
4278	120 x 70	Oak	61	H/S	undated

4261= MUS06 151

Table 14: Other Pile-dwelling structural timbers, dendrochronological samples

Num	Dimensions	Wood	Rings	Sap/Bark	Result
3341	160 x 100	Oak	41	22+Bw ch	YZ
5201	155 x 85	Oak	39	12+Bw	YZ
5837	175 x 70	Oak	51	-	undated
7060	55 x 40	Oak	43	-	undated

5837 = MUS06 630/376

Table 15: Year zero oak intra t-values in numerical order not structural order

	2772	2775	2780	2784	2785	2787	2803	2804	2821	2945	3341	3505	3526	3565	3600	3601	3626	3747	3916	3936	4261	4777	5054	5201	5243	5262
0663	-	3.90	-	-	3.16	-	-	3.13	-	-	4.62	4.67	-	4.73	4.53	3.38	4.31	-	-	-	3.21	-	3.25	4.14	-	-
2772		3.88	5.08	5.07	6.00	5.38	5.96	5.32	3.87	3.59	-	3.94	5.40	3.85	3.89	-	5.26	3.72	7.38	-	4.74	3.59	3.85	8.83	4.77	3.92
2775			4.09	-	3.09	4.37	4.67	5.69	3.80	3.81	4.20	4.28	3.51	5.77	4.80	4.52	4.21	4.86	3.02	5.55	4.40	4.62	3.67	4.29	4.16	-
2780				4.45	6.65	6.80	5.97	5.69	4.68	4.58	4.01	4.91	6.04	3.27	4.73	3.61	6.48	5.09	5.78	3.80	4.69	3.94	-	5.23	4.64	-
2784					3.95	4.41	3.51	3.49	4.39	3.16	3.13	3.84	-	-	4.82	-	-	3.64	5.95	-	3.08	3.94	-	3.79	5.39	-
2785						4.82	5.99	5.67	3.80	4.21	3.29	5.44	7.77	3.30	4.80	-	5.36	3.97	6.66	4.24	3.04	4.00	3.24	8.17	5.02	-
2787							4.98	4.60	6.57	3.59	4.29	4.34	7.02	-	4.52	-	4.15	6.90	6.62	5.51	3.51	5.09	-	4.53	5.43	-
2803								5.99	4.16	4.14	3.99	3.32	5.46	4.26	4.64	3.38	4.88	4.87	6.19	4.40	4.44	5.54	3.02	5.59	5.51	3.42
2804									5.37	4.42	3.54	5.06	4.27	4.35	4.45	-	5.45	6.69	5.14	4.28	3.57	3.11	3.85	5.01	4.65	-
2821										4.27	-	3.92	5.77	-	-	-	3.17	6.79	6.72	3.22	3.92	4.58	-	-	4.28	-
2945											-	3.90	4.10	3.53	-	4.41	6.44	3.34	4.42	-	3.83	6.00	3.67	3.33	-	-
3341												4.58	-	-	11.57	-	-	4.49	3.82	4.62	-	3.23	-	4.58	3.49	-
3505													4.36	3.26	5.86	-	5.01	-	5.18	3.63	-	4.14	-	6.59	3.32	-
3526														-	-	-	4.89	5.23	6.92	4.06	3.27	3.96	-	5.48	4.78	3.10
3565															-	5.81	5.47	-	-	3.49	3.95	3.03	6.40	5.03	-	-
3600																-	3.08	4.29	4.40	4.59	-	4.09	-	6.32	4.56	-
3601																	4.43	-	-	-	4.15	4.63	-	3.63	-	-
3626																		-	4.25	-	4.96	3.29	6.50	7.62	-	-
3747																			4.91	5.38	3.40	3.56	-	3.55	4.40	-
3916																				3.61	3.62	4.66	-	5.93	5.41	3.59
3936																					-	3.46	-	3.53	4.75	-
4261																						5.34	3.34	5.18	-	-
4777																							-	3.51	5.50	3.53
5054																								4.97	-	-
5201																									3.84	3.27
5243																										3.18

Table 16: Year zero ash intra t*-values? This is sorted Palisade first, other 5 matched ash at the end*

	2719	2731	2735	2737	2738	2743	2748	2753	2755	2759	2760	2762	2770	2774	2777	2781	2806	2815	2819	2820	2822	2824	2830	2834	2840	2845	2848	2849	2869	2881	2882	2913	2914	2915	2916	2918	2921	3008	6038	6501	3022	3542	5148	5272	5702
2717	-	3.75	-	-	5.22	3.35	-	-	4.00	-	-	4.05	-	-	-	4.52	3.99	-	3.70	-	-	-	4.69	-	3.56	-	3.47	-	-	3.97	3.57	5.01	3.64	3.03	-	-	4.24	4.58	3.06	-	3.49	3.76	6.23	3.84	4.34
2719		3.18	-	3.85	5.52	6.14	4.24	5.23	4.39	5.02	4.06	3.87	6.99	3.77	4.10	5.36	7.07	5.44	-	3.62	4.20	4.34	3.57	4.47	-	7.45	7.84	5.05	-	6.10	4.49	5.62	5.00	5.30	4.54	3.77	4.76	4.11	6.16	5.47	-	5.22	3.26	4.17	-
2731			4.54	-	6.40	3.92	3.35	3.70	3.38	-	4.13	4.01	3.28	-	-	5.22	4.27	3.10	-	-	-	3.93	3.87	3.43	4.40	3.89	3.61	-	3.50	3.19	3.95	4.78	4.15	5.23	3.94	3.71	3.30	3.04	-	4.58	3.29	5.84	4.76	4.47	-
2735				-	-	4.72	3.54	3.13	3.59	3.74	5.66	3.17	-	-	-	-	-	-	-	3.60	-	4.70	3.88	4.15	3.57	3.42	3.03	-	5.70	3.13	-	3.21	-	5.40	5.61	3.81	-	-	3.47	5.31	3.82	4.02	-	3.18	-
2737					3.08	4.35	3.61	-	3.92	-	3.46	-	-	-	4.72	3.44	4.94	-	-	-	-	-	-	-	3.33	3.50	3.29	-	-	-	-	-	-	4.08	3.22	3.43	3.24	-	3.90	3.82	-	-	-	-	-
2738						5.82	6.72	4.77	7.56	-	-	4.60	5.68	3.18	4.55	5.86	9.02	5.59	4.45	4.97	-	6.94	6.35	5.19	4.83	7.06	8.30	5.09	3.03	6.73	7.19	8.46	5.45	4.68	7.37	3.65	5.21	5.31	6.06	6.34	5.64	7.35	6.55	6.91	5.88
2743							6.72	6.11	5.39	5.49	4.70	3.24	6.43	3.24	5.19	8.21	7.47	6.00	-	4.05	-	4.02	5.93	4.83	5.15	6.27	6.97	5.31	4.39	9.17	5.66	6.96	6.14	9.07	6.71	4.99	4.10	3.94	6.69	7.63	3.60	4.75	-	3.78	-
2748								4.89	4.43	5.31	3.40	5.85	4.91	4.21	6.57	5.64	5.63	5.65	-	4.95	-	4.92	3.96	5.11	3.57	6.07	6.84	5.67	3.89	8.26	5.07	5.66	4.27	4.57	6.57	4.04	4.28	6.02	5.73	5.08	4.48	4.98	-	4.92	-
2753									3.09	3.33	3.15	4.27	4.70	5.03	4.50	5.45	5.56	4.57	-	3.67	-	4.38	4.46	5.01	-	6.85	4.27	3.44	3.38	6.40	4.37	5.07	4.99	5.02	5.19	3.37	4.69	4.51	3.63	5.64	4.52	4.78	-	4.18	-
2755										4.38	-	4.64	5.85	3.59	4.35	4.16	6.10	6.39	4.91	4.09	-	6.45	4.74	4.09	4.10	4.64	5.73	4.21	3.87	5.59	6.29	6.46	3.14	6.69	7.62	3.86	6.76	5.43	6.73	3.65	6.75	3.03	3.02	4.77	4.60
2759											-	4.02	5.92	4.53	3.46	4.54	4.58	4.70	3.99	3.96	5.88	4.81	-	4.51	-	4.49	5.49	4.58	3.21	6.67	4.07	6.14	-	5.76	4.70	-	5.35	5.24	5.75	3.25	3.75	3.08	3.67	3.76	-
2760												-	3.27	-	-	4.97	6.18	-	-	-	-	4.44	4.81	4.10	-	3.55	3.83	-	3.48	4.82	-	-	3.44	4.33	4.01	4.62	-	-	4.29	5.17	-	5.06	-	3.07	-
2762													4.01	4.70	4.65	3.65	4.08	4.63	3.64	-	-	6.12	4.14	4.24	3.74	4.28	5.40	-	4.90	5.30	6.10	6.78	3.65	4.19	8.12	-	5.27	5.59	5.17	3.79	5.11	5.21	4.68	4.37	-
2770														3.96	3.76	4.51	5.32	5.19	-	4.72	3.66	5.15	3.91	6.10	-	6.55	6.81	5.39	-	7.79	5.15	5.10	4.72	6.41	4.56	3.51	6.67	5.78	6.05	3.91	5.68	3.60	3.35	5.24	4.75
2774															4.86	-	3.67	5.05	3.20	-	-	4.55	-	4.05	-	5.51	3.06	-	3.15	4.58	5.16	4.17	-	3.31	4.68	-	6.00	6.76	4.01	-	5.30	3.25	-	4.55	-
2777																4.55	5.28	4.26	-	3.41	-	4.03	3.37	3.26	-	6.61	4.82	3.94	-	5.24	5.05	4.93	3.09	4.98	5.55	3.51	3.79	4.53	4.59	4.19	3.81	3.26	-	3.99	-
2781																	8.35	6.51	-	3.87	-	4.39	5.19	4.14	3.53	4.95	6.79	4.52	4.03	9.12	5.18	8.67	5.63	6.81	6.02	3.75	5.25	4.70	5.06	7.45	3.15	5.90	5.43	4.57	-
2806																		4.36	-	5.26	3.68	6.30	6.43	4.84	3.38	9.06	8.72	4.24	-	7.58	5.37	8.20	6.04	8.19	5.50	6.82	6.09	4.13	6.72	7.32	4.25	6.25	4.64	6.11	3.20
2815																			3.31	3.55	-	4.52	-	3.75	3.51	5.86	5.22	4.46	4.81	7.16	7.63	6.05	3.38	5.03	8.48	-	5.08	6.54	3.81	3.64	4.07	4.13	3.25	3.83	3.52
2819																				-	3.65	3.34	-	3.15	-	-	3.04	-	-	-	3.53	3.90	-	-	3.46	-	3.94	4.33	3.21	-	4.48	-	4.73	3.17	3.21
2820																					3.50	3.98	-	4.98	-	5.13	5.67	4.33	-	4.72	4.29	4.37	3.37	3.81	3.75	-	3.82	4.68	4.38	4.79	4.23	3.56	3.23	5.57	-
2822																						-	-	3.95	-	4.34	4.64	-	-	3.31	-	3.43	-	-	-	-	3.71	-	4.04	-	-	3.00	3.52	3.61	-
2824																							4.44	5.36	-	5.95	5.41	3.75	3.41	5.44	5.04	5.68	3.64	5.93	7.55	4.78	7.22	5.09	5.59	4.21	6.57	5.14	3.52	6.26	3.53
2830																								3.58	4.27	3.86	5.51	-	3.02	5.70	3.46	5.20	5.95	6.60	4.40	6.94	4.71	-	4.39	7.14	3.68	4.66	-	4.74	3.29
2834																									-	5.94	5.69	3.95	3.94	7.04	5.33	4.39	3.23	4.73	5.79	-	4.45	4.61	5.54	5.61	6.11	4.82	-	4.43	-
2840																										-	-	-	5.17	3.52	5.28	3.85	4.13	4.99	4.40	5.50	3.07	-	3.02	3.85	3.40	3.84	-	-	-
2845																											6.74	3.93	-	9.98	4.93	4.98	4.35	5.26	5.79	3.24	5.69	4.67	5.18	5.62	4.58	8.25	5.12	6.56	-
2848																												5.27	-	7.85	5.29	7.23	4.42	6.78	5.56	3.63	5.25	5.53	8.58	6.52	4.45	6.95	4.86	5.37	4.43
2849																													-	5.44	3.94	5.30	3.40	3.39	4.89	-	-	4.35	4.74	3.39	3.49	-	-	3.34	-
2869																														3.65	3.90	3.73	-	3.96	6.79	-	3.39	3.21	3.33	3.40	4.97	-	-	-	-
2881																															6.68	7.54	4.60	6.08	6.57	4.61	7.25	7.21	6.23	5.69	4.80	5.98	4.80	4.90	3.28
2882																																8.06	4.23	6.38	7.45	-	6.32	6.92	4.83	4.36	6.01	4.09	3.81	3.96	3.23
2913																																	4.34	8.24	7.49	-	4.93	6.07	5.80	5.72	5.22	4.86	4.76	5.80	4.14
2914																																		5.61	3.66	5.70	4.17	3.02	3.07	6.12	-	4.28	3.05	4.58	-
2915																																			6.59	5.71	5.68	3.39	5.79	8.13	4.63	4.73	-	4.96	-
2916																																				4.04	4.85	5.70	5.71	5.23	6.81	5.06	3.03	4.49	3.65
2918																																					4.03	-	4.14	6.04	3.59	5.27	-	5.16	-
2921																																						6.58	5.41	3.56	5.76	3.66	3.99	5.46	3.43
3008																																							6.08	3.24	6.44	3.90	5.03	5.57	5.88
6038																																								4.92	5.21	3.94	3.11	3.88	-
6501																																									3.50	7.44	3.37	4.97	-
3022																																										3.94	-	5.33	4.84
3542																																											6.87	5.56	3.37
5148																																												5.03	4.55
5272																																													5.28

Table 17: Pile-dwelling Sub-30 ring test data

Num	Dimensions	Wood	Rings	Sap/Bark	Result	Structure
2718	80 x 80	Ash	19	+Bw	YZ	Palisade
2720	80 x 80	Ash	19	+Bw	YZ	Palisade
2778	140 x 125	Oak	28	14+Bw	YZ	Str 1
2792	160 x 155	Oak	27	12+Bw	YZ	Str 1
3684	120 x 110	Oak	27	17+Bw	YZ	Str 1
3776	85 x 85	Oak	27	12	undated	Str 1
4722	150 x 130	Ash	28	+Bw	YZ	Str 2
4894	140 x 60	Ash	24	+Bw	undated	Str 2
4320	70 x 70	Oak	28	8+ch	undated	Str 5
3153	125 x 60	Oak	28	11+Bw	YZ	Other structural

Table 18: t-*values between the Year Zero oak composite sequence, and 4 of the sub-30 year oaks. 2778, 2792 and 3684 are from Structure 2, 3153 is an unattributed Structural timber*

	2778	2792	3684	3153
YZ oak composite	6.47	3.57	4.06	5.15

Table 19. t-*values between the Year Zero ash composite sequence, and 3 of the sub-30 year ash. 2718 & 2720 are from the Palisade, 4722 is from Structure 2*

	2718	2720	4722
YZ ash composite	5.69	3.49	4.63

Table 20: Other timbers unattributed to Pile-dwelling structures, dendrochronological samples

Num	Site	Dimensions	Wood	Rings	Sap/Bark	Result
1475	MUS10	80 x 45	Oak	82	H/S?	undated
1550	MUS11	160 x 75	Oak	36	14+sB	undated
1769	MUS11	150 x 75	Oak	58	-	990–933 BC
2700	MUS15	125 x 60	Oak	63	-	undated
2709	MUS15	290 x 220	Oak	57	7	undated
2711	MUS15	150 x 55	Oak	119	-	1046–928 BC
2970	MUS15	120 x 90	Oak	60	-	undated
5812	MUS15	280 x 35	Oak	91	-	undated
7316	MUS15	145 x 50	Oak	76	-	1008–933 BC
7324	MUS15	205 x 55	Oak	97	-	1065–969 BC
7325	MUS15	180 x 50	Oak	126	H/S?	1032–907 BC
100	MAP08	220 x 105	Oak	81	-	1004–924 BC

*Table 21. Non-pile-dwelling intra-*t*-values*

	2711	7316	7324	7325	MAP100
1769	7.48	5.31	-	6.51	9.13
2711		3.82	5.11	8.28	9.79
7316			3.67	4.33	5.86
7324				3.81	-
7325					6.39

Table 22. Non-pile dwelling inter t*-values, in distance order*

	1769	2711	7316	7324	7325	MAP100
Cambs FF88 JN	5.40	9.79	5.53	5.08	7.92	8.23
Cambs FG137 JN	-	6.08	3.60	6.25	3.69	3.27
Notts NQ02 NQ06 NQBM IT	3.48	4.26	3.09	3.03	4.64	4.73
Wales Caldicot Castle JH	\	4.67	\	-	3.97	\
Somerset Skinners (Hillam 1993)	\	3.67	-	-	-	-
Somerset Greylake JH	4.61	4.57	-	3.38	5.72	3.75
Co Durham Swan Carr QUB	-	-	-	-	-	3.70

Table 23. The dating of 2 late timbers from Fengate. It was previously known that these cross-matched each other; Y1121/Y1338 t*-value 14.23, and that they, or at least Y1338 which is the longer sequence, matched a handful of other series from the Flag Fen/Fengate sites (Neve and Hillam pers comm)*

	Y1121	Y1338	Y1121+Y1338
Fengate Y92	-	5.52	5.63
Flag Fen A1895	\	5.85	6.00
Flag Fen A8044	\	5.26	5.25
Flag Fen B61+B1721+B63+B190	\	10.20	10.20

Table 24. All six later Must Farm and Magna Park series replicate this result

	1769	2711	7316	7324	7325	MAP100
Y1121	5.03	3.03	-	\	4.29	6.34
Y1338	4.99	6.65	4.49	4.62	5.12	8.14
Y1121+Y1338	5.66	6.62	4.60	5.01	5.98	8.93

Table 25: Must Farm timber WD2759 radiocarbon and stable isotope results. Replicate measurements have been tested for statistical consistency and combined by taking a weighted mean before calibration as described by Ward and Wilson (1978; T'(5%)=3.8, ν=1 for all).

Laboratory reference	Material & context	Radiocarbon Age (BP)	$\delta^{13}C_{IRMS}$ (‰)
SUERC-74902	Waterlogged wood, *Fraxinus excelsior L.*, rings −59 to −55, from wooden pile WD2759, part of a palisade of ash and oak piles (F.900)	2766±33	−26.7±0.2
OxA-36039	Replicate of SUERC-74902	2745±25	−28.4±0.2
Rings 59 to 55	^{14}C: 2753±20 BP, T′=0.3; $\delta^{13}C$: −27.6±0.15‰, T'=36.1;		
OxA-36040	Waterlogged wood, *Fraxinus excelsior L.*, rings −54 to −50, as SUERC-74902	2731±25	−28.7±0.2
SUERC-74906	Waterlogged wood, *Fraxinus excelsior L.*, rings −49 to −45, as SUERC-74902	2744±33	−26.4±0.2
OxA-36203	Waterlogged wood, *Fraxinus excelsior L.*, rings −44 to −40, as SUERC-74902	2712±30	−25.9±0.2
SUERC-74907	Waterlogged wood, *Fraxinus excelsior L.*, rings −39 to −35, as SUERC-74902	2683±33	−23.6±0.2
OxA-36041	Waterlogged wood, *Fraxinus excelsior L.*, rings −34 to −30, as SUERC-74902	2675±24	−24.2±0.2
SUERC-74908	Waterlogged wood, *Fraxinus excelsior L.*, rings −29 to −25, as SUERC-74902	2669±33	−24.0±0.2
OxA-36042	Replicate of SUERC-74908	2728±24	−26.0±0.2
Rings 29 to 25	^{14}C: 2708±20 BP, T′=2.1; $\delta^{13}C$: −25.0±0.15‰, T'=50.0;		
OxA-36043	Waterlogged wood, *Fraxinus excelsior L.*, rings −24 to −20, as SUERC-74902	2719±24	−24.5±0.2
OxA-36044	Replicate of OxA-36043	2670±24	−25.2±0.2
Rings 24 to 20	^{14}C: 2695±17 BP, T′=2.1; $\delta^{13}C$: −24.9±0.15‰, T'=6.1;		
SUERC-74909	Waterlogged wood, *Fraxinus excelsior L.*, rings −19 to −15, as SUERC-74902	2771±33	−23.4±0.2
OxA-36045	Waterlogged wood, *Fraxinus excelsior L.*, rings −14 to −10, as SUERC-74902	2707±24	−24.1±0.2
SUERC-74910	Waterlogged wood, *Fraxinus excelsior L.*, rings −9 to −5, as SUERC-74902	2694±33	−22.8±0.2
SUERC-74911	Waterlogged wood, *Fraxinus excelsior L.*, rings −4 to 0, as SUERC-74902	2797±33	−26.5±0.2
OxA-36075	Replicate of SUERC-74911	2744±28	−25.3±0.2
Rings 4 to 0	^{14}C: 2723±22 BP, T′=1.3; $\delta^{13}C$: −25.9±0.15‰, T'=18.0;		

Table 26: Must Farm timber WD2882 radiocarbon and stable isotope results. The replicate measurements have been tested for statistical consistency and combined by taking a weighted mean before calibration as described by Ward and Wilson (1978; T'(5%)=7.8, ν=3).

Laboratory reference	Sample ID, material & context	Radiocarbon Age (BP)	$\delta^{13}C_{IRMS}$ (‰)	$\delta^{13}C_{AMS}$ (‰)
ETH-106013	Waterlogged wood, *Fraxinus excelsior L.*, ring 0 from wooden pile 2882, part of a palisade of ash and oak piles (F.900)	2775±26		−21.7
ETH-106014	Replicate of ETH-106013	2739±16		−24.5
GrM-22056	Replicate of ETH-106013	2731±24	−27.1±0.15	
GrM-22056	Replicate of ETH-106013	2750±25	−27.4±0.15	
Ring 0	^{14}C: 2746±11 BP, T′=1.9			

Table 27: Must Farm 2005–6 evaluation: radiocarbon and stable isotope results

Laboratory reference	Material & context	Radiocarbon Age (BP)	$\delta^{13}C_{IRMS}$ (‰)
Beta-227132	Waterlogged wood, *Quercus* sp., ?heartwood (stripped of its bark and sapwood) causeway pile, post 40	2920±60	−25.3
Beta-202662	Waterlogged wood, *Fraxinus* sp., sapwood from palisaded settlement pile post 1, <30 years	2810±40	−26.7
Beta-202663	Waterlogged wood, *Fraxinus* sp., sapwood from palisaded settlement pile, post 7, <30 years	2760±40	−25.9
Beta-202664	Waterlogged wood, *Quercus* sp., sapwood palisaded settlement pile, post 14, <30 years	2750±40	−28.7
Beta-201982	Waterlogged wood, unidentified ?heartwood, grab sample of submerged timbers<8>	2790±70	−25.0*
Beta-201983	Waterlogged wood, unidentified ?heartwood, grab sample of submerged timber<10>	2480±60	−25.0*
Beta-243230	Carbonised residue adhering to the interior of ceramic vessel, Pot M, from the ‘cultural horizon’	2700±40	−23.1

* assume value

Table 28: Must Farm animal and human bone radiocarbon and stable isotope results. Replicate measurements have been tested for statistical consistency and combined by taking a weighted mean before calibration as described by Ward and Wilson (1978; T'(5%)=3.8, ν=1).

Laboratory code	Sample ID, material & context	$\delta^{13}C_{IRMS}$ (‰)	$\delta^{15}N_{IRMS}$ (‰)	C:N	Radiocarbon age (BP)
ETH-96049	<4089> [3211]A Animal bone, sheep/goat, right mandible (V Rajkovaca) from a semi-articulated lamb skeleton<4089>	−23.5±0.1	10.7±0.1	3.6	2763±22
GrM-17691	<4089> [3211]B Replicate of ETH-96049	−23.3±0.15	10.7±0.3	3.4	2776±24
^{14}C: 2747±17 BP, T'=0.9; $\delta^{13}C$: −23.3±0.1‰, T'=0.0; $\delta^{15}N$: 3.8±0.7‰, T'=6.4					
ETH-96048	SF4718 Animal bone, sheep/goat, right mandible (V Rajkovaca) <2818> SF4718 [3211] from part of a group of semi-articulated lamb skeletons (3–6 months) within the footprint of collapsed Structure 1 [3211]	−23.4±0.1	10.0±0.1	3.5	2787±22
GrM-17690	SF4118 Animal bone, sheep/goat, right mandible (V Rajkovaca) <2189> SF4118 [3231] part of a semi-articulated lamb skeleton (3–6 months) within the footprint of collapsed Structure 4 [3231]	−23.2±0.15	9.9±0.3	3.5	2776±24
GrM-17689	SF4504 Human skull fragment, left parietal (N Dodwell), <2600> SF4504 [3208] from the formative midden deposit located immediately outside (west) of the footprint of Structure 2.	2750±25	−20.5±0.15	10.3±0.3	3.2
ETH-96046	SF3167 Human skull fragment (no mandible and left temporal bone missing) (N Dodwell), <1171> SF3167 [3207] from formative midden deposit [3208] between Structure 1 and 2	2769±23	−20.5±0.1	10.7±0.1	3.5

Table 29: Must Farm palaeochannel (MU06) radiocarbon and stable isotope results

Laboratory number	Sample ID, material & context	Radiocarbon Age (BP)	δ13CIRMS (‰)	δ15CIRMS (‰	C:N ratio
UBA-35750	26a [−1.615 to −1.625m OD] Waterlogged plant remains, 2 *Ranunculus acris/bulbosus/repens* achene +4 *Rumex* sp. small achene + 1 *Alnus glutinosa* cone + 4 *Oenanthe aquatica* mericarp + 5 *Rumex maritimus* fruit + 13 *Schoenoplectus lacustris* nut + 1 *Rumex* sp. large achene + 2 *Carex* sp. trigonous nut, from context (356), 0.465–0.457m down core; a silt with rare shell or wood fragments that formed in the palaeochannel long after the conflagration of the platform.	2698±30	−27.3±0.22		
SUERC-76592	26b [−1.615 to −1.625m OD] Waterlogged unidentified twig fragment, from the same context as 26a	2661±30	−28.0±0.2		
OxA-36406	24a [−1.905 to −1.915m OD] 1 *Ranunculus acris/bulbosus/repens* achene + 4+1 frag *Rumex* sp. small achene + 2 frag *Alnus glutinosa* cone + 2 *Rubus* subgen. *Rubus* seed + 1 *Alnus glutinosa* seed + 5 *Oenanthe aquatica* mericarp + 2 *Chenopodium* sp. seed +1 *Sambucus* sp. seed + 1 *Rumex maritimus* fruit +30 *Schoenoplectus lacustris* nut + 2 *Rumex* sp. large fruit +6 *Carex* sp. trigonous nut + 5 *Rumex* sp. large achene, from context (357), 0.755–0.765m down core; a shelly/woody silt that formed in the palaeochannel after the conflagration of the platform	2911±28	−26.8±0.2		
UBA-35749	24b [−1.905 to −1.915m OD] Waterlogged unidentified twig fragment, from the same context as 24b	3430±30	−27.5±0.22		
UBA-35748	19a [−2.205 to −2.215m OD] Waterlogged plant remains, 2 *Ranunculus acris/bulbosus/repens* achene +8 *Rumex* sp. small achene + 1 frag *Alnus glutinosa* cone + 1 *Oenanthe aquatica* mericarp+ 1 *Alnus glutinosa* seed + 1 *Oenanthe* sp. mericarp + 1 frag *Atriplex patula/prostrata* seed + 1 *Solanum dulcamara* seed + 2 *Persicaria* sp. achene + 29 *Schoenoplectus lacustris* nut + 2 *Rumex maritimus* fruit +2 *Carex* sp. trigonous nut +2+1 frag *Rumex* sp. large achene, from context (367c); 1.055–1.065m down core, a major shell-rich silt that formed in the palaeochannel prior to construction of the platform.	2958±30	−26.5±0.22		
OxA-36405	19b [−2.205 to −2.215m OD]	3494±28	−28.2±0.2		

Laboratory number	Sample ID, material & context	Radiocarbon Age (BP)	$\delta^{13}C_{IRMS}$ (‰)	$\delta^{15}C_{IRMS}$ (‰	C:N ratio
	Waterlogged unidentified twig fragment, from the same context as 19a				
ETH-96047	<1349> [390] Animal bone, *Canis*, right rib (V Rajkovaca) from the 'disarticulated' remains (7 ribs, 2 mandibles, 1 tibia & 2 femurs) of a large dog found close together on the surface of river silt [368] and immediately below the shell influx layer [367]	3006±23	−20.3±0.1	7.6±0.1	3.5
OxA-36404	15a [−2.39 to −2.4m OD] Waterlogged plant remains, 1 *Ranunculus acris/bulbosus/repens* achene + 4 *Rumex* sp. small achene +1 small Ranunculus sp. achene + 1 Rubus subgen. Rubus seed + 1 frag *Alnus glutinosa* cone + 1 *Ilex aquifolium* seed + 1 *Alnus glutinosa* seed + 3 *Oenanthe* sp. mericarp + 1 Chenopodium sp. seed + 18 *Schoenoplectus lacustris* nut + 1 *Atriplex patula/prostrata* seed, from context (367a), 1.24–1.25m down core; a major shell-rich silt that formed in the palaeochannel prior to construction of the platform.	3000±29	−26.4±0.2		
SUERC-76591	15b [−2.39 to −2.4m OD] Waterlogged unidentified twig fragment, from the same context as 15a	3349±30	−27.7±0.2		
UBA-35747	10a[−2.76 to −2.77m OD] Waterlogged plant remains, 2+1 frag *Alnus glutinosa* cone + 3 *Oenanthe aquatica mericarp + 5 Rumex sp*. large fruit + *Sambucus sp*. seed + *1 Rumex sp*. small achene + *7 Schoenoplectus lacustris* nuts +*1 Rubus subgen Rubus* seed + *Carex sp. trigonous* nut, from context (380); 1.61–1.62m down core; a shell-rich silt lens within [381], a major deposit of freshwater silts laminated with thin bands of sand.	3267±34	−27.2±0.22		
SUERC-76192	10b[−2.76 to −2.77m OD] Waterlogged unidentified twig fragment, from the same context as 10a	3324±26	−27.0±0.2		
OxA-36403	2a[−3.25 to −3.26m OD] Waterlogged plant remains, *Alnus gutinosa* 8x cones + 7x cone fragments, from context (378), 2.1–2.11m down profile; a woody silt forming the first freshwater sediment in the palaeochannel underneath the platform	3301±27	−26.2±0.2		
SUERC-76191	2b[−3.25 to −3.26m OD] Waterlogged unidentified twig fragment, from the same context as 2a	3282±29	−27.3±0.2		

Table 30: Must Farm: MUS06 palaoechannel statistical consistency of radiocarbon determinations for duplicate samples from 10mm sediment samples

Sample ref.	Depth down profile	Laboratory Code	Radiocarbon Age (BP)	Statistical consistency (Ward and Wilson 1978; T'(5%)=3.8, ν=1;)
26 [−1.615 to −1.625m OD]	0.465–0.457m	UBA-35750	2698±30	T'=0.8
		SUERC-76592	2661±30	
24 [−1.905 to −1.915m OD]	0.755–0.765m	OxA-36406	2911±28	T'=160.4
		UBA-35749	3430±30	
19 [−2.205 to −2.215m OD]	1.055–1.065m	UBA-35748	2958±30	T'=169.5
		OxA-36405	3494±28	
15 [−2.39 to −2.4m OD]	1.24–1.25m	OxA-36404	3000±29	T'=70.0
		SUERC-76591	3349±30	
10 [−2.76 to −2.77m OD]	1.61–1.62m	UBA-35747	3267±34	T'=1.6
		SUERC-76192	3324±27	
2 [−3.25 to −3.26m OD]	2.1–2.11m	OxA-36403	3301±27	T'=0.2

FIGURES

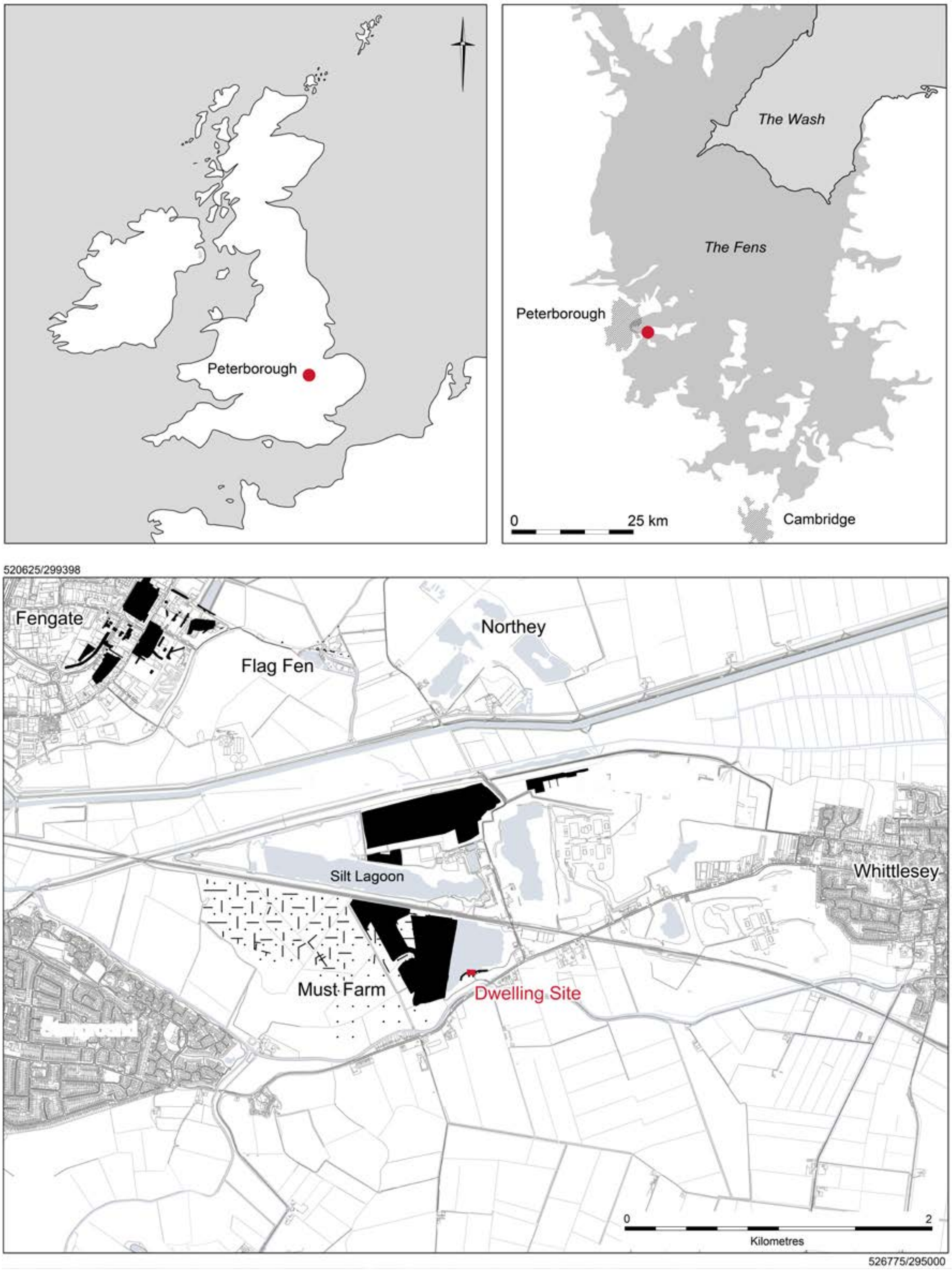

Figure 1: Site location (© Cambridge Archaeological Unit)

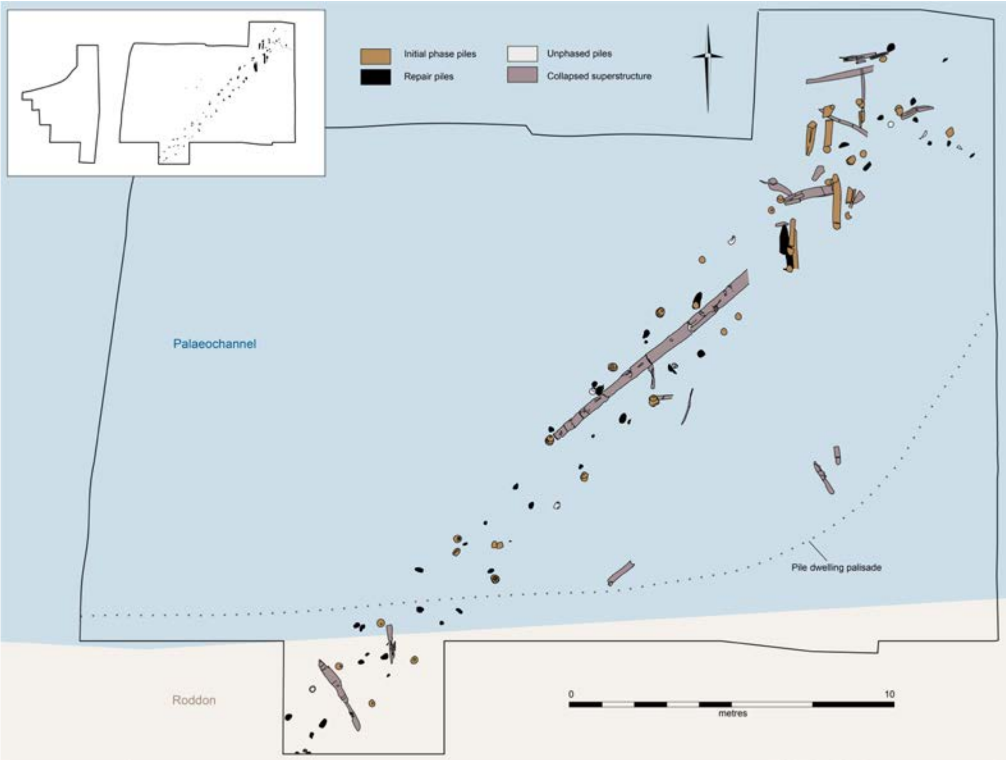

Figure 2: Plan of the Must Farm causeway (© Cambridge Archaeological Unit)

Figure 3: Causeway piles from initial phase: (a) deep-set bridge pile; (b) detail of 'carved lugs (© Cambridge Archaeological Unit)

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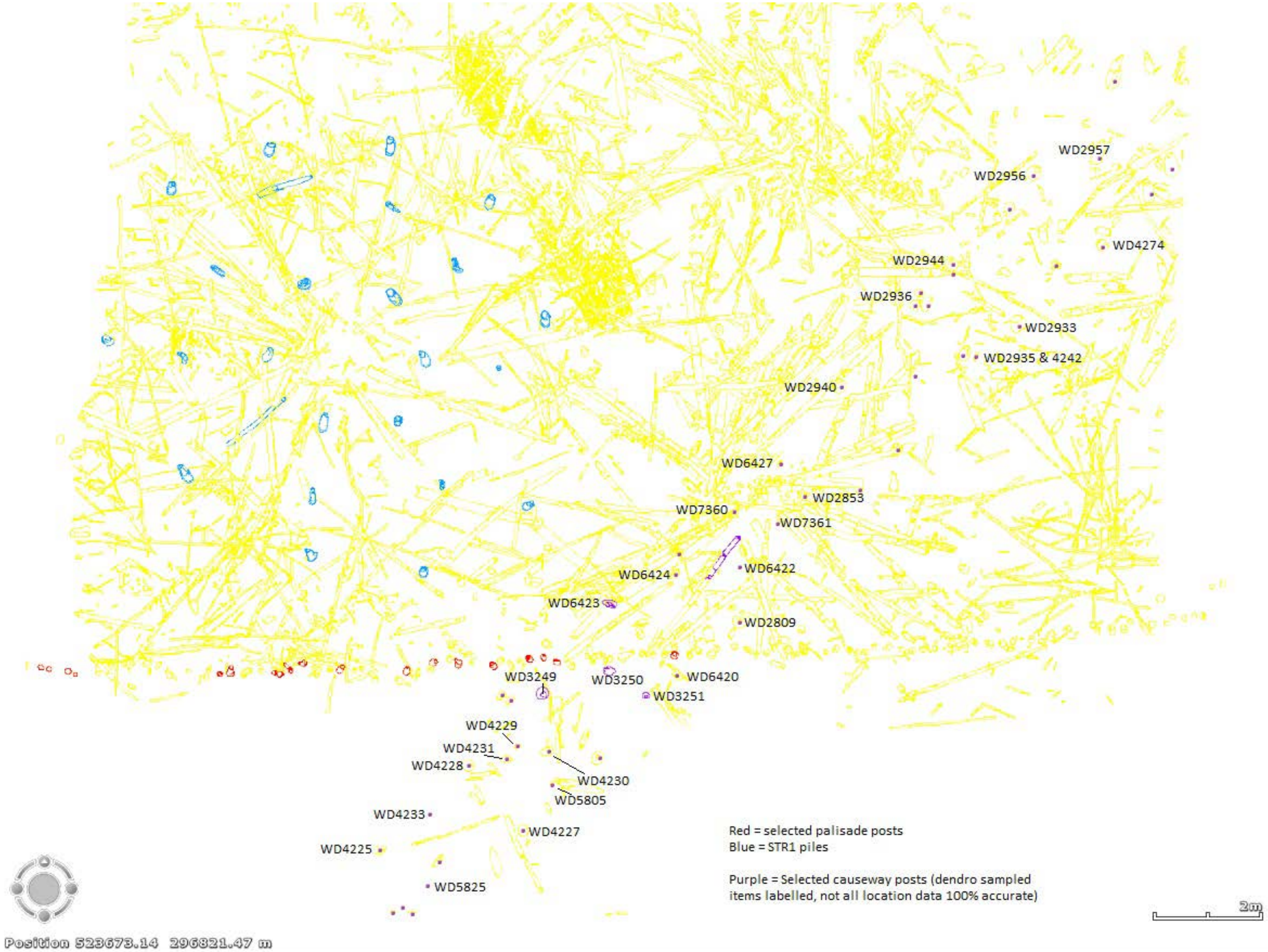

Figure 4: Causeway posts sampled for dendrochronological analysis, WD2809, WD2853, WD2933, WD2935, WD2936. (© Cambridge Archaeological Unit)

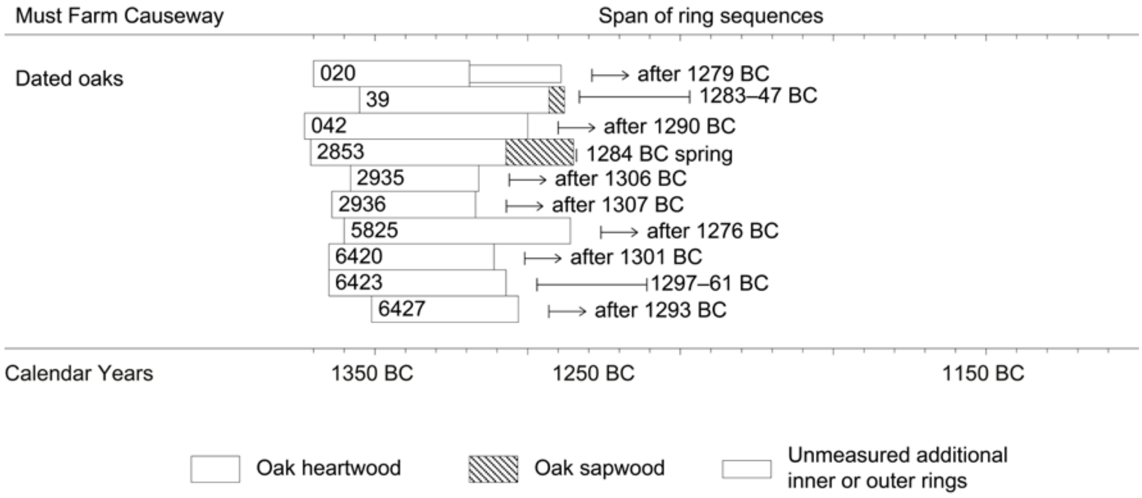

Figure 5: Bar diagram showing dated oak tree-ring sequences from the Must Farm causeway. Interpretations using a 10–46 year sapwood estimate

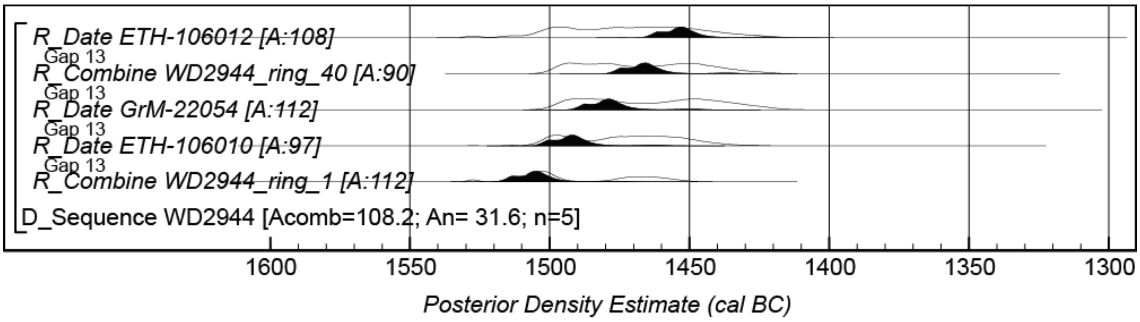

Figure 6. Probability distributions of dates from WD2944. Each distribution represents the relative probability that an event occurs at a particular time. For each of the dates two distributions have been plotted: one in outline, which is the simple radiocarbon calibration, and a solid one, based on the wiggle-match sequence. The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly

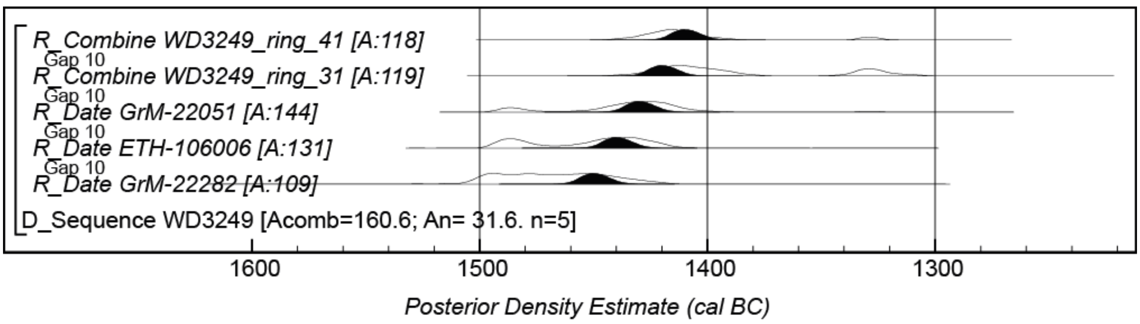

Figure 7. Probability distributions of dates from WD3249. The format is identical to that of Figure 6. The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly

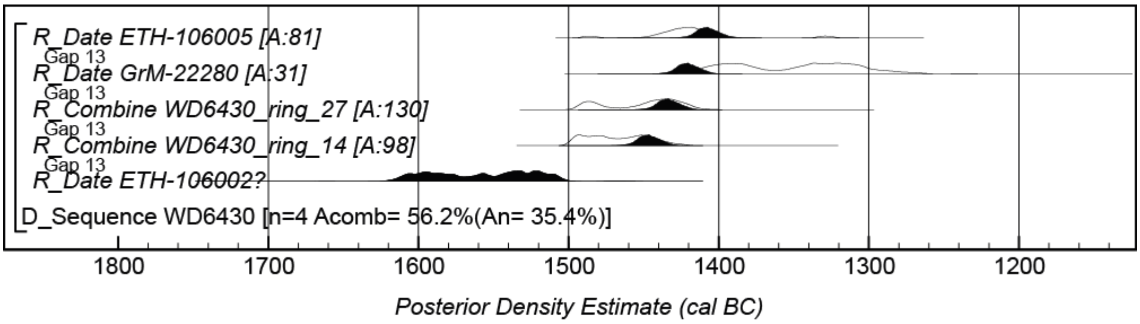

Figure 8. Probability distributions of dates from WD6430. The format is identical to that of Figure 6. The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly

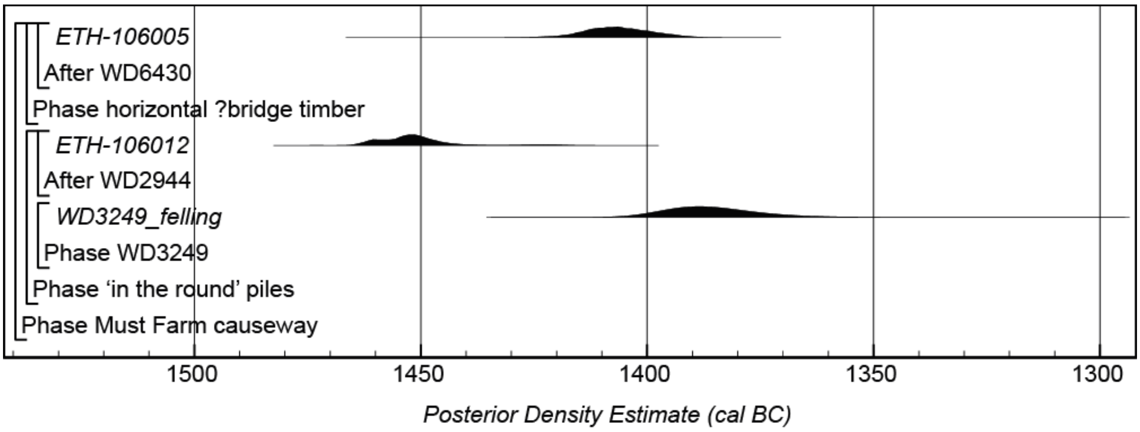

Figure 9. Probability distributions of dates from timbersWD3249, WD2944, and WD6430. The distributions are derived from the models shown in Figures 6–8

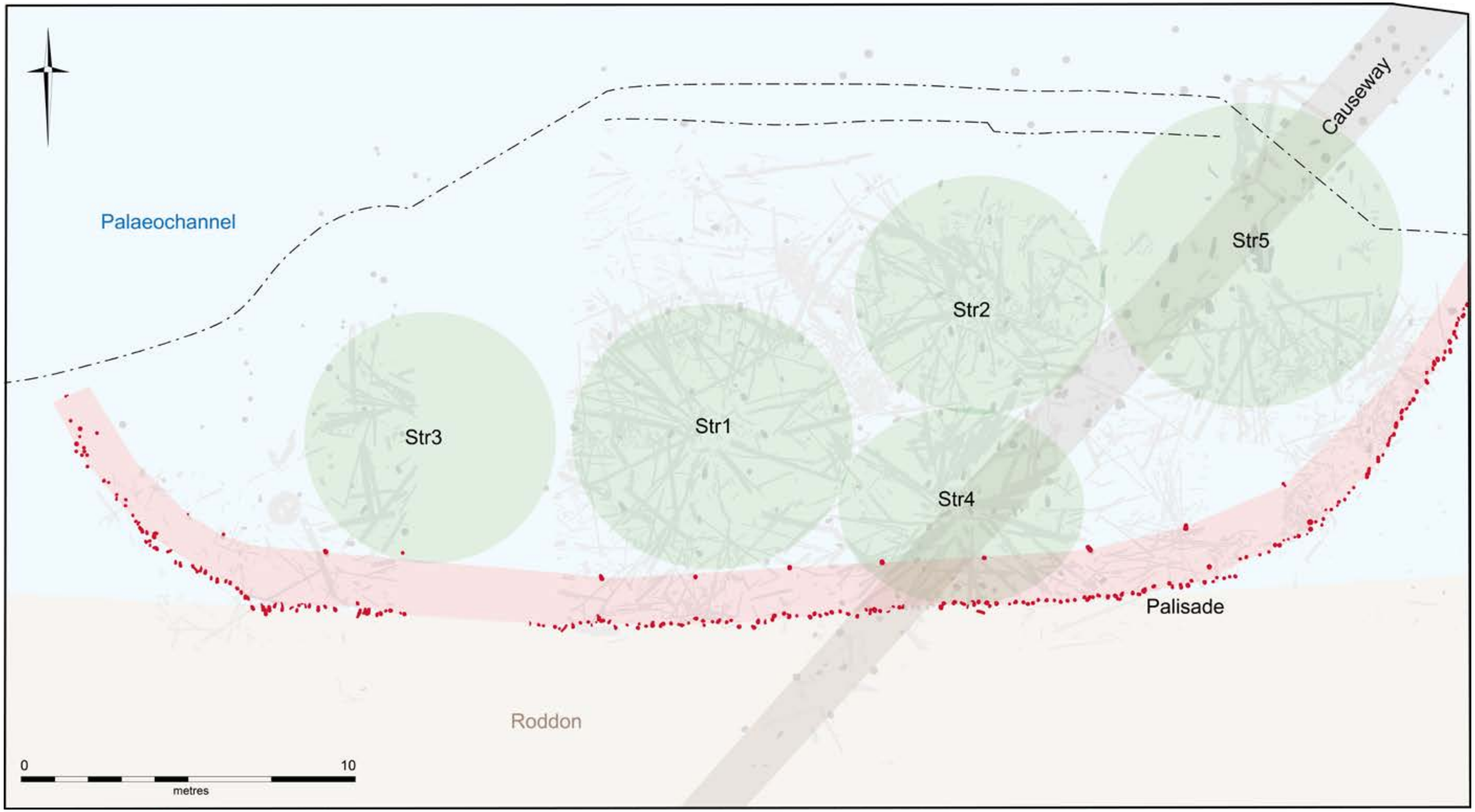

Figure 10: The pile-dwelling settlement and palisade. (© Cambridge Archaeological Unit)

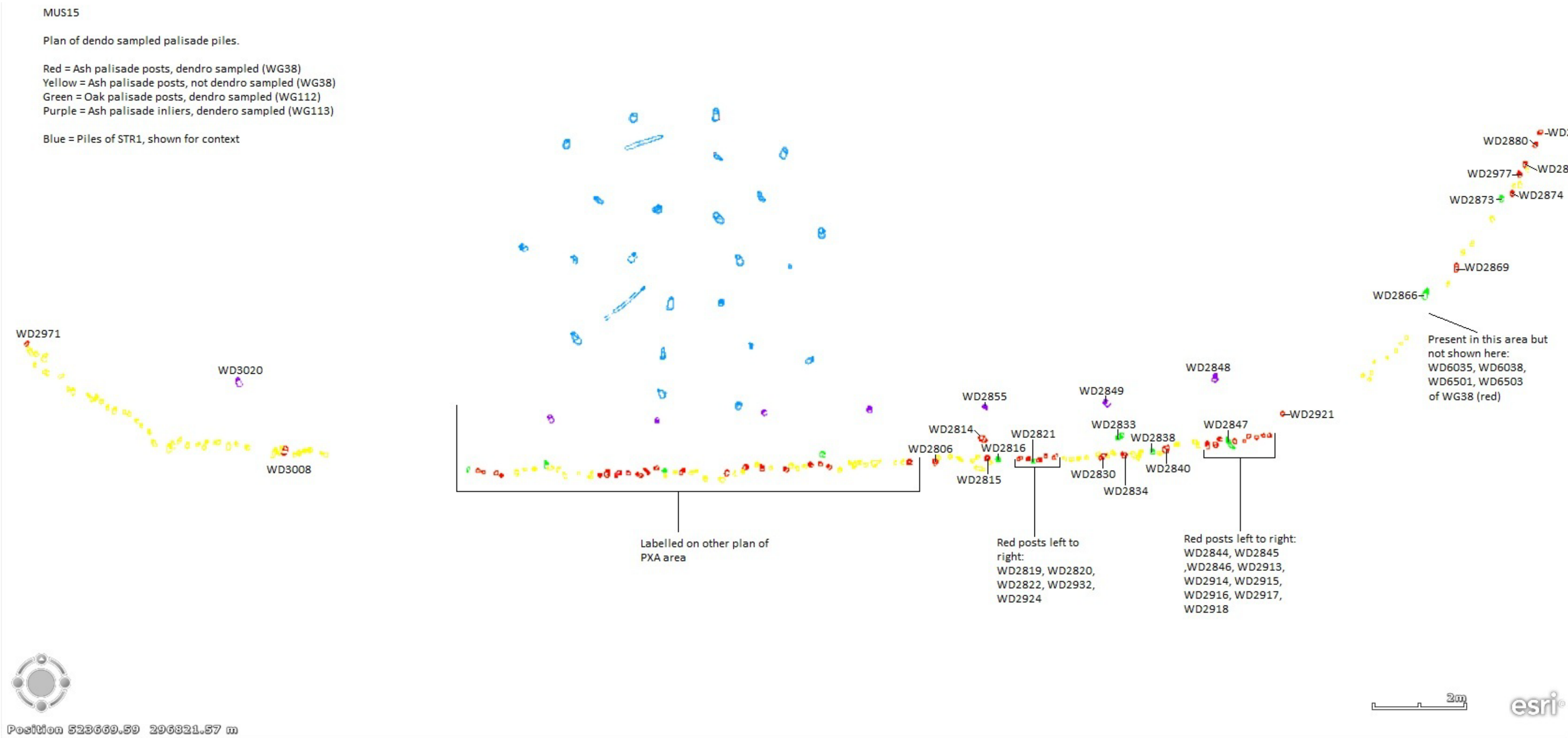

Figure 11: Palisade piles sampled for dendrochronology, WD2806, WD2815, WD2819, WD2820, WD2830, WD2834, WD2840, WD2845, WD2848, WD2849, WD2822, WD2881, WD2913, WD2914, WD2915, WD2916, WD2917, WD2918, WD2921, WD2869, WD2932, WD2924, WD3008, WD3020, WD6038, WF6501. (© Cambridge Archaeological Unit)

Figure 12: Palisade piles sampled for dendrochronology, WD2717, WD2718, WD2719, WD2731, WD2735, WD2737, WD2738, WD2743, WD2748, WD2753, WD2755, WD2759, WD2762, WD2770, WD2774, WD2777, and WD2781. (© Cambridge Archaeological Unit)

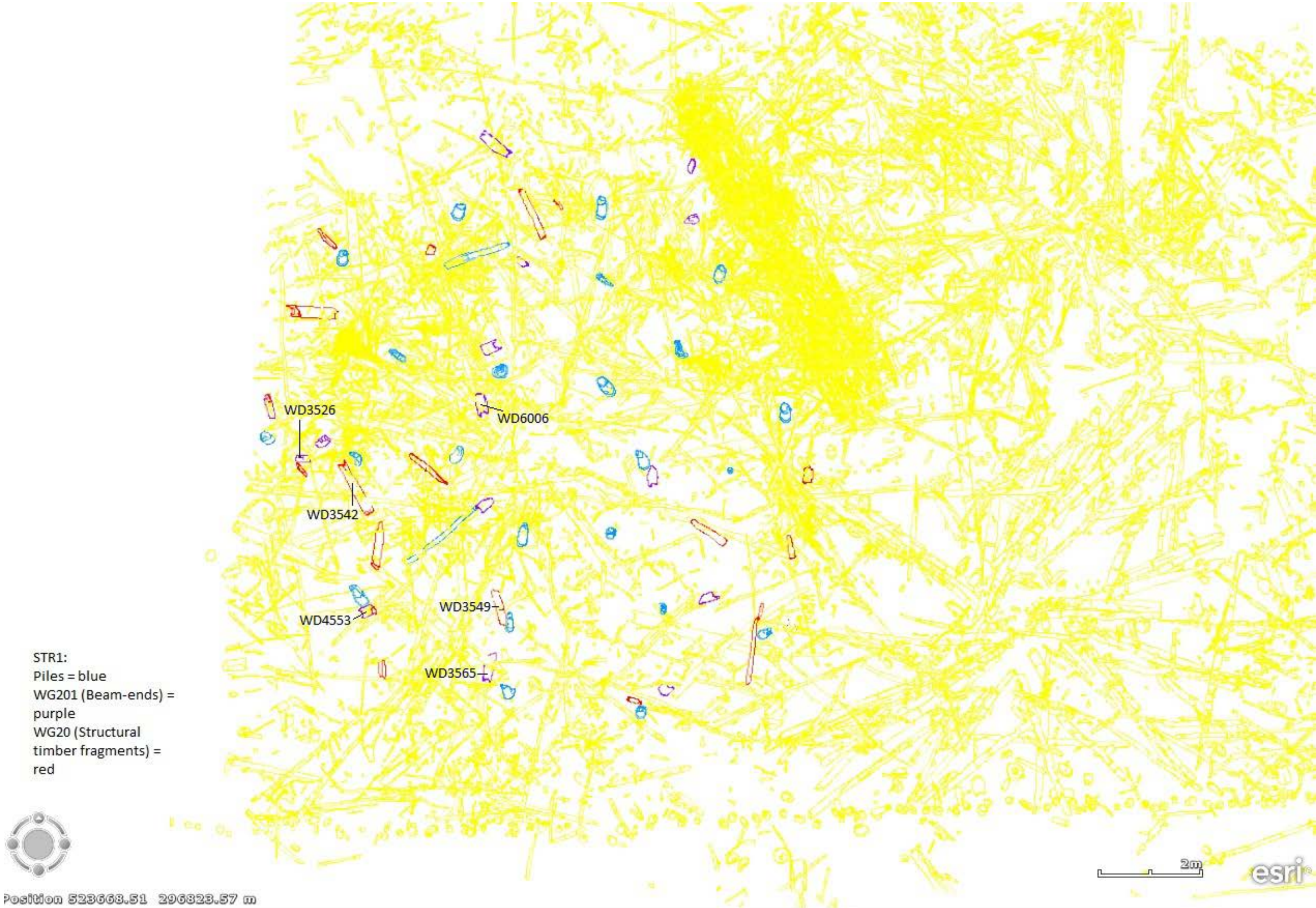

Figure 13: Structure 1 timbers sampled for dendrochronology, WD3256, WD3542, and WD3565. (© Cambridge Archaeological Unit)

Figure 14: Structure 1 timbers sampled for dendrochronology, WD3505, WD3600, WD3601, WD3626, WD3916, and WD3936. (© Cambridge Archaeological Unit)

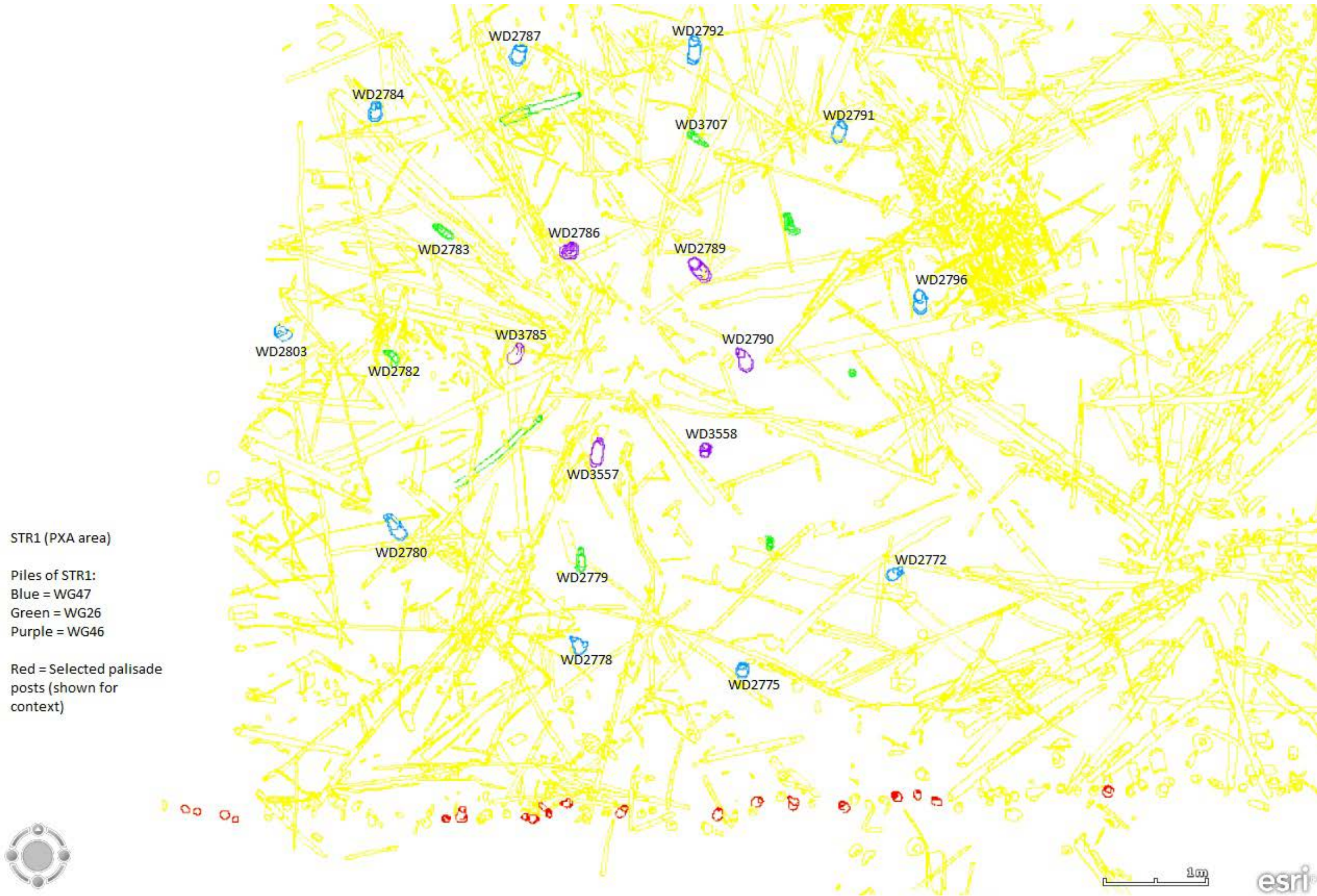

Figure 15: Structure 1 timbers sampled for dendrochronology, WD2772, WD2775, WD2784, WD2787, WD2780 and WD2803. (© Cambridge Archaeological Unit)

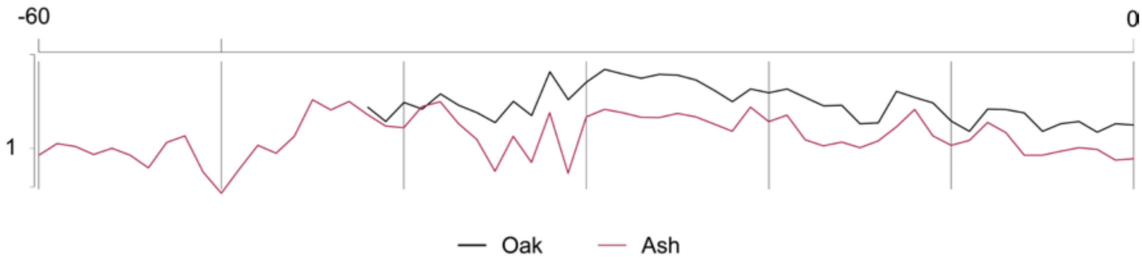

Figure 16: Pile-dwelling settlement composite tree-ring chronologies

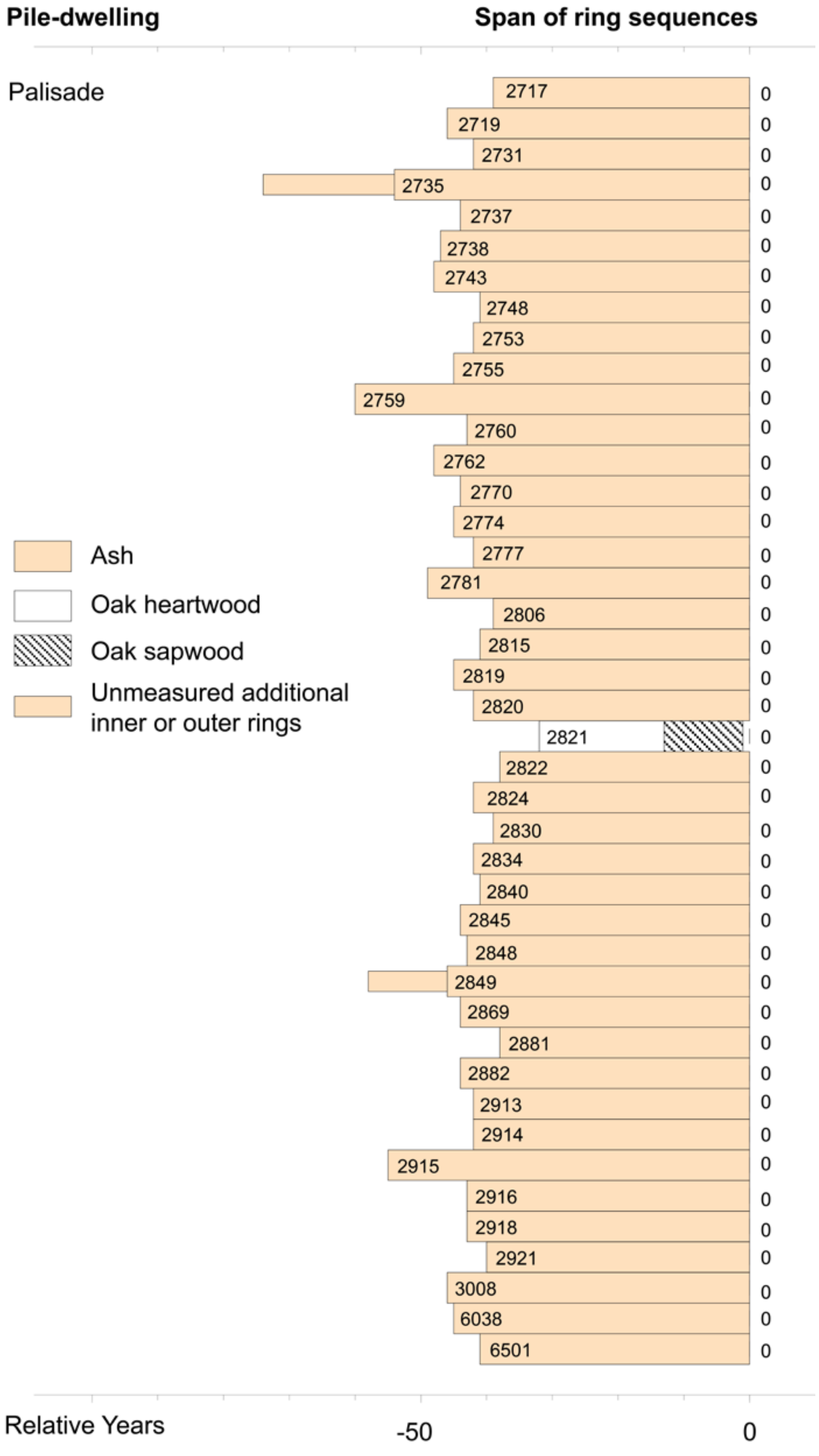

Figure 17: Bar diagram showing relatively dated oak and ash sequences from the pile-dwelling palisade. (Note the arbitrary horizontal scale of this and Figure 18 are the same, and deliberately use a zero-year to distinguish them from the absolute date diagrams.

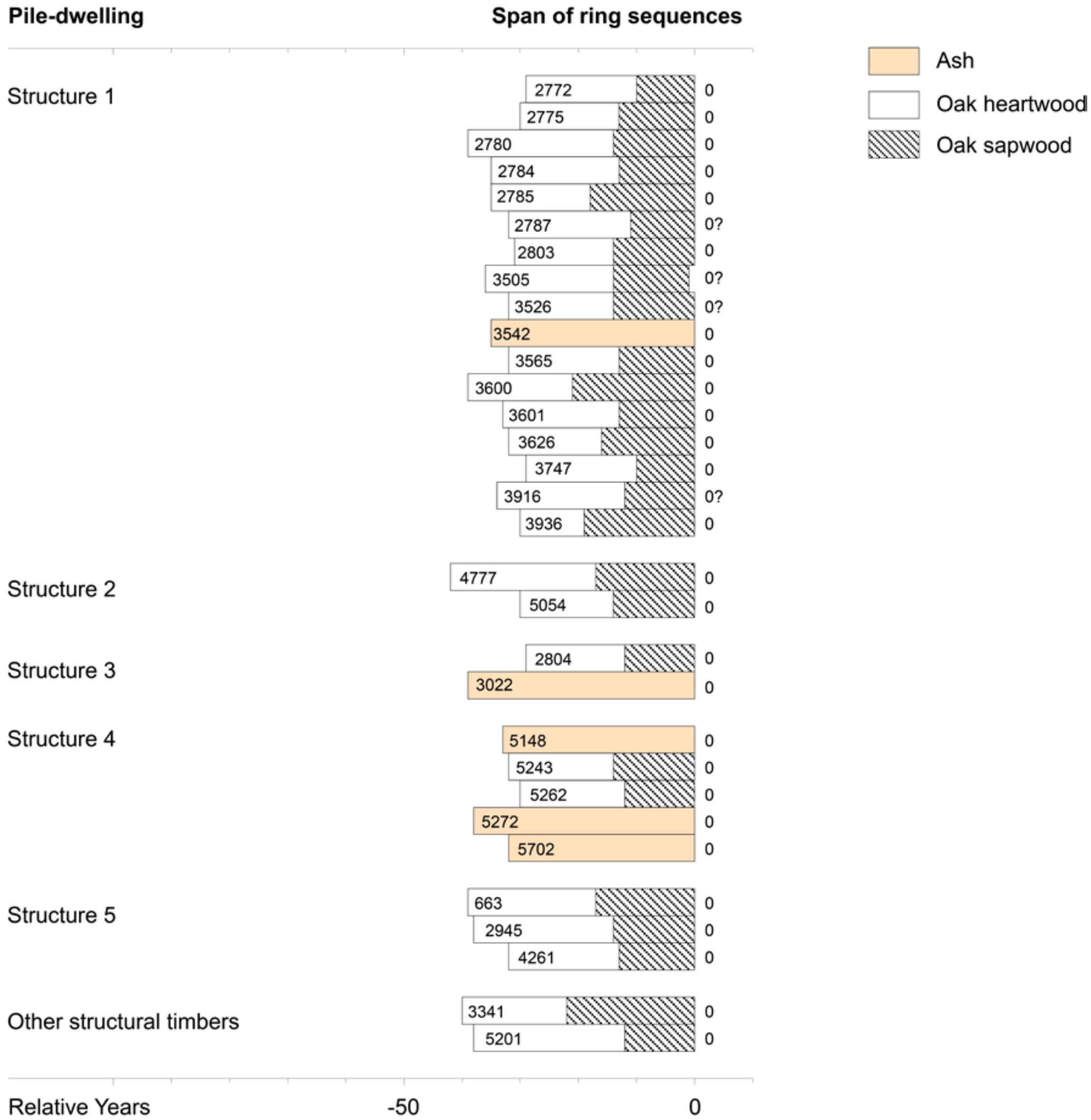

Figure 18: Bar diagram showing relatively dated oak and ash sequences from the pile-dwelling Structures 1–5 and other timbers. (Note the arbitrary horizontal scale of this and Figure 17 are the same, and deliberately use a zero-year to distinguish them from the absolute date diagrams. The heavy charring of several of the Structure 1 timbers has resulted in some potential loss of their outermost ring, these are given 0? Interpretations.)

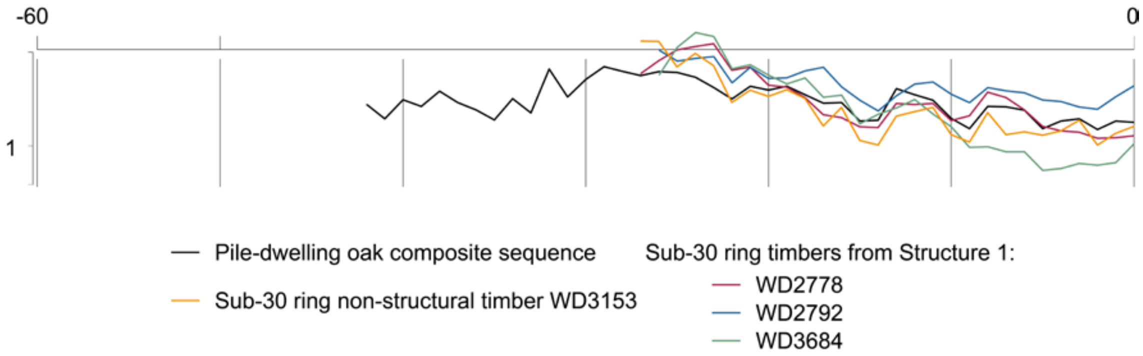

Figure 19: Visual comparison of four sub-30 ring oak series with the oak composite sequence from the pile-dwelling

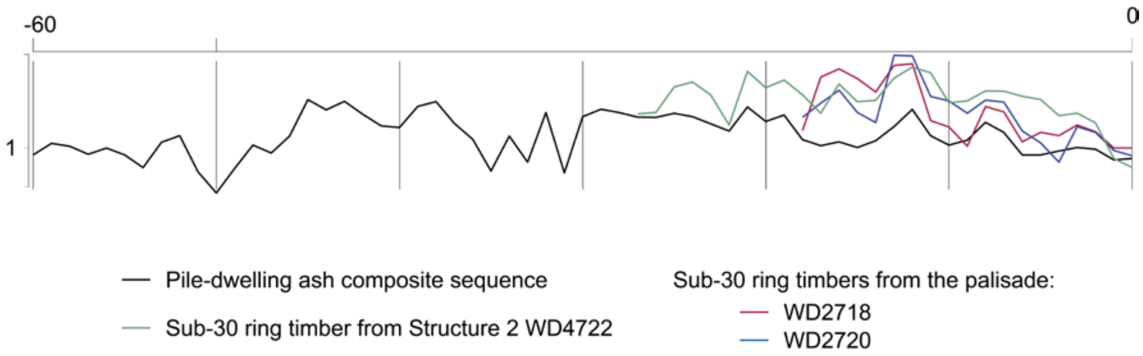

Figure 20: Visual comparison of four sub-30 ring oak series with ash composite sequence from the pile-dwelling

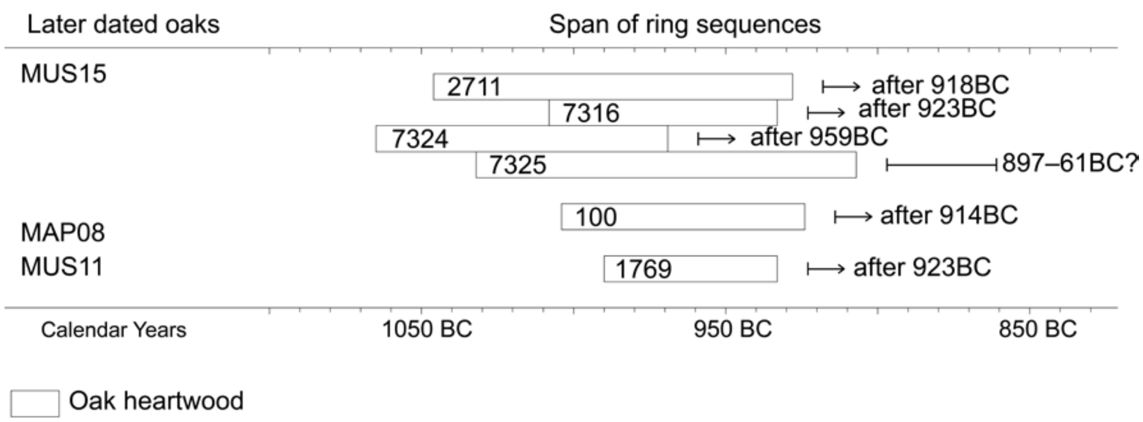

Figure 21: Bar diagram showing dated oak tree-ring sequences dated by reference to Flag Fen/Fengate and other datasets (MUS15=pile-dwelling excavation; MUS11 = palaeochannel excavation and MAP08=Horsey Hill

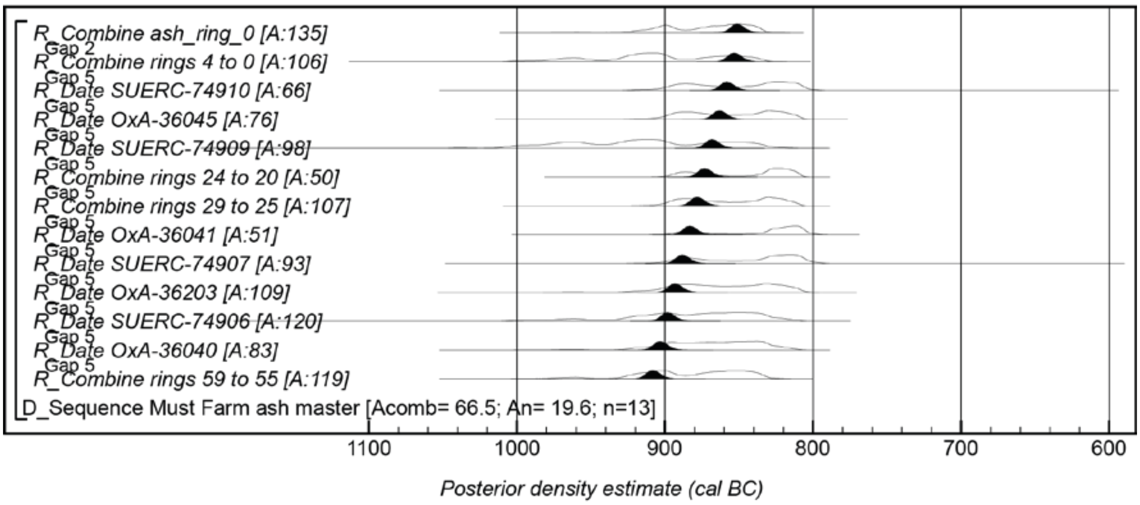

Figure 22: Probability distributions of dates from the ash master sequence (WD2759). The format is identical to that of Figure 6. The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly

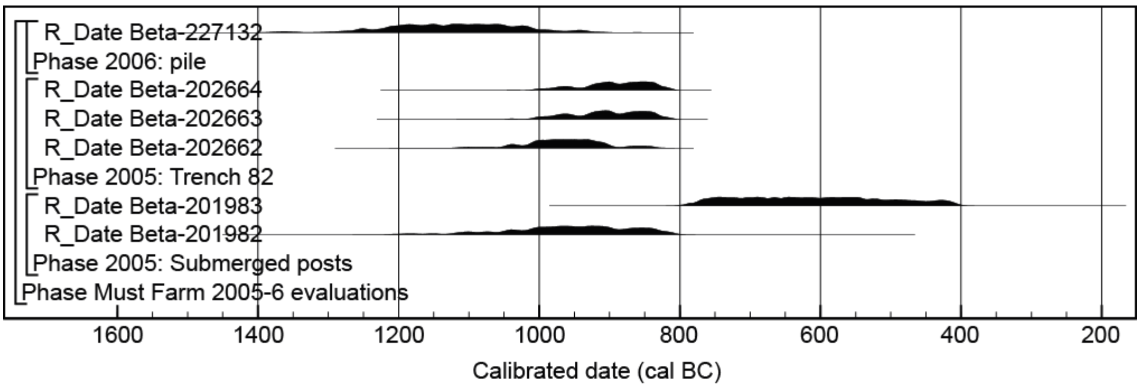

Figure 23: Probability distributions of dates from waterlogged timbers from the 2005–6 evaluation. The distributions are the results of simple calibration (Stuiver and Reimer 1993)

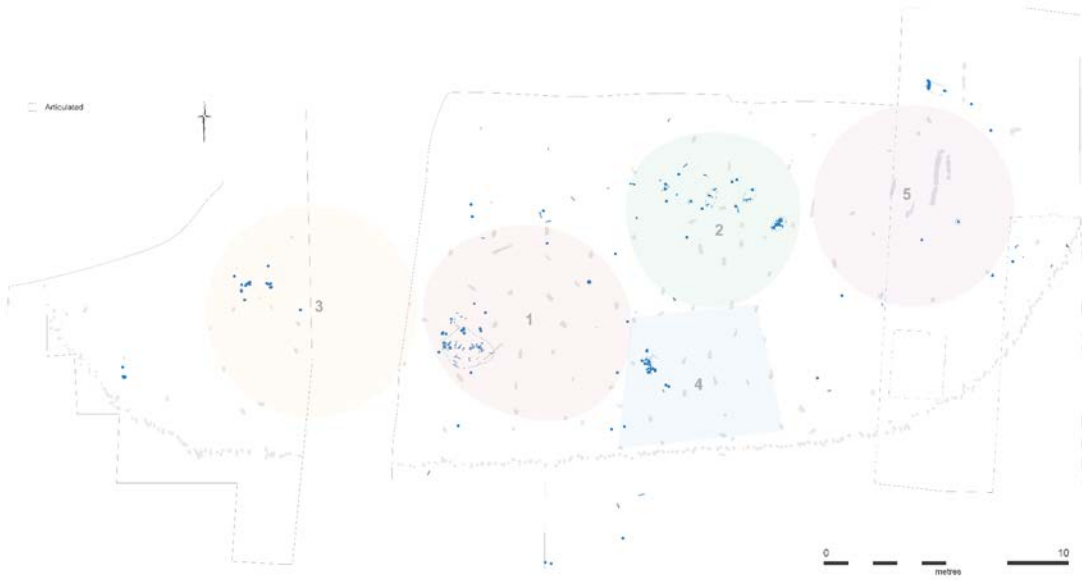

Figure 24: Distribution of associated/ articulated remains of lambs. (© Cambridge Archaeological Unit)

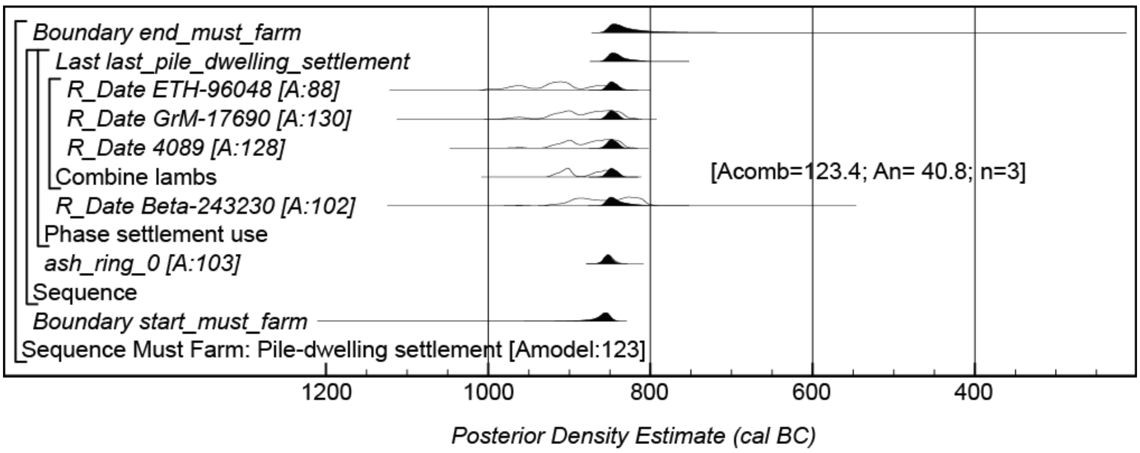

Figure 25: Probability distributions of dates from the Pile-dwelling settlement. Each distribution represents the relative probability that an event occurs at a particular time. For each of the dates two distributions have been plotted: one in outline, which is the result of simple radiocarbon calibration, and a solid one, based on the chronological model used. Other distributions correspond to aspects of the model. For example, the distribution 'last_pile_dwelling_settlement' *is the estimated date of the conflagration/abandonment event. The distribution ash_ring_0 is derived from the model shown in Figure 22. The large square brackets down the left-hand side of the diagram, along with the OxCal keywords, define the overall model exactly (http://c14.arch.ox.ac.uk/).*

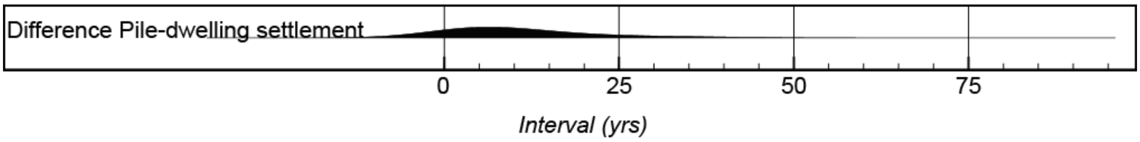

Figure 26: Probability distribution for the number of years during which Pile-dwelling settlement was in use, derived from the model defined in Figure 25.

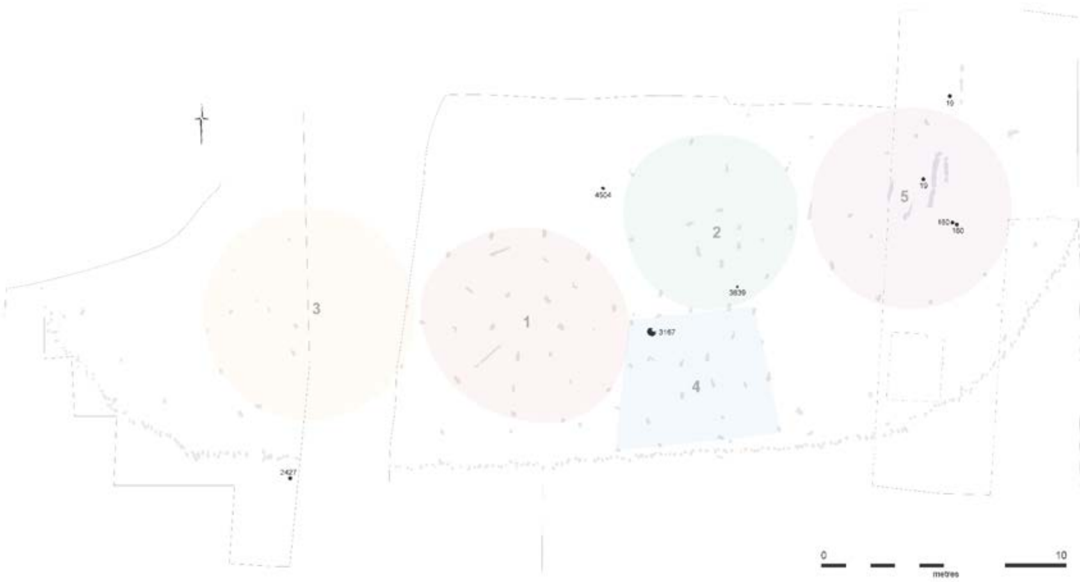

Figure 27: Location of human bone fragments. (© Cambridge Archaeological Unit)

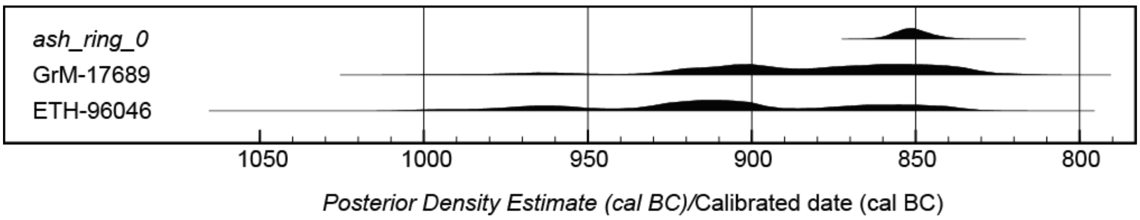

Figure 28. Probability distributions of dates for the human skull fragments and construction of the Pile-dwelling settlement (ash_ring_0; derived from the model shown in Fig 22)

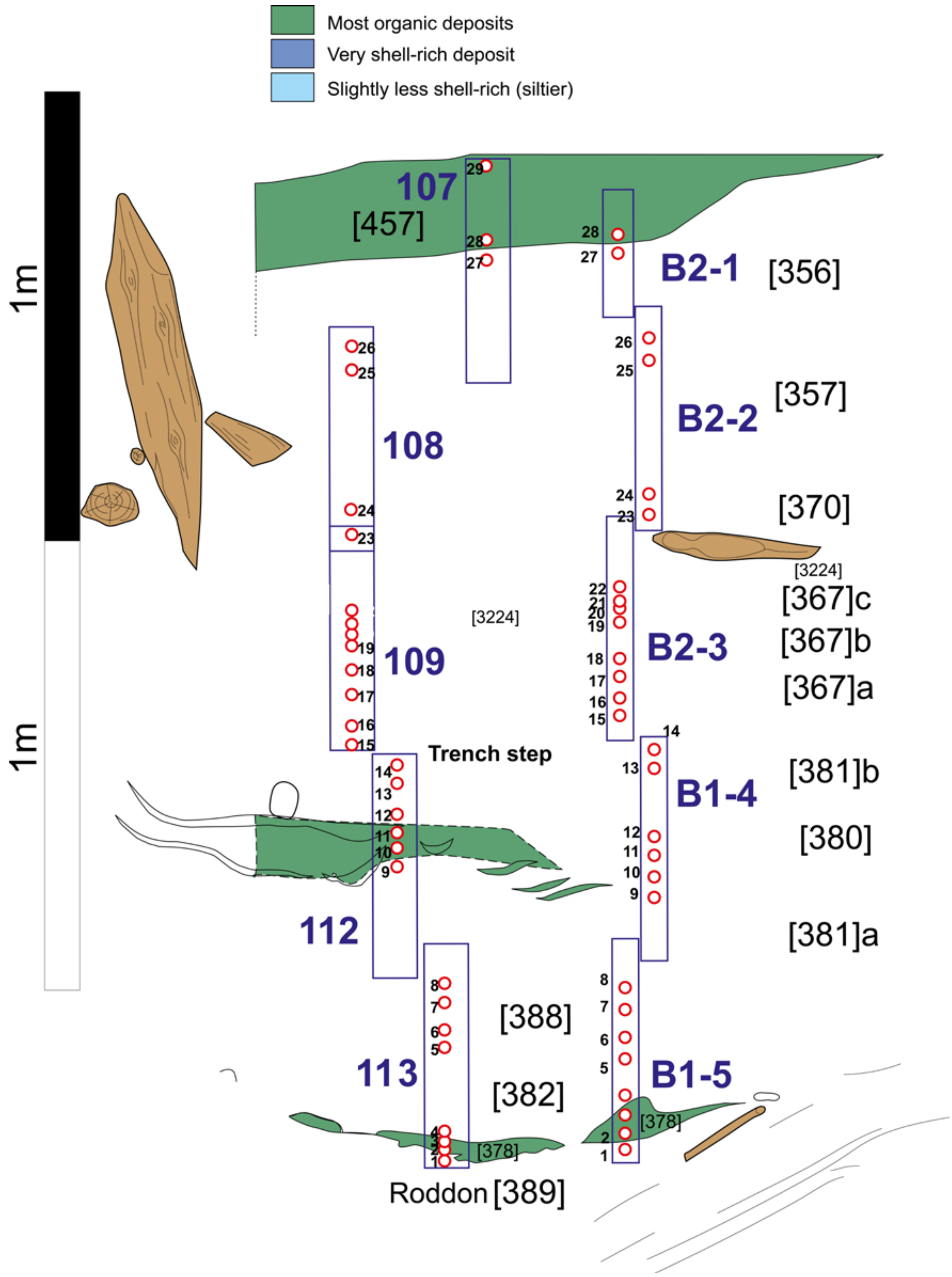

Figure 29: The palaeochannel (MUS06). (© Cambridge Archaeological Unit)

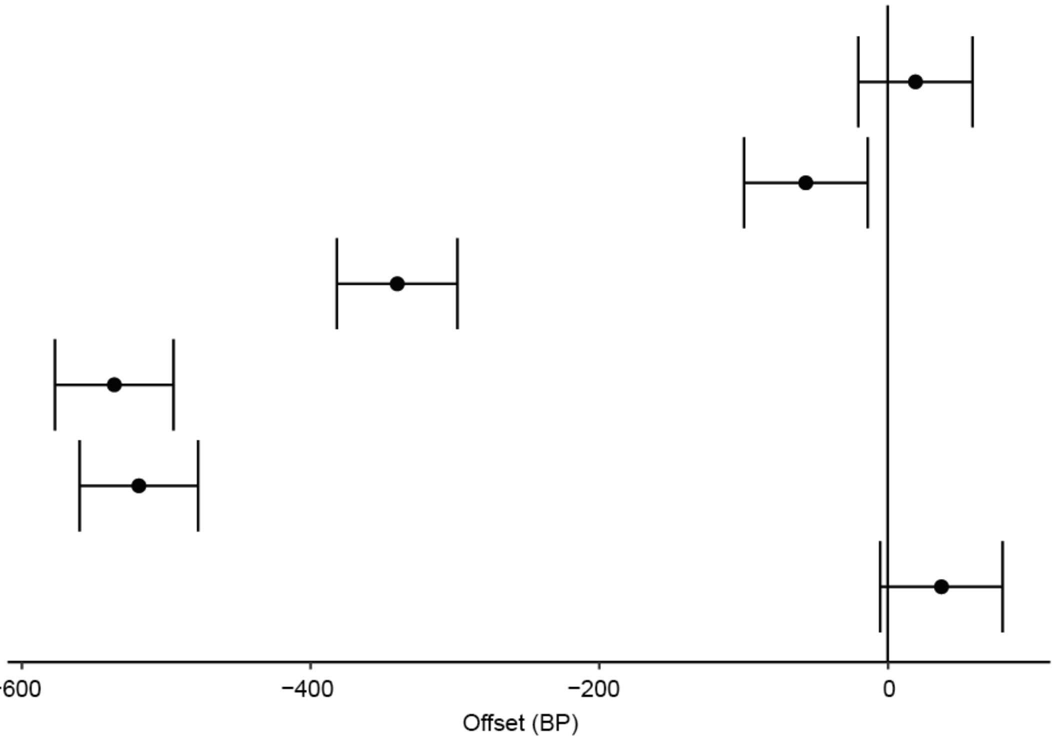

Figure 30. Offsets between pairs of radiocarbon measurements (bulked waterlogged plant remains and single twigs) from the sample 10mm palaeochannel horizon

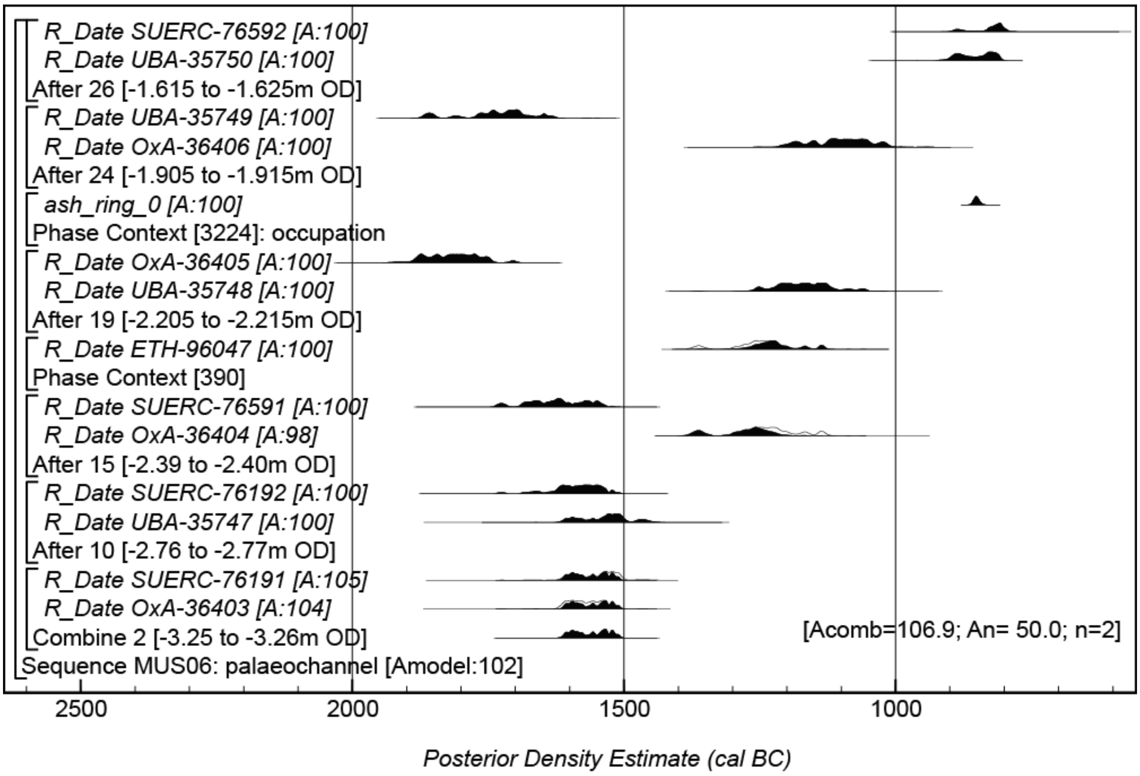

Figure 31. Probability distributions of dates from the palaeochannel (MUS06). The distribution ash_ring_0 *is derived from the model shown in Figure 22. The large square brackets down the left-hand side of the diagram, along with the OxCal keywords, define the overall model exactly (http://c14.arch.ox.ac.uk/).*

APPENDIX 1: TREE-RING DATA

100=1mm

MAP08 100

203	238	200	157	117	97	176	96	81	77
145	141	144	97	162	153	110	154	189	153
166	229	114	85	130	80	100	128	169	120
79	84	111	150	91	100	112	206	218	120
128	143	103	85	92	57	81	81	160	122
168	138	101	114	148	107	107	129	185	104
150	150	116	84	102	109	67	99	158	113
162	184	143	138	151	158	131	129	153	107
135									

MUS06 20

285	413	316	159	191	276	281	195	191	230
149	216	112	211	254	417	270	140	123	128
67	68	39	51	105	139	109	87	61	51
52	83	44	93	86	48	47	77	57	45
38	48	37	42	41	52	48	46	51	60
47	38								

MUS06 38

428	279	398	409	413	566	481	423	455	514
465	442	454	386	402	356	397	372	333	423
397	375	402	351	258	279	350	458	527	331
292	191	211	181	399	336				

MUS06 39

254	650	394	375	598	342	398	150	215	288
293	257	191	168	212	329	314	132	224	223
155	209	259	171	148	224	278	83	132	315
220	156	137	168	191	221	183	156	181	162
186	81	78	85	89	132	142	110	67	72
121	78	77	117	126	87	97	89	110	140
122	128	112	116	144	110	149	139		

MUS06 42

445	383	403	536	479	484	397	541	664	474
438	338	378	259	397	192	346	358	416	409
236	185	194	167	144	181	230	258	331	339
193	167	172	262	248	236	301	296	163	268
177	130	105	156	182	78	232	267	168	94
128	166	166	175	100	82	104	93	111	74
73	129	126	146	191	126	89	102	106	80
88	82	109	91						

MUS06 55

288	250	228	328	341	274	345	396	380	279
400	424	313	261	220	313	334	331	191	359
305	221	233	126	250	213	256	243	203	198
231	127	147	159	238	229	206	186	159	143
145									

MUS06 127

260	123	145	100	57	56	60	51	64	95
225	266	228	160	138	175	166	196	166	153
85	115	80	136	86	117	146	151	127	92
108	93	85	82	99	85	91	68	63	50
54	49	32	45	59	42	45	53	44	43
40									

MUS06 128

247	265	106	130	149	59	47	40	35	111
91	169	55	226	372	307	166	116	176	129
144	95	144	155	130	68	41	44	61	72
140	216	88	116	128	149	203			

MUS06 163

361	387	373	420	353	511	146	192	261	366
413	325	111	105	152	158	80	78	91	69
78	151	167	245	99	98	110	149	188	261
227	121	101	131	252	105	132	97	84	57
88	59	74	102	176	66	84	104	95	270
252	227	444	465	458	424				

MUS06 180

578	581	487	467	557	569	499	717	332	370
264	301	345	421	502	533	292	347	249	346
272	391	410	606	536	307	182	290	287	321
383	332	366	189	223	254	83	66	71	107
127	106	114	140	144	238				

MUS06 181

193	186	115	277	274	195	258	303	250	311
214	175	120	60	83	67	131	237	89	119
163	95	72	108	68	75	116	102	128	140
175	140	122	83	87	139	154	74	82	74
110	117	73	60	62	71	95	61	69	72
90	85	86	110	66	49	125	77	74	71
132	104	163	163	133	108	128	153	136	176
314	349	218	179	191	170	172	228	252	204
153	188	263	230	74	63	68	82	60	92
200	225	72	67	100	161	140	309	317	89
80	81	118	276	166	214	221	102	133	137
96	130	251	324	304					

MUS06 186

365	328	209	443	325	240	313	344	255	200
196	280	240	293	259	224	241	324	259	278
251	161	128	209	252	275	260	357	320	336
347	289	173	233	152	201	237	151	137	116
155	109	198	139	219	177	242	151	206	169

MUS06 362

157	190	140	144	97	195	125	184	200	136
224	187	165	109	144	183	245	372	510	395
51	56	64	42	65	70	116	150	214	212
365	372	413	355	339	391	85	115	104	249
297	359	555	260	244	408	378	524	124	103
245	226	218	151	156	186	319			

MUS06 369

74	64	74	72	125	135	159	197	111	108
116	75	74	152	175	142	182	105	55	75
76	90	64	76	134	167	284	228	208	145
115	195	182	129	145	292	282	310	232	121
137	184	387	504	488	257	271	200	231	233
290	206	292	343	191	72	181	326	243	257
395	443	554	402	133	86	225	348	350	193
103	81	100	191	208	311	313	309	261	225
241	157	159	119	126	194	256	264	91	69
82	106	135	59	56	47	90	129	167	93
92	100								

MUS06 663

218	228	238	252	250	381	289	474	318	368
345	303	179	157	145	95	84	104	112	77
78	41	31	36	49	49	92	104	109	74
52	92	98	62	63	56	55	45	62	64

MUS10 1475

78	45	51	60	88	72	60	82	111	102
81	93	76	80	70	61	69	85	102	110
81	87	132	75	44	49	50	60	113	72
85	83	145	127	110	102	120	91	70	115
104	103	93	140	96	125	101	170	190	118
116	86	79	70	104	159	128	119	91	98
99	109	76	110	122	124	139	148	88	135
166	118	93	111	123	100	102	88	117	99
113	103								

MUS11 1550

569	468	328	262	211	275	366	357	237	221
338	255	144	177	299	300	274	252	330	243
170	178	139	160	189	177	172	122	112	92
88	125	202	112	107	76				

MUS11 1769

243	244	144	185	220	171	168	195	132	116
192	163	191	160	201	186	93	126	194	207
154	203	250	234	319	144	158	208	156	125
161	83	111	143	203	171	162	116	103	131
143	103	126	143	157	123	157	185	151	111
89	128	71	87	131	127	180	169		

MUS15 2700

189	167	250	344	198	235	212	212	263	206
187	214	239	120	183	234	181	110	71	121
207	158	172	186	127	189	258	192	245	244
164	171	182	139	221	142	184	156	229	174
260	213	274	184	106	178	228	148	96	100
85	97	103	120	140	164	225	218	200	169
214	143	160							

MUS15 2709

118	81	88	98	89	50	43	54	74	88
68	130	120	174	170	129	110	261	274	269
514	389	335	465	447	433	105	43	70	86
119	245	280	257	265	257	451	380	843	571
633	520	585	680	694	777	667	653	788	628
521	601	628	550	581	379	576			

MUS15 2711

194	181	180	193	177	192	173	211	107	118
128	154	210	242	190	197	170	123	147	106
169	192	247	121	110	156	180	107	128	228
221	177	250	142	105	82	100	98	137	131
105	165	190	235	129	112	99	90	147	107
67	65	86	107	104	98	251	160	102	115
146	141	170	230	103	81	148	110	162	119
165	160	74	83	84	165	111	87	103	164
183	102	122	145	106	109	113	64	102	84
176	148	231	173	111	94	85	83	180	141
151	118	125	184	125	90	73	132	72	87
144	102	120	148	133	89	83	85	64	

MUS15 2713

349	233	148	145	180	151	250	265	344	260
153	296	288	247	554	541	469	582	561	404
424	467	474	411	326	347	259	290	120	68
70	154	234	206	245	230				

MUS15 2717

304	151	84	61	50	78	84	120	46	95
127	126	99	40	159	72	65	61	119	83
56	53	60	79	148	141	195	351	177	124
83	239	232	124	134	187	193	101	126	114

MUS15 2718

134	328	376	319	255	399	409	158	142	103
200	183	111	130	123	147	131	100	100	

MUS15 2719

269	399	192	264	168	175	205	237	277	227
210	80	111	89	129	43	102	128	143	133
161	140	130	60	67	61	69	69	44	65
56	59	74	70	127	69	67	115	141	83
85	81	112	98	136	93	98			

MUS15 2720

167	212	263	181	153	472	467	237	220	179
223	216	133	109	79	143	130	96	88	

MUS15 2731

373	162	116	172	138	108	81	79	87	44
72	29	104	81	97	71	54	78	62	64
58	66	62	107	101	77	80	90	106	147
205	88	94	145	246	288	187	135	155	66
70	43	45							

MUS15 2735

68	158	155	66	65	78	124	134	50	277
147	136	50	45	24	52	45	46	41	50
138	69	277	138	271	338	258	216	173	71
63	59	50	41	31	68	41	56	50	60
83	176	170	88	90	58	146	111	56	85
53	51	52	39	32					

MUS15 2737

127	237	105	79	100	176	192	140	72	42
65	62	104	30	108	157	233	199	183	99
84	30	30	30	134	168	32	29	90	197
239	395	360	182	184	98	97	99	64	74
77	75	99	80	77					

MUS15 2738

113	156	36	61	108	61	90	74	88	109
55	42	34	74	46	140	35	142	180	185
134	119	162	123	120	94	94	50	71	34
31	36	33	49	77	149	106	69	123	192
219	142	169	221	252	209	160	204		

MUS15 2743

99	33	32	89	228	255	146	107	154	214
260	162	161	65	172	104	392	118	406	405
471	287	329	319	282	230	279	327	292	211
70	82	92	79	104	114	213	88	85	104
160	135	77	91	42	40	53	44	57	

MUS15 2748

257	241	302	308	183	140	85	123	70	144
51	137	125	108	107	76	95	68	68	47
65	58	72	51	68	93	72	78	106	135
133	134	124	133	122	127	126	98	113	125
94	93								

MUS15 2753

208	290	180	128	229	160	141	56	193	72
237	61	212	126	57	47	68	87	90	56
35	62	53	54	45	93	147	182	219	409
478	174	183	180	251	198	128	149	185	97
126	81	87							

MUS15 2755

180	149	172	109	121	182	226	250	141	81
55	90	69	122	57	140	152	178	194	199
180	186	175	171	249	158	206	77	63	57
62	81	79	138	132	85	84	145	122	76
47	81	104	118	106	117				

MUS15 2759

89	108	103	90	100	110	64	66	115	78
47	56	68	63	59	189	160	148	104	74
85	124	181	88	133	60	130	90	175	46
140	148	142	133	144	138	137	70	108	176
128	113	113	89	94	61	56	35	39	56
39	46	64	45	37	38	29	30	40	41
38									

MUS15 2760

374	280	120	63	157	67	102	94	45	96
66	207	89	173	141	147	147	123	103	127
129	90	76	96	119	63	60	49	45	53
62	87	46	47	49	64	44	32	36	39
29	39	28	27						

MUS15 2762

91	79	166	213	188	177	129	116	93	183
190	91	41	37	101	74	119	52	116	165
143	89	89	105	79	103	59	143	84	118
96	107	118	106	84	122	207	152	139	170
196	135	134	157	203	141	124	77	58	

MUS15 2770

174	158	111	126	149	213	208	232	224	97
161	131	252	91	248	271	247	194	303	308
188	181	151	315	201	251	160	141	131	104
89	106	131	110	78	105	136	100	63	40
44	61	90	81	80					

MUS15 2772

642	664	592	611	652	420	284	263	379	302
314	281	240	242	123	126	279	213	192	115
104	203	207	270	167	181	242	197	186	168

MUS15 2774

576	309	293	273	236	228	175	191	143	91
56	100	58	53	38	92	102	105	117	110
109	114	82	79	145	131	118	100	83	85
74	60	68	75	80	90	106	122	119	81
98	105	92	130	114	116				

MUS15 2775

292	316	432	468	566	506	508	378	314	311
315	309	227	197	223	184	162	262	227	219
165	108	184	151	159	126	143	106	94	121
131									

MUS15 2777

260	172	136	150	141	128	79	53	94	48
62	24	74	141	142	159	198	255	306	316
148	381	294	367	68	109	122	78	103	99
161	164	181	161	217	160	156	180	166	154
165	116	184							

MUS15 2778

334	416	499	528	553	354	374	276	267	224
168	160	137	135	203	199	203	152	165	245
224	182	138	128	125	113	114	118		

MUS15 2780

249	303	159	230	97	230	144	316	216	242
315	235	261	222	219	275	217	190	220	220
225	194	160	148	89	112	162	156	154	109
99	127	178	154	127	127	132	112	122	135

MUS15 2781

114	191	141	103	150	197	404	249	133	95
135	145	115	107	61	103	73	164	95	248
270	283	255	189	200	182	137	145	196	163
119	69	63	58	53	55	56	62	39	24
33	34	34	31	31	30	27	23	28	24

MUS15 2784

182	114	110	394	277	387	401	333	383	466
504	425	369	260	352	310	343	268	239	209
147	157	172	178	169	145	139	236	143	179
126	140	165	155	138	122				

MUS15 2785

162	203	136	271	145	191	301	342	278	324
306	312	268	224	283	214	289	231	175	157
107	129	264	158	172	136	116	167	176	138
86	91	136	97	86	139				

MUS15 2787

456	244	357	460	369	358	327	287	311	264
173	303	283	312	248	226	235	179	184	305
269	227	149	150	168	160	161	124	119	139
109	149	127							

MUS15 2792

498	414	433	446	287	373	309	313	351	373
268	214	179	231	281	291	237	206	265	251
243	215	210	191	184	227	273			

MUS15 2803

137	229	301	351	333	383	500	427	335	257
264	277	301	297	230	215	144	153	262	244
244	153	143	196	212	182	92	105	105	101
176	133								

MUS15 2804

448	446	477	578	460	398	333	270	272	254
295	236	204	179	118	138	228	196	175	135
136	225	248	186	171	179	178	165	231	189

MUS15 2806

295	298	183	166	71	127	96	204	49	169
169	170	177	165	188	195	145	133	117	127
99	49	33	49	47	85	113	183	142	115
179	218	188	133	143	176	167	133	145	138

MUS15 2809

334	177	298	326	401	385	274	334	342	293
372	229	313	317	236	372	348	313	449	581
586	252	229	213	315	412	127	158	73	80
50	52	93	111	221	238	484	304	243	245
452	391	514	632	386	158	119	100	107	149
189	257	364	248	173	222	199	231	265	449

MUS15 2815

145	104	162	208	157	84	60	91	67	151
119	309	323	290	359	338	346	317	185	215
334	204	258	121	125	106	92	89	69	118
77	71	96	127	99	99	88	76	110	105
83	69								

MUS15 2819

102	125	105	85	140	143	178	230	127	59
66	72	58	95	42	136	108	130	109	116
175	193	135	159	168	166	139	226	108	113
105	79	64	59	99	69	74	104	95	70
49	76	102	76	87	85				

MUS15 2820

140	129	111	146	185	169	131	69	131	85
217	58	235	289	204	194	188	138	161	116
97	84	55	34	30	22	27	25	85	161
182	175	201	149	214	172	149	105	99	193
169	140	97							

MUS15 2821

216	152	210	262	198	233	271	232	288	270
204	241	212	243	191	170	136	115	105	204
217	174	159	156	193	156	151	103	122	110
101	104								

MUS15 2822

319	291	224	141	133	176	185	59	155	214
232	197	189	177	222	175	160	201	184	196
259	187	154	125	128	74	69	80	89	107
119	78	71	51	58	47	59	59	57	

MUS15 2824

279	190	149	161	166	102	93	57	120	80
134	46	88	70	65	84	78	72	88	107
84	172	132	225	167	118	118	105	111	161
237	225	167	191	249	158	97	117	133	138
130	102	114							

MUS15 2830

520	379	134	127	39	101	98	262	89	178
259	199	198	153	197	158	246	146	219	152
209	70	95	109	104	117	162	224	81	76
84	124	180	58	55	42	31	16	18	28

MUS15 2834

116	136	113	162	137	163	88	51	108	54
168	40	113	119	120	161	199	193	161	217
184	234	180	182	216	204	235	194	188	173
148	123	124	150	155	145	77	84	99	99
131	110	88							

MUS15 2840

106	210	298	197	77	100	155	293	116	340
178	295	368	357	208	249	291	211	157	180
234	208	256	81	67	73	88	104	105	218
75	101	97	129	153	80	79	60	58	60
57	36								

MUS15 2845

261	180	93	104	104	80	108	149	93	44
93	51	124	30	174	178	163	138	137	161
164	139	109	193	143	215	104	94	115	82
135	132	201	122	102	130	185	112	103	147
146	142	140	112	102					

MUS15 2848

297	274	151	172	228	355	188	164	58	109
89	198	45	141	246	231	216	178	298	277
282	257	280	203	237	122	136	163	98	129
130	162	107	79	143	140	90	71	51	67
111	105	76	91						

MUS15 2849

148	234	159	328	236	213	197	208	279	223
188	114	136	126	294	104	160	151	178	169
217	209	228	177	143	169	125	98	60	62
58	42	45	50	102	103	77	77	83	82
73	74	57	78	117	89	78			

MUS15 2853

370	429	444	279	223	253	386	167	249	274
307	182	295	177	336	338	319	304	165	187
147	112	104	82	233	379	352	282	197	133
75	176	210	211	206	234	104	185	189	163
108	144	192	91	111	219	181	231	110	175
189	196	148	146	195	109	130	157	87	103
115	159	148	123	102	120	236	130	229	147
176	149	159	133	125	165	83	94	156	125
122	112	115	103	130	109	97			

MUS15 2869

133	195	68	56	55	178	212	107	54	54
177	70	227	171	254	259	234	210	174	140
93	57	46	70	54	76	58	76	90	105
123	111	106	60	81	75	97	107	45	56
36	33	46	30	35					

MUS15 2881

433	452	244	77	154	67	226	65	229	263
235	244	232	307	224	233	184	340	222	197
113	112	141	132	147	141	199	140	108	111
174	103	97	79	64	77	75	85	80	

MUS15 2882 = MUS06 638

214	118	218	237	202	245	237	171	103	90
142	76	113	57	114	130	159	144	171	177
138	147	138	218	147	122	77	66	73	78
116	108	177	133	118	169	178	160	121	112
115	141	152	129	129					

MUS15 2913

185	202	143	234	452	219	185	134	214	141
258	81	224	294	266	246	233	227	218	187
186	248	166	112	59	56	52	53	59	72
152	114	85	118	154	113	80	53	59	44
51	57	76							

MUS15 2914

87	101	118	166	142	96	130	60	111	98
220	78	189	205	161	180	174	227	119	132
105	194	141	125	61	47	47	33	64	97
219	51	49	34	24	32	23	27	31	22
21	19	24							

MUS15 2915

68	84	108	99	59	30	36	61	84	64
149	179	178	119	91	91	146	166	94	100
60	78	52	93	32	86	95	99	110	142
131	135	156	134	240	159	178	60	50	40
36	42	45	55	37	37	78	102	85	41
33	25	21	22	28	30				

MUS15 2916 = MUS06 136

246	253	151	155	240	262	170	63	63	128
73	206	81	218	201	170	177	200	154	177
156	131	219	144	189	83	91	86	56	63
51	91	63	44	54	68	56	35	50	49
55	63	60	60						

MUS15 2917

115	157	114	140	116	130	122	198	215	115
59	51	48	52	32	34	39	48	69	94
114	146	142	115	107	151	127	109	71	84

MUS15 2918 = MUS06 134

130	82	41	179	238	119	72	107	81	125
96	186	67	146	184	106	129	133	112	112
120	91	123	118	216	85	91	98	95	129
178	271	134	103	126	176	140	81	107	91
67	65	51	67						

MUS15 2921

121	190	135	79	74	37	106	91	132	65
165	175	168	191	213	233	184	181	141	348
283	314	227	129	117	115	117	104	108	81
64	75	104	91	76	71	101	132	128	120
126									

MUS15 2933

181	113	126	209	182	203	270	173	194	235
270	394	362	380	302	186	314	361	228	406
370	358	375	335	193	320	358	461	671	477
430	254	330	335	484	527	591	681	524	468
387	326								

MUS15 2935

286	646	506	666	503	464	477	638	426	339
473	516	588	523	475	334	396	350	450	513
453	581	409	350	445	398	282	228	455	546
228	386	532	408	389	316	397	396	368	293
223	285	231							

MUS15 2936

116	78	103	162	210	166	290	225	440	389
451	345	331	324	537	363	346	389	434	462
471	450	340	398	369	553	347	552	532	336
408	274	280	214	290	417	239	337	587	452
390	330	410	564	477	327	240	371		

MUS15 2940

263	326	381	192	322	286	200	140	360	388
507	459	410	490	467	434	463	465	466	360
230	219	351	307	92	117	164	284	101	115
154	104	93	77	59	96	145	180	173	297
309	358	348	280	82	97	78	71	123	108
168	155	118	150	91	98	73	75	96	97

MUS15 2944

301	307	265	182	263	438	404	361	336	263
242	165	151	287	413	481	491	475	398	507
500	518	547	480	292	230	238	235	218	358
453	425	399	335	229	197	163	298	380	296
289	146	210	156	244	280	274	252	182	157
165	163	162							

MUS15 2945

381	193	126	131	180	147	323	215	351	349
264	341	242	222	245	244	198	190	198	156
192	218	254	182	208	377	349	263	216	134
202	223	169	102	144	122	106	98	144	

MUS15 2946

529	440	334	356	384	351	353	332	285	203
160	150	193	273	431	354	228	275	98	54
88	105	118	99	108	154	153	65	178	127
95	80	65	97	85	125	60	99	86	139
187	200	133	165	241	180	184	181	164	274
264	194	143	156	267	214	96	171	225	132
246	200	234	236	237	217	87	163	159	

MUS15 2955

252	234	147	238	131	255	250	314	336	310
290	262	283	193	169	192	128	108	113	80
106	97	70	74	95	93	95	59	48	66
82	72	66	57	54	44	49			

MUS15 2956

357	334	317	272	281	606	730	605	528	435
549	138	147	408	513	369	364	164	254	486
251	246	375	541	672	783	829	146	148	214
297	436	517	327	481					

MUS15 2957

181	144	308	319	355	552	561	399	267	394
361	367	299	343	357	268	196	209	256	373
520	379	297	345	114	59	112	82	84	74
73	73	65	36	86	80	50	44	42	47
46	83	34	63	52	107	144	193	105	152
160	122	130	93	96	143	169	130	96	91
155	189	121	169	223	134	249	236	232	197
187	231	68	187	240	150	131	100	172	205
253	212								

MUS15 2970

300	305	421	334	369	580	360	432	326	301
350	326	242	313	181	119	186	205	157	120
81	101	152	203	151	162	128	164	187	205
420	263	213	139	125	103	129	102	106	85
164	125	173	142	148	123	123	131	161	143
124	102	98	101	99	118	220	195	165	156

MUS15 3008

177	307	231	258	354	256	300	320	393	277
188	97	180	74	108	48	118	146	128	107
89	106	100	91	78	177	151	130	140	149
155	162	139	165	241	220	133	123	158	149
116	98	109	174	158	107	80			

MUS15 3020

320	237	114	133	160	167	153	140	142	126
156	134	149	95	163	158	176	180	176	191
196	162	116	174	146	150	264	179	158	188
150	123	196	172	157	177	129	113	98	102
99	110	139	100	88					

MUS15 3021

195	286	219	154	43	50	40	51	86	44
60	67	40	81	87	154	179	193	194	236
175	181	233	189	211	209	218	275	185	213
183	234	210	215	208	220	230	136	83	120
131	97	87	75						

MUS15 3022

179	288	159	87	82	136	81	159	70	145
213	191	256	318	393	382	371	269	551	432
453	374	265	302	233	243	351	341	334	248
215	292	230	86	76	95	121	177	136	137

MUS15 3153

581	577	376	471	384	207	254	229	256	221
139	190	109	101	164	177	190	120	106	174
120	126	119	128	153	101	123	138		

MUS15 3249

250	297	173	342	320	223	235	254	205	179
241	235	353	418	394	279	402	417	424	385
418	289	272	257	259	223	201	245	222	272
277	324	402	184	104	113	168	223	254	197
222									

MUS15 3250

132	201	118	103	121	129	195	184	168	216
110	103	77	111	172	135	165	144	98	144
85	79	94	121	74	79	84	54	51	50
47	40	54	49	44	71	108	58	105	60
50	34	44	73	65	93	105	98	106	73
85	111	139	67	75	94	128	113	98	68
83	58	72	136	236	272	97	64	109	152
169	73	80	81	107	100	112	30	47	55
100	160	168	97	226	207	119	64	53	75
63	55	66	70	102	242	143	108	158	149
93	70	81	117	140	62	57	86	89	83
102	106	80	111	56	37	46	53	69	58
64	58	40	54	70	75	75	75	88	129
158	67	58	92	95	53	81	88	87	33
80	78	48	55	98	88	111	138	157	94
94	156	208	336	210	240	260	221	69	62
66	60	58	50	91	89	107	102	95	87
119	135	141	129						

MUS15 3251

148	157	191	209	179	210	156	212	282	260
260	188	150	86	203	180	213	258	212	171
204	134	83	102	116	88	179	92	98	114
96	94	122	172	191	119	158	203	201	231
152	107	145	196	267	236	196	188	289	162
176	149	184	221	261	286	253	279	252	288
205	252	204	82	98	214	188	296	225	225
246	203	110	112	87	100	118	87	101	99
105	76	85	67	74	74	66	61		

MUS15 3341

179	183	182	183	182	176	296	246	395	268
390	465	398	408	441	459	323	225	158	214
246	295	185	132	179	134	128	123	126	104
67	64	79	106	76	69	69	74	72	79
131									

MUS15 3505

126	115	240	225	483	293	377	458	353	294
376	365	381	318	330	428	384	416	327	302
333	250	197	322	219	182	151	123	155	157
98	110	97	102	95	117				

MUS15 3526

242	208	219	320	308	294	313	337	374	334
230	259	244	254	216	191	181	137	121	230
196	152	147	115	140	148	138	100	92	117
85	80	68							

MUS15 3542

38	35	19	60	18	78	117	128	155	107
204	277	245	290	410	347	544	401	401	387
335	316	489	566	203	232	229	302	166	117
147	158	164	95	66	51				

MUS15 3565

456	290	334	339	481	352	336	306	237	198
196	222	216	174	184	146	160	124	112	181
173	184	145	89	133	147	118	113	152	133
116	177	172							

MUS15 3600

141	213	210	193	157	235	202	437	270	353
432	344	353	372	370	280	168	127	152	149
194	136	93	114	91	96	104	83	79	51
50	75	90	78	67	68	69	68	83	92

MUS15 3601

157	348	223	340	385	407	358	321	302	344
264	231	268	242	138	150	121	149	142	114
179	194	223	170	107	170	193	179	125	145
100	112	133	111						

MUS15 3626

267	265	335	442	381	319	328	281	281	273
290	347	289	229	200	186	194	120	144	221
207	167	141	85	146	197	135	103	93	111
82	108	126							

MUS15 3684

326	521	668	624	364	389	326	282	311	225
233	144	169	188	217	170	137	97	98	90
90	66	68	74	72	75	103			

MUS15 3747

139	122	186	239	187	200	209	118	191	234
380	283	241	229	193	193	385	427	358	220
220	307	353	308	248	264	288	231	284	243

MUS15 3776

168	163	188	149	150	198	154	153	131	155
140	204	211	239	231	190	176	156	139	234
163	143	101	44	103	45	39			

MUS15 3916

201	102	427	301	418	491	426	372	504	498
480	405	355	408	413	433	361	329	299	202
198	363	326	253	178	225	274	276	286	168
203	236	157	137	87					

MUS15 3936

283	495	436	376	413	392	374	311	144	172
160	192	146	125	159	109	99	145	101	128
88	91	141	136	116	97	110	113	61	87
105									

MUS15 4225

797	624	351	517	602	525	456	477	262	345
212	575	529	605	507	480	104	119	118	142
339	371	487	517	163	110	143	209	260	316
102	101	118	170	140	232	528	323	359	345
561	492								

MUS15 4227

325	376	363	232	310	481	282	253	317	439
203	190	461	481	369	467	557	540	418	505
471	531	773	572	467	707	918	699	499	561
788	515	524	275	211	191				

MUS15 4231

1243	1026	1129	943	1005	815	196	174	231	231
177	179	92	82	63	80	78	87	125	71
48	95	83	78	100	58	80	109	96	75
46	35	39	72	152	129	163	67	99	90
183	209	215	72	56	63	132	84	91	99
166	113	96	121	165	190	284	276	449	364
308	328	351	347	383	256	175	171		

MUS15 4233

512	559	677	735	785	672	645	528	588	303
588	385	253	249	117	75	120	120	131	148
109	219	99	134	140	113	144	89	214	200
159	317	311	241	189	184				

MUS15 4242

442	494	481	604	628	637	716	652	62	72
133	144	134	42	48	61	49	47	54	64
115	117	179	269	276	324	208	316	298	425
469	372	327	313	333	343	245	353	309	357
126	80	72	74	91	198	263	239	195	105

MUS15 4261 = MUS06 151

430	216	309	344	283	294	355	340	345	321
295	328	238	244	239	219	180	149	139	228
273	281	165	93	120	105	129	92	106	102
82	104	99							

MUS15 4266

134	139	90	87	112	121	77	208	177	324
334	327	422	380	318	243	237	451	524	485
455	421	401	291	241	216	309	269	252	393
195									

MUS15 4278

103	80	125	107	150	154	149	141	130	111
191	160	124	63	79	59	103	109	66	70
128	130	94	69	73	69	40	49	54	44
50	44	39	36	26	15	22	26	33	49
63	84	74	104	96	66	60	76	131	84
105	115	85	55	101	70	74	86	123	146
93									

MUS15 4320

216	264	280	217	147	202	246	158	94	223
307	238	352	245	245	239	168	193	250	267
362	190	245	250	234	227	245	173		

MUS15 4722

177	181	278	302	243	147	360	274	312	244
179	292	217	222	322	387	353	213	220	260
259	238	225	172	179	152	84	72		

MUS15 4777

200	157	254	178	298	226	115	126	196	191
420	218	407	399	322	275	246	336	439	370
281	315	339	289	288	212	169	137	127	231
219	211	118	79	97	69	80	56	64	55
49	73	53							

MUS15 4894
256 221 208 219 239 248 189 366 290 260
412 383 338 212 275 253 282 217 239 173
137 113 110 100

MUS15 5054
334 509 463 426 371 316 148 209 235 359
365 307 334 349 363 234 251 420 296 302
239 133 242 279 233 190 199 219 116 258
271

MUS15 5148
45 98 43 138 160 192 120 91 147 180
154 216 294 216 217 277 177 185 159 183
223 304 196 127 132 185 136 132 130 145
166 89 85 111

MUS15 5201
138 239 232 149 152 130 330 141 268 439
408 305 358 370 252 211 204 274 215 256
235 171 227 126 131 219 182 155 105 71
113 174 176 154 182 257 186 256 180

MUS15 5243
183 135 233 233 241 183 194 255 268 222
170 240 287 399 285 195 212 136 217 387
316 299 240 217 381 268 326 218 260 238
195 149 153

MUS15 5262
74 142 92 51 46 86 81 89 92 220
175 256 378 409 390 381 355 690 706 603
501 504 649 540 619 416 575 554 552 499
463

MUS15 5272
169 124 85 55 57 53 60 25 98 136
146 216 240 246 286 284 206 341 257 290
244 213 192 143 139 262 327 224 186 181
294 310 214 216 224 277 208 191 200

MUS15 5309

190	190	169	209	138	218	152	127	149	122
109	157	157	141	178	191	221	191	221	180
112	110	142	115	132	109	143	131	108	134
135	118	140	125	102	135	96	104	100	112
98	89	77	97	104	74	101	95	140	109
95	123	155	109	75	70	68	76	57	56
52	64	73	97	81	77	79	75	75	67
78	98	83	124	88	104	86	62	67	45
45	40	57	73	68	83	82	104	101	95
118	122	109	113	80	41	29	36	58	45
39	62	59	65	67	111	91	52	38	43
56	65	72	91	137	170	162	242	216	226
213	277	246	273	296	199	137	139	147	147
106	120	133	135	104	135	127	124	117	

MUS15 5319

248	234	271	172	236	324	352	316	317	426
492	516	466	592	334	481	442	327	292	282
368	343	338	181	424	231	562	441	674	712
412									

MUS15 5602

409	234	242	300	263	316	345	365	250	273
314	266	217	274	295	182	212	220	194	165
160	176	242	266	195	197	176	182	252	156
161	196	246	166	225	244	217	193	192	189

MUS15 5679

344	156	199	171	178	184	179	266	269	280
242	333	282	285	254	247	227	149	161	109
164	146	131	128	186	235	212	162	146	183
165	154	171							

MUS15 5702

498	104	267	245	192	163	162	203	212	139
157	188	157	188	199	210	238	184	186	237
412	270	141	151	214	185	84	64	85	150
102	84	118							

MUS15 5812

393	360	425	348	319	155	160	149	288	299
274	237	281	249	151	151	173	130	143	115
233	371	234	136	139	156	136	161	199	218
278	184	151	91	148	183	241	276	293	245
232	192	156	254	188	104	183	179	200	200
166	166	109	318	260	117	146	300	172	265
153	153	134	135	296	205	222	200	245	152
94	132	109	93	172	261	346	335	242	219
147	200	152	174	215	277	307	310	253	272
201									

MUS15 5825

151	145	70	154	175	202	163	136	157	178
169	161	134	149	128	185	260	169	69	130
175	245	101	199	151	209	207	192	154	88
205	224	53	78	131	156	145	143	267	306
236	241	213	255	180	173	106	79	154	143
226	193	130	48	66	69	32	42	70	60
48	40	29	54	55	34	43	66	63	78
51	89	136	173	146					

MUS15 5837 = MUS06 630/376

323	163	154	320	443	669	495	521	496	203
230	289	346	357	341	379	588	249	333	401
114	92	93	102	107	135	158	82	104	130
150	143	149	132	175	182	170	217	263	548
622	628	554	491	525	467	601	358	512	692
718									

MUS15 6038

252	386	296	245	188	210	234	218	154	139
83	144	110	171	80	140	159	148	106	86
75	87	93	97	107	125	105	77	75	74
68	64	66	70	79	58	79	83	74	56
55	73	80	113	67	99				

MUS15 6420

296	215	186	257	279	267	363	141	282	297
434	348	260	203	165	144	136	116	199	300
302	281	296	165	256	361	316	266	354	302
240	343	216	226	188	273	338	98	222	243
318	285	298	328	314	237	176	227	245	146
239	182	104	135	193					

MUS15 6422

439	531	576	455	739	546	511	196	150	359
406	369	390	347	283	319	322	272	233	191
114	174	171	140	114	94	102	113	124	109
151	152	105	73	66	70	71	56	67	89
103	120	114	124	118	153	136	115	108	113
183	224	105	139	172	207	105	150	185	187
244	267	253	180						

MUS15 6423

148	126	157	183	171	108	185	116	267	346
298	276	196	209	103	98	86	86	172	152
194	150	133	66	144	226	221	169	282	264
288	252	254	213	178	302	311	109	201	288
351	283	336	361	322	295	199	234	299	184
223	221	110	179	238	215	224	165	149	

MUS15 6424

322	493	417	413	334	394	215	285	178	100
208	220	200	335	117	284	174	264	212	168
221	165	248	220	289	228	284	273	282	245
231	251	220	287	225	236	280	182	236	243
218	163	263	245	228	101	153	211	199	244
208	214								

MUS15 6427

188	150	165	113	243	324	267	233	216	105
103	128	166	165	164	204	128	144	132	130
100	129	165	97	153	287	258	241	145	236
235	246	172	201	217	151	177	174	94	149
137	168	187	172	127	170	155	205	201	

MUS15 6501

147	85	231	245	172	154	84	162	92	385
68	206	311	216	210	184	126	187	154	131
148	130	115	56	75	83	85	126	182	170
50	52	56	66	69	38	47	37	34	22
33	22								

MUS15 7316

164	191	180	221	216	231	210	176	165	152
159	111	125	96	131	160	167	201	305	219
234	251	338	285	292	312	184	168	282	268
327	297	250	226	194	183	241	251	178	201
250	240	262	141	137	155	200	126	162	151
165	178	234	128	171	148	108	183	209	136
113	111	122	116	150	133	109	160	151	139
116	121	156	154	261	206				

MUS15 7324

98	90	89	89	80	96	136	144	156	119
130	134	121	187	130	201	208	168	241	236
200	287	242	203	253	283	256	177	242	245
331	415	475	433	379	214	133	179	285	342
268	335	224	212	216	173	165	160	269	344
309	417	329	211	197	215	126	202	184	199
299	325	352	235	199	146	150	170	174	113
125	134	165	169	138	209	183	160	187	223
231	213	178	116	115	149	197	248	233	189
203	172	222	230	153	134	142			

MUS15 7325

200	241	190	179	183	245	221	190	261	170
147	163	215	158	245	302	272	263	378	248
221	230	164	186	258	245	195	235	246	216
182	236	204	132	185	124	128	96	110	130
136	116	203	173	140	155	147	156	154	155
111	114	128	145	194	115	149	179	102	117
167	192	149	102	103	157	158	74	87	139
131	118	141	85	115	124	149	112	116	107
112	97	94	97	94	119	139	99	112	117
96	86	98	95	80	71	85	85	106	125
99	91	74	65	89	91	123	107	117	132
101	97	119	108	126	110	103	76	86	74
67	56	47	44	55	63				

MUS15 6430

458	506	532	414	506	480	377	529	605	591
751	632	467	492	555	135	193	315	386	357
350	406	410	342	435	529	597	573	436	316
408	475	131	87	144	124	94	133	201	250
266	122	87	95	103	161	238	204	300	87
85	133	135							

MUS15 6645

187	334	183	55	69	107	159	200	282	325
246	177	219	168	130	130	86	126	159	107
108	138	68	77	103	76	59	61	114	152
94	90	136	53	61	66	69	87	128	228
181	65	55	79	119	76	105	68	43	63
76									

MUS15 7060

180	149	147	138	138	141	94	139	108	130
200	157	140	134	114	101	88	113	106	103
107	103	115	101	101	119	96	94	104	81
73	90	89	85	83	116	108	83	98	94
128	99	101							

MUS15 7122

460	326	226	253	449	237	170	300	184	305
306	334	84	156	96	112	173	245	102	77
91	196	130	84	76	138	147	89	187	157
116	120	204	93	95	66	79	177	118	132
151	118	94	53	89	98	61	79	100	97
75	73	123	169	102	92	119	96	89	157
88	184								

MUS15 7360

295	353	351	109	103	116	137	201	177	105
83	163	249	319	338	110	111	110	110	56
90	94	52	86	53	61	126	157	174	63
101	178	42	54	48	96	168	56	91	134
199	71	44	85	110	126	172	244	160	174
202	245	259	351	321	400	169	113	145	172
147	130	96	191	174	67	55	93	77	123
115	99	70	139	115	82	50	50	45	54

MUS15 7490

113	142	176	192	146	212	138	125	228	278
176	249	277	313	304	277	159	136	196	328
502	541	284	333	232	392	337	293	423	522
331	130	76	73	141	140	159	256	282	385
437	130	107	284	295	361	429	147	97	197
235	259	282	275	409	251	163	130	101	95
93	99	117	211	362					

APPENDIX 2: RADIOCARBON DATING AND CHRONOLOGICAL MODELLING

Methods

Sixty-seven radiocarbon measurements have been obtained from waterlogged wood, waterlogged plant remains, faunal and human remains and a carbonised residue adhering to the interior of a ceramic vessel from excavations at Must Farm. Details of the dated samples, radiocarbon ages, and associated stable isotopic measurements are provided in Tables 5–7 and 25–29. The radiocarbon results are conventional radiocarbon ages (Stuiver and Polach 1977), corrected for fractionation using $\delta^{13}C$ values measured by Accelerator Mass Spectrometry (AMS).

Radiocarbon dating was undertaken by Beta Analytic following the 2005–6 evaluation, the Oxford Radiocarbon Accelerator Unit (ORAU) and Scottish Universities Environmental Research Centre (SUERC) in 2017, with further samples being dated at the Centre for Isotope Research, University of Groningen (GrM-), the Netherlands and the Laboratory of Ion Beam Physics, ETH Zürich (ETH-), Switzerland in 2019–20.

Five samples of waterlogged wood and a carbonised residue were dated by Beta Analytic using the methods outlined at https://www.radiocarbon.com/. The waterlogged wood was dated using radiometric methods and the carbonised residue by AMS.

Eight blocks of waterlogged wood (all comprising five annual growth rings) and four waterlogged plant macrofossils were dated at the Oxford University Radiocarbon Accelerator Unit. The samples were pretreated using the acid-base-acid protocol, with the waterlogged wood additionally undergoing bleaching with sodium chlorite (Brock *et al* 2010, table 1 (UW)). The samples were then combusted and graphitised as described by Brock *et al* (2010, 110) and Dee and Bronk Ramsey (2000) and dated by AMS (Bronk Ramsey *et al* 2004).

The six blocks of waterlogged wood (all comprising five annual growth rings) and four waterlogged plant macrofossils that were dated at the SUERC were converted to α-cellulose, combusted, graphitised, and dated by AMS as described by Dunbar *et al* (2016).

The Queen's University, Belfast processed four waterlogged plant macrofossil samples using methods described by Reimer *et al* (2015). All samples were graphitised using hydrogen reduction (Vogel *et al* 1984).

Fifteen samples were dated at the Centre for Isotope Research, University of Groningen, the Netherlands in 2019–20. The 12 single ring waterlogged wood samples were converted to α-cellulose using an intensified aqueous pretreatment (Dee *et al* 2019) and the three bone samples were pretreated using an acid-base-acid protocol (4% HCl, 1% NaOH, <1% HCl), gelatinised, and filtered (50μm) (Dee *et al* 2020). All the samples were combusted in an elemental analyser (IsotopeCube NCS), coupled to an Isotope Ratio Mass Spectrometer (Isoprime 100). The resultant CO_2 was graphitised by hydrogen reduction in the presence of an iron catalyst. The graphite was then pressed into aluminium cathodes and dated by AMS (Synal *et al* 2007; Salehpour *et al* 2016).

Seventeen samples were dated at ETH Zürich, Switzerland in 2019–20. Cellulose was extracted from each of the 13 single ring waterlogged wood sample using the base-acid-base-acid-bleaching (BABAB) method described by Němec *et al* (2010) and the four bone samples underwent ultrasonic cleaning in distilled water before gelatinisation and ultrafiltration as described by Hajdas *et al* (2007; 2009). All the samples were then combusted and graphitised as outlined in Wacker *et al*. (2010a) and dated by AMS (Synal *et al* 2007; Wacker *et al* 2010b). Carbon and nitrogen ratios were obtained on sub-samples of the ultrafiltered gelatin from the bone samples at the Department of Geology, ETH Zürich, using an elemental analyzer (ThermoFisher Flash-EA 1112) coupled through a Conflo IV interface to an Isotope Ratio Mass Spectrometer (ThermoFisher Delta V).

At both the Groningen and Zürich laboratories data reduction was undertaken as described by Wacker *et al* (2010c).

All five facilities maintain continual programmes of quality assurance procedures (Aerts-Bijma *et al* 2020; Sookdeo *et al* 2020), in addition to participation in international inter-comparison exercises (Scott *et al* 2017; Wacker *et al* 2020). Replicate radiocarbon measurements are available on 12 samples, four blocks of waterlogged wood (all comprising five annual rings), seven single rings of waterlogged wood and a single animal bone. Four blocks and five single rings of waterlogged wood are statistically consistent at the 5% significance level along with the single animal bone. Two of the seven single rings of waterlogged wood are statistically significantly different at the 5% significance level but are consistent at the 1% significance level; this is not in line with statistical expectation. The yield of α-cellulose of many of the single ring waterlogged wood samples processed at Groningen was relatively low in comparison to better preserved wood, with the CO_2 yield after combustion of the α-cellulose for some samples also relatively low (%C approximately 40% of that for well=reserved wood). The poor preservation of some of the dated samples probably explains the observed reproducibility (see Bayliss and Marshall 2019, 1152).

Calibration

Radiocarbon ages are not the same as calendar dates because the concentration of ^{14}C in the atmosphere has fluctuated over time. A radiocarbon measurement has thus to be calibrated against an independent scale to arrive at the corresponding calendar date. That independent scale is the IntCal20 calibration curve (Reimer *et al* 2020). For the period covered by this study, this is constructed from radiocarbon measurements on tree-ring samples dated absolutely by dendrochronology. The probability distributions of the calibrated radiocarbon dates from the dated tree-ring sequences, derived from the probability method (Stuiver and Reimer 1993), and are shown in outline in figures.

Wiggle-matching

Wiggle-matching is the process of matching a series of calibrated radiocarbon dates which are separated by a known number of years to the shape of the radiocarbon calibration curve. At its simplest, this can be done visually, although statistical methods are usually employed. Floating tree-ring sequences are particularly suited to this approach as the calendar age separation of tree-rings submitted for dating is known precisely by counting the rings in the timber. A review of the method is presented by Galimberti *et al* (2004).

The approach to wiggle-matching adopted here employs Bayesian chronological modelling to combine the relative dating information provided by the tree-ring analysis with the calibrated radiocarbon dates (Christen and Litton 1995). It has been implemented using the program OxCal v4.4 (http://c14.arch.ox.ac.uk/oxcal.html; Bronk Ramsey *et al* 2001; Bronk Ramsey 2009). The modelled dates are shown in black in Figures 6–8 and 22 and quoted in italics in the text. The Acomb statistic shows how closely the assemblage of calibrated radiocarbon dates as a whole agree with the relative dating provided by the tree-ring analysis that has been incorporated in the model; an acceptable threshold is reached when it is equal to or greater than An (a value based on the number of dates in the model). The A statistic shows how closely an individual calibrated radiocarbon date agrees its position in the sequence (most values in a model should be equal to or greater than 60).

Bayesian chronological modelling

Chronological modelling of radiocarbon dates from the Pile-dwelling and Palaeochannel has been undertaken using OxCal 4.4 (Bronk Ramsey 1995; 2009; 2017), and the internationally agreed calibration curve for terrestrial samples from the northern hemisphere (IntCal20; Reimer *et al* 2020). The models are defined by the OxCal CQL2 keywords and by the brackets on the left-hand side of Figures 21 and 25. In the diagrams, calibrated radiocarbon dates are shown in outline and the posterior density estimates produced by the chronological modelling are shown in solid black. The Highest Posterior Density intervals which describe the posterior distributions are given in italics.

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APPENDIX 3: CQL2 CODE FOR CHRONOLOGICAL MODELS

WD2944 (Fig 6)

```
//WD2944, wigglematch
Options()
 {
  Resolution=1;
  kIterations=20000;
 };
 Plot()
 {
  D_Sequence("WD2944")
  {
   R_Combine("WD2944_ring_1")
   {
    R_Date("ETH-106009", 3252, 16);
    R_Date("GrM-22053", 3215, 18);
   };
   Gap(13);
   R_Date("ETH-106010", 3214, 16);
   Gap(13);
   R_Date("GrM-22054", 3190, 18);
   Gap(13);
   R_Combine("WD2944_ring_40")
   {
    R_Date("GrM-22055", 3200, 30);
    R_Date("ETH-106011", 3195, 16);
   };
   Gap(13);
   R_Date("ETH-106012", 3210, 26);
  };
 };
```

WD3249 (Fig 7)

```
//WD3249, wigglematch
Options()
 {
  Resolution=1;
  kIterations=20000;
 };
 Plot()
 {
  D_Sequence("WD3249")
  {
   R_Date("GrM-22282", 3201, 24);
   Gap(10);
   R_Date("ETH-106006", 3173, 16);
```

```
  Gap(10);
  R_Date("GrM-22051", 3154, 18);
  Gap(10);
  R_Combine("WD3249_ring_31")
  {
   R_Date("ETH-106007", 3163, 26);
   R_Date("GrM-22283", 3086, 24);
  };
  Gap(10);
  R_Combine("WD3249_ring_41")
  {
   R_Date("GrM-22052", 3147, 18);
   R_Date("ETH-106008", 3122, 16);
  };
 };
};
```

WD6430 (Fig 8)

```
//WD6430, wigglematch
Options()
 {
  Resolution=1;
  kIterations=20000;
 };
 Plot()
 {
  D_Sequence("WD6430")
  {
   R_Date("ETH-106002", 3288, 26)
   {
    Outlier();
   };
   Gap(13);
   R_Combine("WD6430_ring_14")
   {
    R_Date("ETH-106003", 3202, 16);
    R_Date("GrM-22048", 3190, 20);
   };
   Gap(13);
   R_Combine("WD6430_ring_27")
   {
    R_Date("ETH-106004", 3182, 16);
    R_Date("GrM-22281", 3070, 45);
   };
   Gap(13);
   R_Date("GrM-22280", 3088, 23);
   Gap(13);
   R_Date("ETH-106005", 3143, 16);
  };
 };
```

WD2759 (Fig 22)

```
//WD2759, wigglematch
Options()
 {
  Resolution=1;
  kIterations=20000;
 };
 Plot()
 {
  D_Sequence("Must Farm ash master")
  {
   R_Combine("rings 59 to 55")
   {
    R_Date("SUERC-74902", 2766, 33);
    R_Date("OxA-36039", 2745, 25);
   };
   Gap(5);
   R_Date("OxA-36040", 2731, 25);
   Gap(5);
   R_Date("SUERC-74906", 2744, 33);
   Gap(5);
   R_Date("OxA-36203", 2712, 30);
   Gap(5);
   R_Date("SUERC-74907", 2683, 33);
   Gap(5);
   R_Date("OxA-36041", 2675, 24);
   Gap(5);
   R_Combine("rings 29 to 25")
   {
    R_Date("SUERC-74908", 2669, 33);
    R_Date("OxA-36042", 2728, 24);
   };
   Gap(5);
   R_Combine("rings 24 to 20")
   {
    R_Date("OxA-36043", 2719, 24);
    R_Date("OxA-36044", 2670, 24);
   };
   Gap(5);
   R_Date("SUERC-74909", 2771, 33);
   Gap(5);
   R_Date("OxA-36045", 2707, 24);
   Gap(5);
   R_Date("SUERC-74910", 2694, 33);
   Gap(5);
   R_Combine("rings 4 to 0")
   {
    R_Date("SUERC-74911", 2797, 33);
    R_Date("OxA-36075", 2744, 28);
   };
   Gap(2);
   R_Combine("ash_ring_0")
```

```
  {
   R_Date("GrM-22056", 2731, 24);
   R_Date("GrM-22057", 2750, 25);
   R_Date("ETH-106013", 2775, 26);
   R_Date("ETH-106014", 2739, 16);
  };
 };
};
```

Palaeochannel (MUS06) (Fig 31)

```
//Palaeochannel (MUS06)
Options()
 {
  Resolution=1;
  kIterations=20000;
 };
 Plot()
 {
  Sequence("MUS06: palaeochannel")
  {
   Combine("2 [-3.25 to -3.26m OD]")
   {
    R_Date("OxA-36403", 3301, 27)
    {
    };
    R_Date("SUERC-76191", 3282, 29)
    {
    };
   };
   After("10 [-2.76 to -2.77m OD]")
   {
    R_Date("UBA-35747", 3267, 34)
    {
    };
    R_Date("SUERC-76192", 3324, 29)
    {
    };
   };
   After("15 [-2.39 to -2.40m OD]")
   {
    R_Date("OxA-36404", 3000, 29)
    {
    };
    R_Date("SUERC-76591", 3349, 30)
    {
    };
   };
   Phase("Context [390]")
   {
    R_Date("ETH-96047", 3006, 23);
   };
```

```
  After("19 [-2.205 to -2.215m OD]")
  {
   R_Date("UBA-35748", 2958, 30)
   {
   };
   R_Date("OxA-36405", 3494, 28)
   {
   };
  };
  Phase("Context [3224]: occupation")
  {
   Prior("ash_ring_0");
  };
  After("24 [-1.905 to -1.915m OD]")
  {
   R_Date("OxA-36406", 2911, 28)
   {
   };
   R_Date("UBA-35749", 3430, 30)
   {
   };
  };
  After("26 [-1.615 to -1.625m OD]")
  {
   R_Date("UBA-35750", 2698, 30)
   {
   };
   R_Date("SUERC-76592", 2661, 30)
   {
   };
  };
 };
};
```

APPENDIX 4: SHINEWATER PLATFORM: RADIOCARBON DATING AND CHRONOLOGICAL MODELLING

Introduction

Fourteen radiocarbon measurements are available (Table A4.1) on samples associated with the Shinewater platform and trackway (Greatorex 2003; Jennings *et al*. 2003).

The samples

Seven measurements on six samples from the platform are available. Replicate measurements on *Quercus* sp. sapwood from Timber 1291 are statistically consistent [Table A4.1, Ward and Wilson 1978] and a weighted mean has been taken as providing the best estimate for the felling of the timber.

The other five measurements from the platform (BM-3042–3044 and BM-3056-3-57) were produced from *Quercus* sp. timbers that we can assume were relatively short-lived as all those sampled for dendrochronology had 24–55 rings (Hillam 2003, 5). As the dated material was not identified prior to submission for dating these radiocarbon measurements could be older than the date of interest, their felling, and as such they have been modelled using the charcoal outlier model described by Dee and Bronk Ramsey (2014). This is a model-averaging approach. As the model is calculated, a shift is applied to each solution drawn. The shift is always to younger ages (charcoal samples, or in this instance the *Quercus* sp. timbers, are always too old than the event of interest, the question is by how much) and its value is randomly selected from an exponential probability density function (1–60 years) estimated by the model itself. The function automatically scales to fit the spread of dates in the modelled phase. As such the scale of the modelled inbuilt age takes account of the other information in the model. It is not independent of it. In these circumstances, indices of agreement (Bronk Ramsey 1995, 429; Bronk Ramsey 2009, 356–7) cannot be used to assess the compatibility of the prior information and data in the model.

Two stakes from below the platform, and therefore assumed to be stratigraphically earlier, were dated. BM-3127 was a wooden stake recovered in a gouge auger as part of palaeoenvironmental sampling to obtain a core (SW4; Jennings *et al* 2003, fig 4) through part of the earliest occupation layer of the platform and into the underlying peat/clay below it (Jennings *et al* 2003, 100). The dated material was identified as young *Quercus* sp. (Ambers and Bowman 2003, 534–5) prior to dating and we have therefore assumed no significant age-at-death offset. The second stake was also obtained as part of coring at SW18 (Jennings *et al* 2003, fig 1) and as it was not identified prior to dating we have also modelled it with the charcoal outlier model (Dee and Bronk Ramsey 2014).

A further three measurements (Beta-108566–8) were obtained on peat samples from the SW4 pollen site (Jennings *et al* 2003). We have not included the date, BM-3127, on the wooden stake obtained as part of coring at this location into this sequence as it must be intrusive, ie driven into the peat and therefore its relationship to the peat samples is unknown. Beta-108566 provides a constraint on the date of construction of the platform as the peat samples was from the "top of the occupation layer" (Jennings *et al* 2003, table 1).

Radiocarbon measurements are also available on two artefacts recovered as part of the archaeological investigations of the platform. A field maple handle from a sickle handle (OxA-6176) was found on the platform and as the artefact could be older than its construction, we have only included it as providing a *terminus post quem* for its context. The context of the worked wooden tube (OxA-7954) appears to have not been recorded and it thus simply provides a date for the object.

Chronological modelling

The chronological modelling presented below has been undertaken using OxCal 4.4 (Bronk Ramsey 2009), and the internationally agreed calibration curve for the northern hemisphere (IntCal20; Reimer *et al*. 2020).

The model is defined by the OxCal CQL2 keywords and by the brackets on the left-hand side of Figure A4.1. On the figure, calibrated radiocarbon dates are shown in outline, and the posterior density estimates produced by the chronological modelling are shown in solid black. The other distributions correspond to aspects of the model. For example, the distribution *BuildPlatform* (Figure A4.1) is the posterior density estimate for the date of construction of the Shinewater platform. In the text highest posterior density intervals, which describe the posterior distributions, are given in italics.

The model shown in Figure A4.1 has good overall agreement (Amodel=84) and provides an estimate for the construction of the platform of *810–745 cal BC* (*BuildPlatfrom;* Fig A4.1) and probably *800–770 cal BC* (*68% probability*).

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Table A4.1: Shinewater radiocarbon and associated stable isotope results. Replicate measurements have been tested for statistical consistency and combined by taking a weighted mean before calibration as described by Ward and Wilson (1978; T'(5%)=3.8, ν=1).

Laboratory reference	Sample ID, material & context	Radiocarbon Age (BP)	$\delta^{13}C_{IRMS}$ (‰)
BM-3127	PE 97, timber 100. Wood, waterlogged: *Quercus* sp. small wooden stake (young wood), found embedded in the peat below the platform (Ambers and Bowman 2003, 534–5; SW18; Jennings *et al* 2003, 94)	2650±40	−27.3
BM-2990	SPE95. 1291. Wood, waterlogged: *Quercus* sp. sapwood (cellulose dated), from horizontal timber within a dense platform associated with wooden piles and overlying a timber deposit (Ambers and Bowman 1998, 424)	2630±70	−26.6
BM-3002	Replicate of BM-2990	2690±35	−25.7
Timber 1291	^{14}C: 2660±50 BP, T′=0.4		
OxA-6176	SPE95 (5). Wood, waterlogged: field maple, from sickle handle (Bronk Ramsey *et al* 1999, 198; Brysbaert 1998)	2655±50	−28.6
OxA-7954	SPE95 (3). Wood, waterlogged: unidentified worked wooden tube (Bronk Ramset *et al* 1999, 198)	3035±40	−31.0
BM-3042	Wood, waterlogged: unidentified (cellulose dated), from platform timber (Jennings *et al* 2003, 94)	2730±45	-
BM-3043	Wood, waterlogged: unidentified (cellulose dated), from platform timber (Jennings *et al* 2003, 94)	2600±45	-
BM-3044	Wood, waterlogged: unidentified (cellulose dated), from platform timber (Jennings *et al* 2003, 94)	2690±40	-
BM-3056	Wood, waterlogged: unidentified (cellulose dated), from platform timber (Jennings *et al* 2003, 94)	2680±45	-
BM-3057	Wood, waterlogged: unidentified (cellulose dated), from platform timber (Jennings *et al* 2003, 94)	2580±35	-
Beta-135994	Wood, waterlogged: unidentified, stake from below trackway (SW18; Jennings *et al* 2003, 94)	2740±60	-
Beta-105868	Peat: top of peat below platform (SW13 platform pollen site; Jennings *et al* 2003, 94)	2980±50	-
Beta-105867	Peat: peat lying on wood of platform (SW13 platform pollen site; Jennings *et al* 2003, 94)	2810±50	-
Beta-105866	Peat: top of occupation layer (SW13 platform pollen site; Jennings *et al* 2003, 94)	2500±60	-

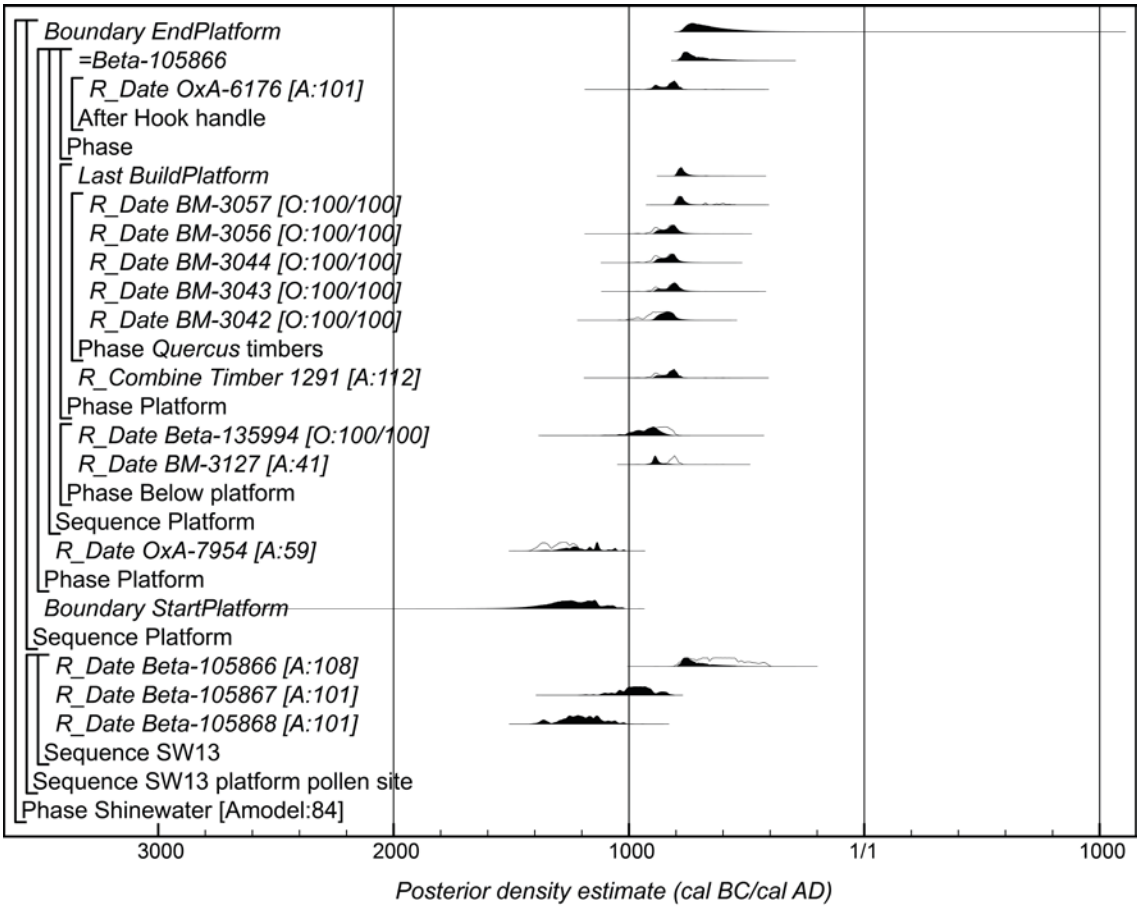
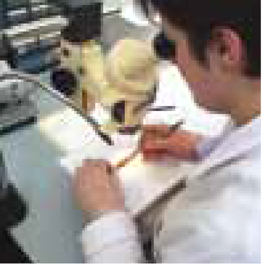
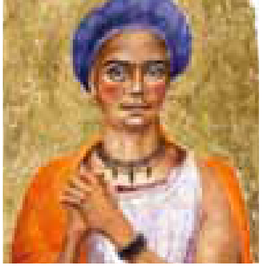
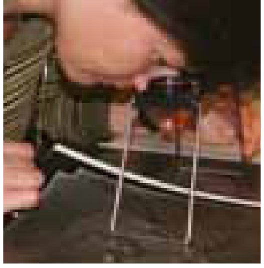


Figure A4.1: Probability distributions of dates from Shinewater Each distribution represents the relative probability that an event occurs at a particular time. For each of the dates two distributions have been plotted: one in outline, which is the simple radiocarbon calibration, and a solid one, based on the wiggle-match sequence. The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly

CQL2 code for Shinewater (Fig A4.1)

```
//Shinewater
Options()
 {
  Resolution=1;
  kIterations=20000;
 };
 Plot()
 {
  Outlier_Model("Oak",Exp(1,-10,0),U(0,1.778),"t");
  Phase("Shinewater")
  {
   Sequence("Shinewater")
   {
    Sequence("Pollen")
    {
     R_Date("Beta-105868", 2980, 50);
     R_Date("Beta-105867", 2810, 50);
     R_Date("Beta-105866", 2500, 60)
     {
     };
    };
   };
   Sequence("Platform & trackway")
   {
    Boundary("StartPlatformTrackway");
    Phase("Platform & trackway")
    {
     R_Date("OxA-7954", 3035, 40);
     Sequence("1")
     {
      Phase("Below platform")
      {
       R_Date("BM-3127", 2650, 40);
       R_Date("Beta-135994", 2740, 60)
       {
        Outlier("Oak", 1);
       };
      };
      Phase("Platform & trackway")
      {
       R_Combine("Timber 1291")
       {
        R_Date("BM-2990", 2630, 70);
        R_Date("BM-3002", 2690, 70);
       };
       Phase("Quercus timbers")
       {
        R_Date("BM-3042", 2730, 45)
        {
         Outlier("Oak", 1);
        };
        R_Date("BM-3043", 2660, 45)
```

```
      {
       Outlier("Oak", 1);
      };
      R_Date("BM-3044", 2690, 40)
      {
       Outlier("Oak", 1);
      };
      R_Date("BM-3056", 2680, 45)
      {
       Outlier("Oak", 1);
      };
      R_Date("BM-3057", 2580, 35)
      {
       Outlier("Oak", 1);
      };
     };
     Last("BuildPlatform");
    };
    Phase()
    {
     After("Hook handle")
     {
      R_Date("OxA-6176", 2655, 50);
     };
     Date("=Beta-105866");
    };
   };
  };
  Boundary("EndPlatformTrackway");
 };
};
};
```



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