RADIOCARBON DATING, Watermead Country Park, Leicestershire (Accession no. A57.1996)

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Introduction

Forty-four radiocarbon samples were dated in 2003 as part of the post-excavation analysis of this site. Four samples were dated during salvage excavations in 1996, at the request of the English Heritage Inspector of Ancient Monuments, in order to assess the significance of the site. Three of these were bulk peat samples from a pollen core (Column 2) (Greig this vol), and one was a human vertebra with cut marks, found in the spoil of machine excavation.

The samples submitted in 2003 were divided into four series:

- The burnt mound sequence (Series A): 14 charcoal, six wood, and four waterlogged plant macrofossil samples collected during the archaeological excavation of the burnt mound
- Animal bones and timber posts (Series B): four bone and three wood samples, recovered during mechanical excavation of peat and fluvial sediment in the adjacent palaeochannel of the River Soar
- Human bones (Series C): two human bone samples, also recovered from the spoil of mechanical excavation
- Palaeoenvironmental samples (Series D): 11 samples of waterlogged plant macrofossils from two pollen columns, Column 4 (Greig this vol) and Column 8 (Brown this vol), which were collected from peat sections exposed by quarrying.

Samples were dated at the Oxford Radiocarbon Accelerator Unit, the Scottish Universities Research and Reactor Centre, and the Centre for Isotope Research at Groningen University, The Netherlands.

Objectives

The initial aim of the dating programme was to help in assessing the significance of the site. Once this had been established, the dating programme aimed to determine when the burnt mound was in use, how long it remained in use, and whether some notable finds recovered from the spoil of machine excavations of the adjacent palaeochannel were similar in age to the burnt mound. It also aimed to provide a chronological framework for the palaeoenvironmental records obtained from columns 2, 4, and 8.

Sample selection

The samples recovered from the peat and fluvial sediments adjacent to the burnt mound were bones and timbers whose radiocarbon age was directly relevant to an objective of the dating programme; namely, to determine whether the butchery activity, burials, and bridge construction could have been contemporary with the use of the burnt mound. Series D samples (columns 4 and 8) consisted of short-lived terrestrial plant macrofossils, which, unless reworked, accurately date peat formation at each sample's depth. To be preserved, these macrofossils had to remain waterlogged. They are therefore unlikely to be reworked, although in fluvial deposits this possibility cannot be excluded. The bulk peat samples from Column 2 should have consisted mainly of the remains of plants that grew *in situ*, whose radiocarbon age is directly relevant to the age of pollen from the same horizons. The humic acid fraction of each of these samples was dated, as humic acids are not mobile in acidic environments.

In addition to meeting the usual criteria for archaeological radiocarbon samples (eg Waterbolk 1983; van Strydonck *et al* 1998), samples from the burnt mound were selected using a Bayesian simulation model (Buck *et al* 1996; Buck and Christen 1998). The aim of this approach is to date events of archaeological interest, rather than simply dating samples associated with these events. The program OxCal v3.5 (Bronk Ramsey 1995; 1998; 2000; 2001) can be used to create Bayesian models that combine radiocarbon results with archaeological phasing, which indicates the relative ages of samples. Such models produce '*posterior density estimates*' of the dates of samples and associated events, and of the duration of episodes of archaeological activity. These estimates, which by convention are always expressed *in italics*, will change according to the stratigraphic interpretation implicit in the model structure, and according to which data are included.

Posterior density estimates depend not only on the number of samples dated, but also on the samples' calendar age. The burnt mound was expected to be roughly contemporary with the human vertebra dated in 1996 (OxA-6831, 2760±55BP, 1020–800 cal BC). The calibration curve is relatively steep in this period. A Bayesian simulation model was used to determine which contexts to sample, how many samples to submit, and the precision required in order to date burnt mound activity to within a century or so. The model combined potential radiocarbon results, given the estimated calendar ages of archaeological features, with the relative ages of the features, based on stratigraphic relationships. The initial model (Figure 1a) showed that a dozen results would be sufficient to determine whether burnt mound activity lasted less than a century. Once it was established that the mound dated to the later third millennium cal BC, the model (Fig 1b) demonstrated that twice as many results were required to achieve the same precision, and a second batch of samples was submitted.

Sample Processing

Samples processed at the Oxford Radiocarbon Accelerator Unit were measured by Accelerator Mass Spectrometry (AMS), following procedures described by Hedges *et al* (1989) and Bronk Ramsey *et al* (2000). Samples processed at the Scottish Universities Research and Reactor Centre in East Kilbride were measured by Liquid Scintillation Counting, following procedures described by Stenhouse and Baxter (1983) and Noakes *et al* (1965). Samples processed at the Centre for Isotope Research at Groningen University, The Netherlands, were measured by AMS, according to the methods set out by Aerts-Bijma *et al* (1997; 2001) and van der Plicht *et al* (2000). Each laboratory maintains internal quality control procedures and takes part in laboratory intercomparison studies (eg Boaretto *et al* 2002). These exercises demonstrate that the measurements are accurate and that the stated precision of each measurement is valid.

Results

The measured results, listed in Table 1, are conventional radiocarbon ages (Stuiver and Polach 1977), quoted according to the Trondheim convention (Stuiver and Kra 1986). The calibrated date ranges (95% confidence intervals) were calculated by the maximum intercept method (Stuiver and Reimer 1986), using the program OxCal v3.5 (Bronk Ramsey 1995; 1998; 2000; 2001) and the INTCAL98 dataset (Stuiver *et al* 1998). Figures 2 (Series A), 3 (Series B–D and OxA-6831), and 4 (Column 2) show the calibration of these results by the probability method (Stuiver and Reimer 1993).

Archaeological interpretation

The burnt mound

The calibrated radiocarbon dates from the burnt mound are shown in Figure 2. The radiocarbon results are inconsistent with the initial archaeological interpretation of the phasing of the burnt mound (Fig 1b). The macrofossil from the trough fill, OxA-12586, is older than the bark samples (OxA-12585 and GrA-23745) from the clay layer into which the trough was cut, and must be residual. Even after the exclusion of OxA-12586, however, and OxA-12484, which must be intrusive, the original model does not approach a satisfactory overall index of agreement (A <<60%) (Fig 5). From the radiocarbon results, it appears that spread 236 is not later than spread 248, and the alder planks are not earlier than the charcoal spreads, as had been thought. These inconsistencies became clear when the second batch of samples was dated; results of the first round were consistent with the original model (as in Fig 1b). The initial phasing of the burnt mound sequence clearly has to be reassessed.

The alder planks overlay a charcoal layer, 147, which lined the base of the trough (Fig ##: section through trough). This suggests that the trough was already in use when the alder planks were added, as it is unlikely that the charcoal was deliberately inserted when the trough was originally cut into the grey clay layer. The planks are not all of the same radiocarbon age (T'=13.5, T'(5%)=7.8, ν=3; Ward and Wilson 1978), but may nevertheless have been added at the same time. The earliest, timber 17 (GU-5983), appears in section to include part of the pith, and none of the outer rings. Its intrinsic age may account for the disparity between its radiocarbon age and that of the other planks, although this offset is unlikely to be substantial, as the sample was identified as probably alder. Withy 31/32 (OxA-12644) may have been added at the same time as the alder planks. Withy 30 (OxA-12998), however, may have been part of the original wooden trough. It appears to be older than any of the charcoal samples.

Charcoal spread 236 was recorded as having overlain layer 205, which in turn overlay layer 248. At least four of the five 248 samples are apparently more recent than any of the five samples from 236, however. One of the 248 samples (OxA-12484) is medieval in age, and must be regarded as intrusive, but the other four are consistent with a single radiocarbon age (T'=6.1, T'(5%)=7.8, ν=3; Ward and Wilson 1978), and could represent a single depositional episode. Whilst it cannot be excluded that the 236 samples were reworked from earlier deposits, the consistency of the results suggests otherwise. All five 236 samples are consistent with a single radiocarbon age (T'=1.8, T'(5%)=9.5, ν=4; Ward and Wilson 1978). The charcoal spreads were relatively thin (<10cm in total) and difficult to follow. The horizons between 248, 205, and 236 are not recorded on the relevant section drawing. To accept the recorded sequence (that 248 is earlier than 236), we would have to argue either that at least four of the five 248 samples were intrusive, or that all five 236 samples were residual. This seems unlikely. Instead, we conclude that 236 was stratigraphically earlier than 248.

We therefore propose a two-phase model for burnt mound activity. Charcoal found beneath the planks of the wooden trough is similar in age to the 236 samples, and is included in the earlier phase. The 248 samples, which are similar in age to the trough timbers, are included in the later phase. Neither hearth can be related stratigraphically to the other dated deposits, except that both hearths are more recent than the grey clay layer, and are associated with burnt mound activity. The radiocarbon results should date the final use of each hearth. Both appear to date to the earlier phase, but our model does not assume that the hearths belong to either phase. Withy 30 (OxA-12998) is placed before the earlier phase of burnt mound activity (although it could be included in the earlier phase without altering our chronology).

Under the proposed model (Fig 6), burnt mound activity began *2550–2470 cal BC (95% probability, start of burnt mound activity)*, ended *2150–1930 cal BC (95% probability, end of burnt mound activity)*, and lasted *320–520 years (95% probability, burnt mound activity;* Fig 7). There was not a significant hiatus between the two phases *(<70 years, 95% probability; <30 years, 68% probability)* (*hiatus,* Fig 7). Burnt mound activity therefore continued through most of the second half of the third millennium cal BC.

Samples from the palaeochannel adjacent to the burnt mound

Of the bone and timber samples from the palaeochannel adjacent to the burnt mound, only the two aurochsen may be contemporary with the burnt mound activity. Their dates (GrA-23585, 3925±45BP, 2570–2230 cal BC and GrA-23589, 3840±50BP, 2470–2130 cal BC) almost certainly fall between the estimated start and end dates of burnt mound activity. The human bones date to the beginning of the third millennium cal BC (middle Neolithic) and the early first millennium (late Bronze Age), while the cattle and horse bones date to the mid-late Iron Age.

The three timber posts appear to have been components of a wooden bridge, whose construction must postdate all three timbers, and may be regarded as the final event in a phase of activity. In OxCal, the function 'Last' is used to estimate the date of the final event in a phase. The best estimate of the date of construction is therefore provided by the distribution 'Last bridge construction' (Fig 8), which has a range of cal AD 480–650 (95% confidence).

Column 2

This column was located *c* 60m north of the burnt mound, near the spot where the cut-marked human vertebra was recovered. The three results are in stratigraphic sequence, and date the peat deposit to the early Holocene, long before the vertebra was deposited (Fig 4). The peat was sealed by alluvium before any of the dated archaeological activity took place.

Column 4

One result, OxA-12482, is clearly out of sequence (Fig 3), but the other six results are consistent with a model that assumes sample age increases with depth below the surface (Fig 9). They suggest that Column 4 dates from the end of the Iron Age or the start of the Roman period to late in the Anglo-Saxon period. A sand horizon noted just below 81cm probably represents an alluviation event, during which older plant material from nearby peat deposits (eg that sampled by Column 2) may have been introduced. Such reworked material could account for the anomalously old result, OxA-12482, at 81cm. The remaining samples appear to date *in situ* peat formation. Column 4 is from a section *c* 10m southeast of the burnt mound, and *c* 5m south of the line of timber posts. The pollen sequence clearly postdates the burnt mound activity, but apparently includes the period in which the bridge was built.

Column 8

Column 8, located *c* 50m southeast of the burnt mound, covers a similar timespan. All four results are consistent with an assumption that sample age increases with depth (Fig 10). It is therefore assumed that each sample dates *in situ* peat formation, starting in the Middle Iron Age, and continuing until late in the Anglo-Saxon period. The entire pollen sequence is therefore later than the burnt mound.

Summary

The earliest dated material was the peat deposit sampled by Column 2, which was sealed by alluvium during the Mesolithic. The earliest archaeological samples dated were the remains of two individuals recovered from the spoil of machine excavation of the palaeochannel fill. These date to the beginning of the third millennium cal BC. Burnt mound activity spanned most of the second half of the third millennium. The remains of two aurochsen found in the palaeochannel fall in the same timespan, but the human vertebra with cut marks dates to the beginning of the first millennium cal BC. Horse and cattle bones from the machine spoil date to the mid-late Iron Age. The timber bridge across the palaeochannel dates to the early Anglo-Saxon period. Pollen diagrams from columns 4 and 8 cover the period from the Late Iron Age to the late Anglo-Saxon period.

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Figures

Figure 1a: simulation model, burnt mound sequence, including recorded stratigraphic relationships between contexts and 12 simulated radiocarbon results corresponding to samples with calendar ages 950–800 cal BC. The calibration of each result by the probability method (Stuiver and Reimer 1993) is shown in outline. The square brackets and OxCal keywords at the left of the diagram exactly define the structure of the model, but '*posterior density estimates*' of the dates of samples and events (solid distributions) vary from one run of the model to the next, according to the simulated radiocarbon results.

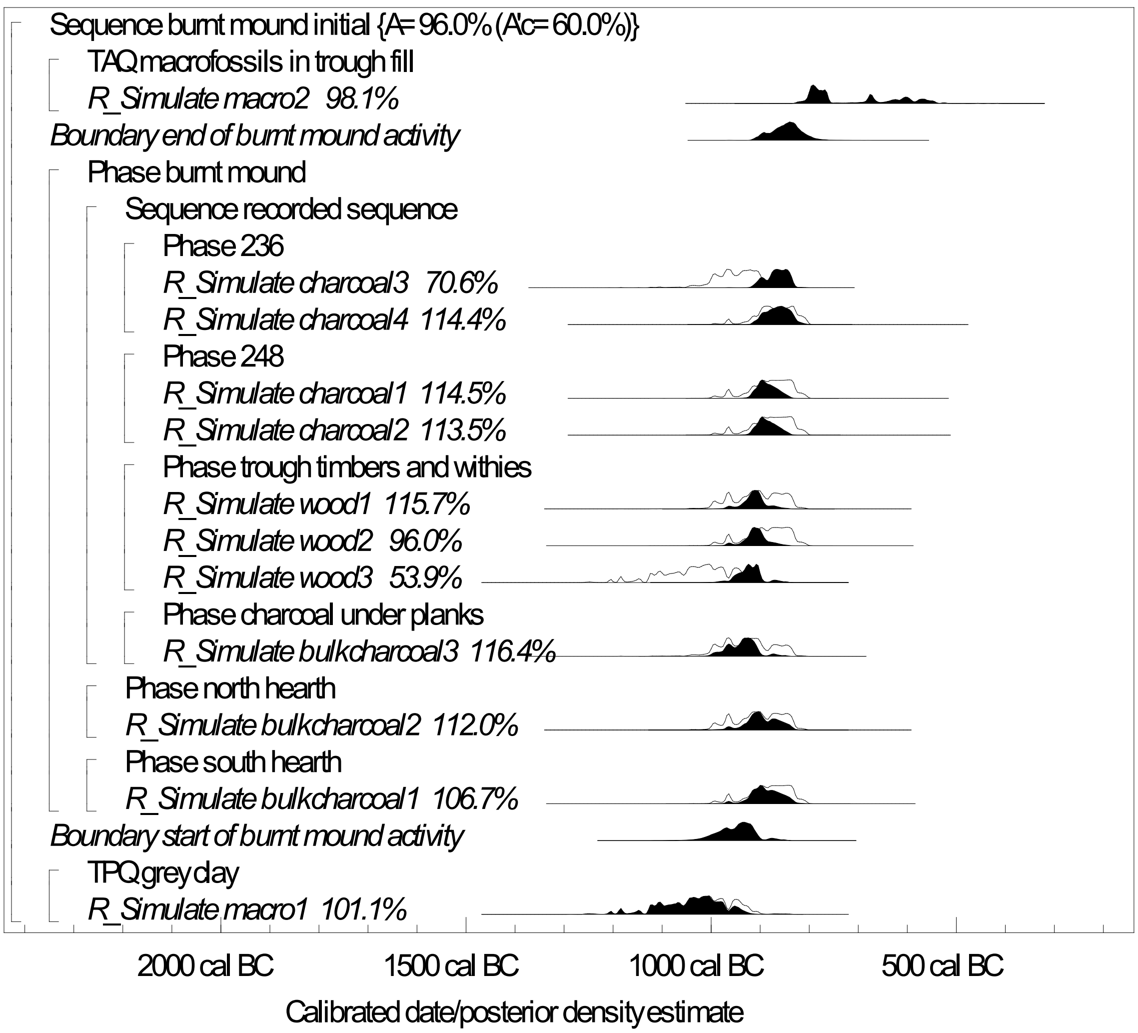

Figure 1b: simulation model, burnt mound sequence, including recorded stratigraphic relationships between contexts, results of the first round of radiocarbon dating, and ten additional simulated radiocarbon results corresponding to samples with calendar ages 2280–2230 cal BC. The format is otherwise identical to that of Figure 1a.

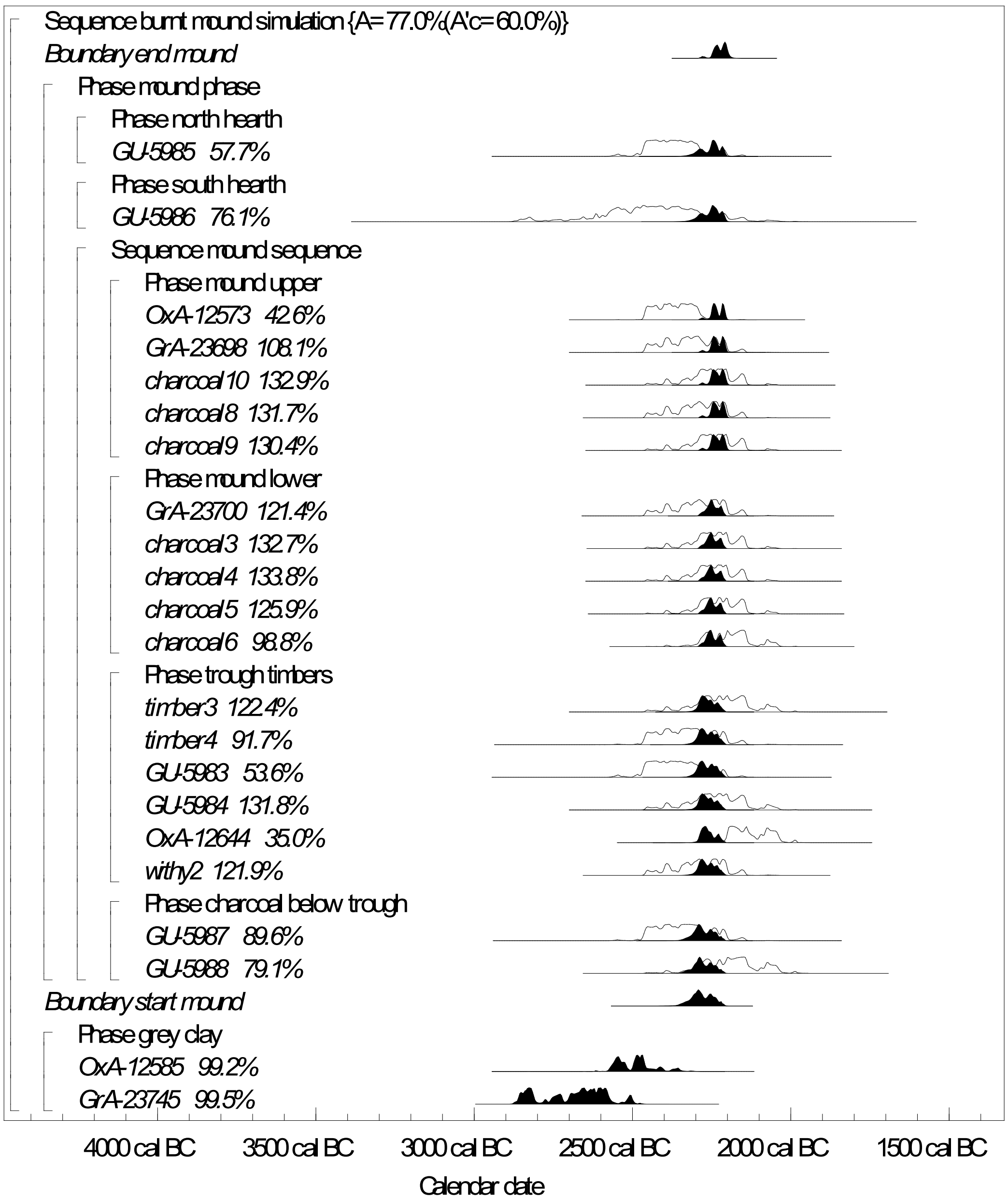

Figure 2: calibration of burnt mound (Series A) radiocarbon results by the probability method (Stuiver and Reimer 1993). Not shown: OxA-12548 (2042±25BP, 120 cal BC–cal AD 30), macrofossils from a peaty gully (229) cutting the burnt mound; OxA-12484 (932±28BP, cal AD 1020–1210), charcoal from spread 248

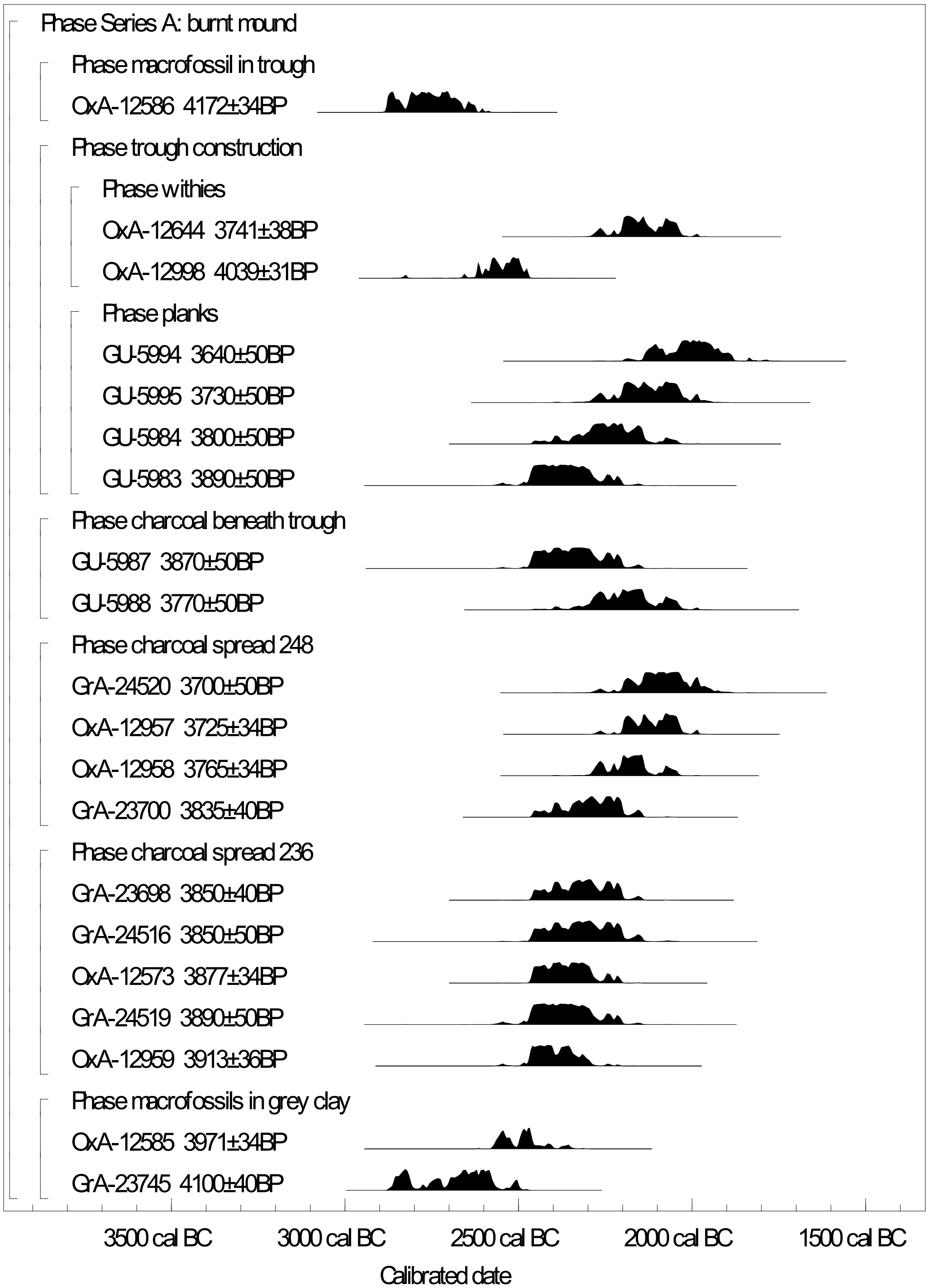

Figure 3: calibration of radiocarbon results, samples from the palaeochannel adjacent to the burnt mound (OxA-6831 and Series B, C, and D), by the probability method (Stuiver and Reimer 1993)

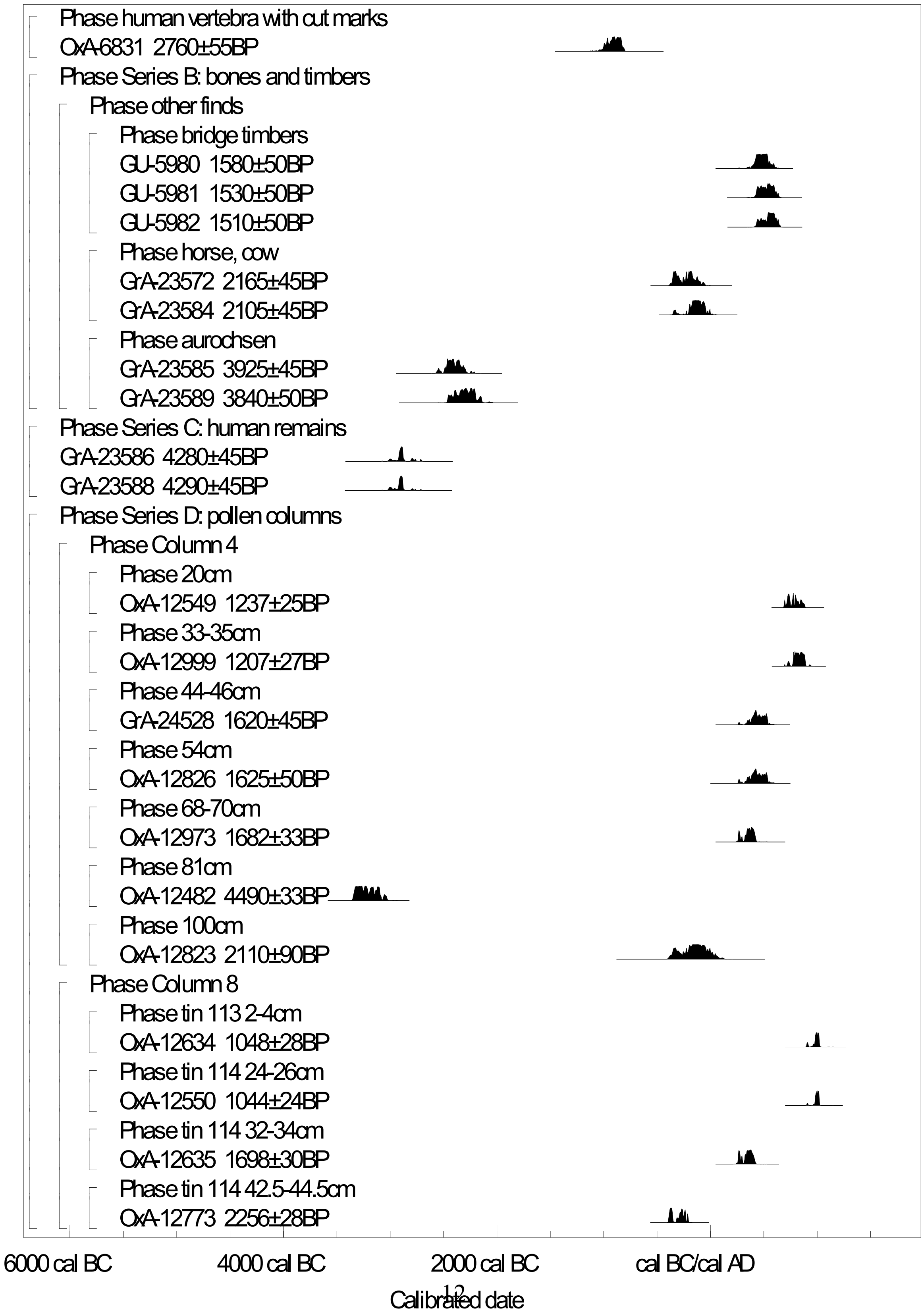

Figure 4: calibration of Column 2 radiocarbon results by the probability method (Stuiver and Reimer 1993)

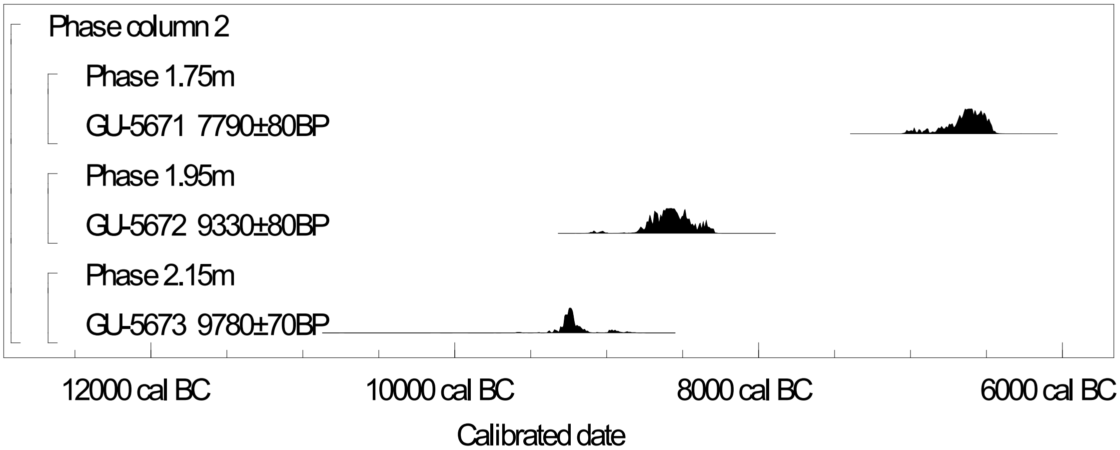

Figure 5: Series A radiocarbon results, combined in a model with the recorded stratigraphy. Not shown: OxA-12548 (2042±25BP, 120 cal BC–cal AD 30), macrofossils from a peaty gully (229) cutting the burnt mound; OxA-12484 (932±28BP, cal AD 1020–1210), charcoal from spread 248. OxA-12484 and OxA-12586 are excluded from the model. The low overall index of agreement (A=0.7%) indicates that the radiocarbon results are not consistent with the model structure, which is identical to that in Figure 1b.

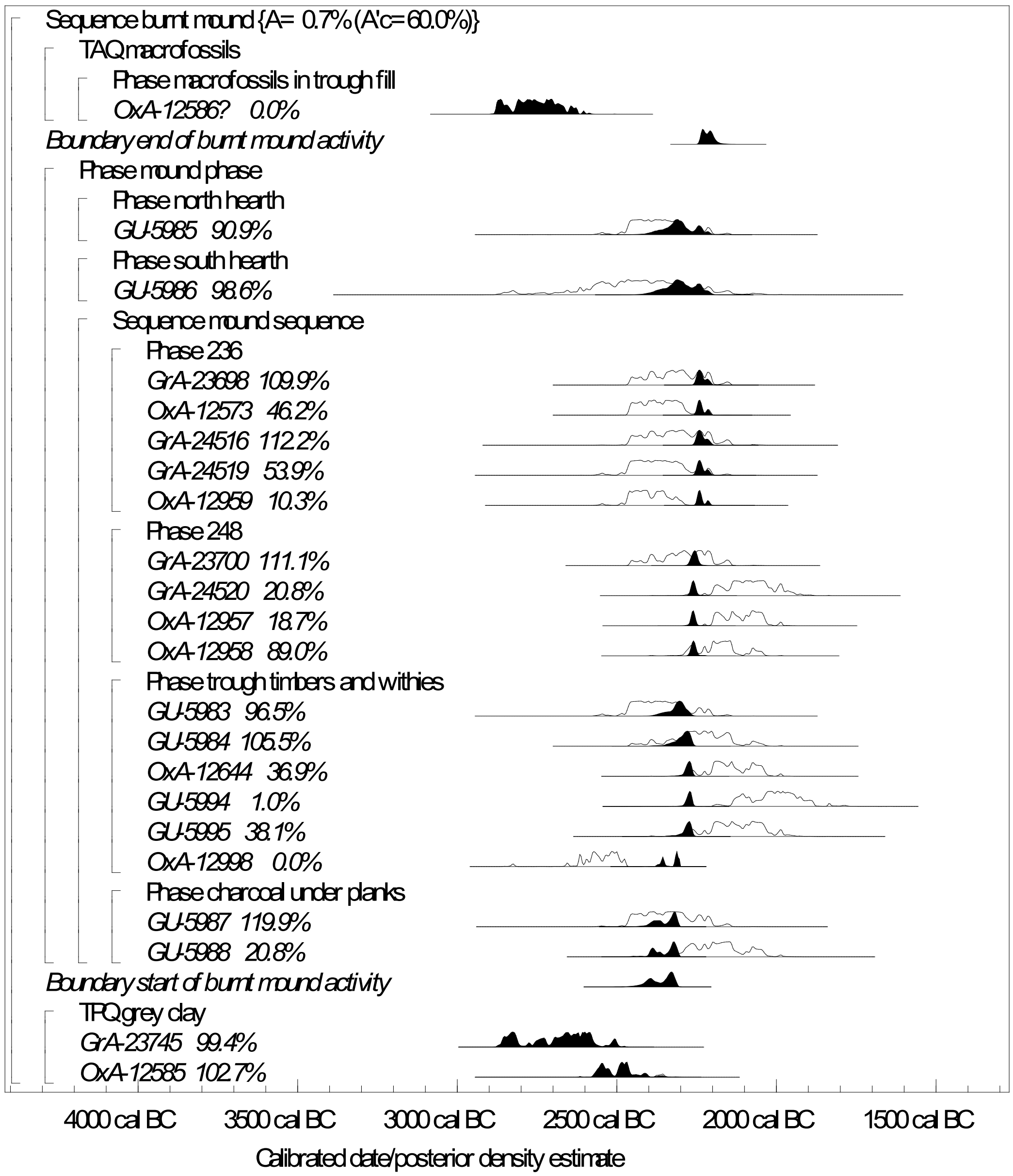

Figure 6: proposed two-phase model of burnt mound activity. Not shown: OxA-12548 (2042±25BP, 120 cal BC–cal AD 30), macrofossils from a peaty gully (229) cutting the burnt mound; OxA-12484 (932±28BP, cal AD 1020–1210), charcoal from spread 248. OxA-12484 and OxA-12586 are excluded from the model. The satisfactory overall index of agreement (A=86.2%) indicates that the model structure is consistent with the radiocarbon results. Distributions in outline represent the calibration of individual results by the probability method (Stuiver and Reimer 1993). Solid distributions are *posterior density estimates* of the date of each sample and of associated events.

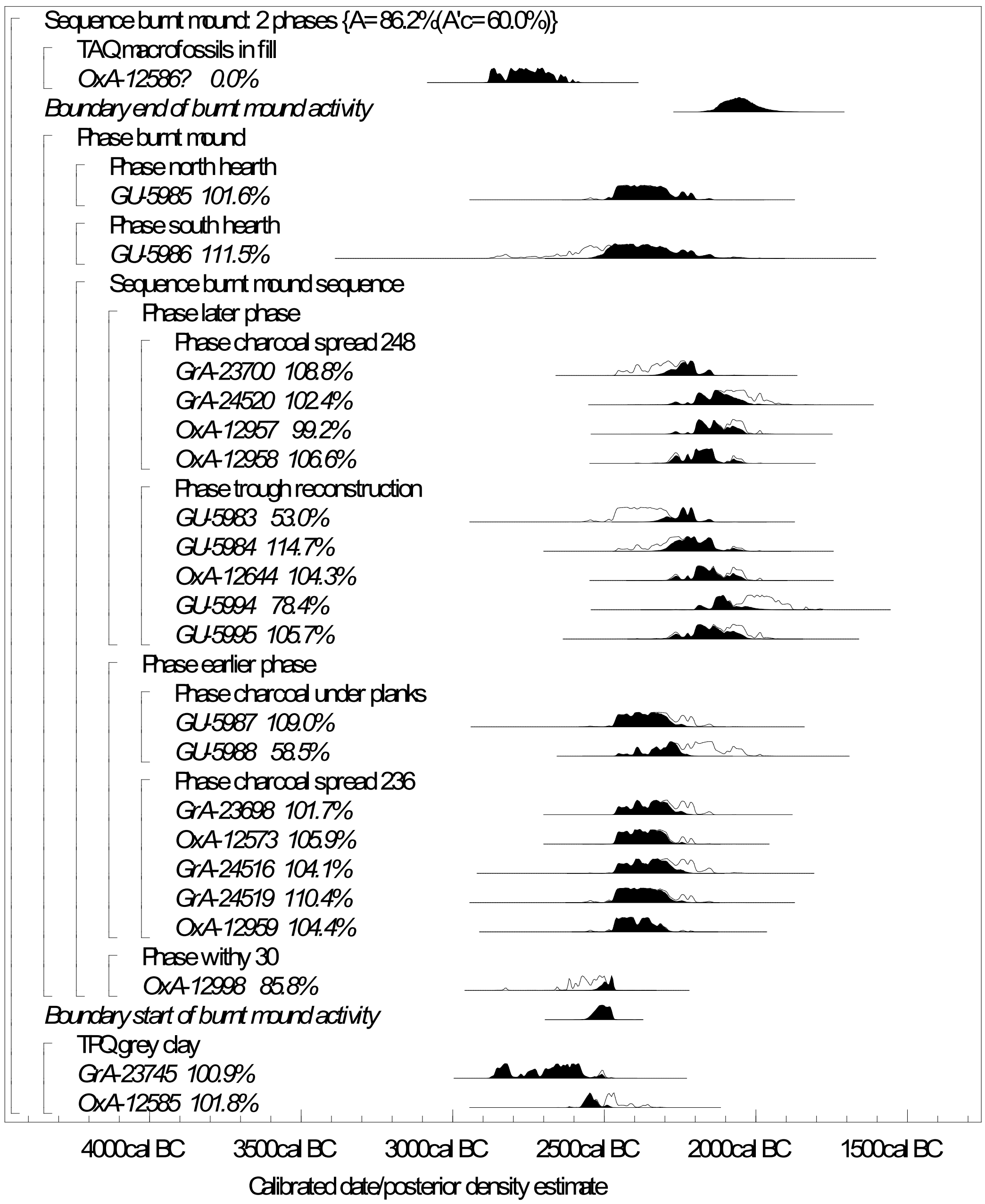

Figure 7: Span (duration) of burnt mound activity estimated by the model shown in Figure 5, equivalent to the difference between the distributions *start of burnt mound activity* and *end of burnt mound activity*. The distribution *hiatus* is the estimated gap between the earlier and later phases of burnt mound activity.

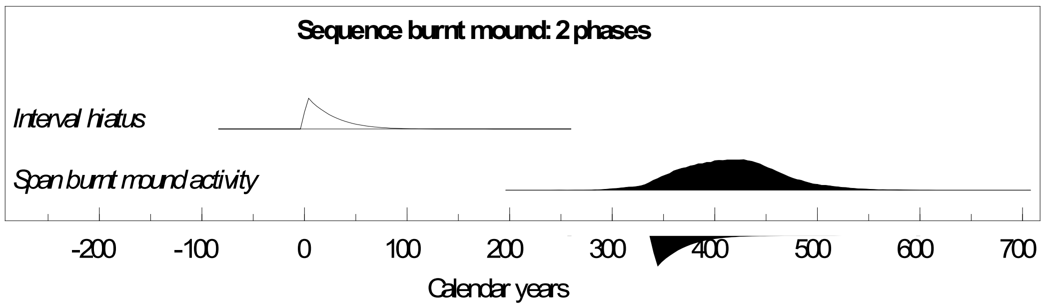

Figure 8: estimated date of bridge construction

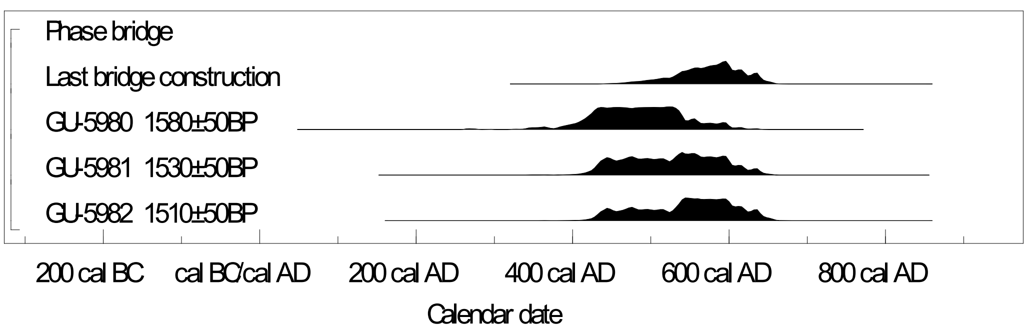

Figure 9: Column 4 radiocarbon results, included in a Bayesian model whose structure is exactly defined by the OxCal keywords and square brackets at the left of the diagram. The model yields a *posterior density estimate* of the actual date of each sample (solid distribution), based on the probability distribution of each calibrated result (shown in outline) and the assumption that sample age increases with depth.

Not included: OxA-12482 (4490±33BP, 3360–3020 cal BC) (81cm)

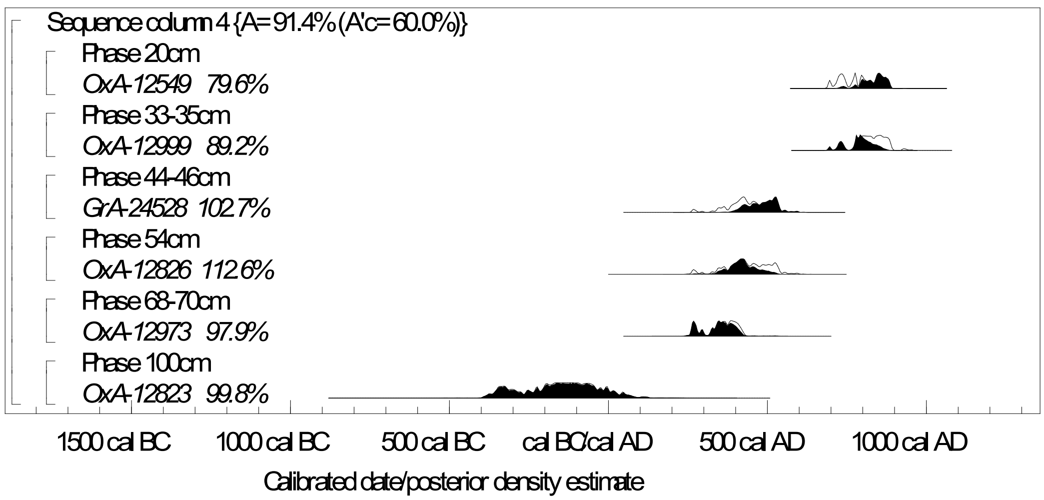

Figure 10: Column 8 radiocarbon results, in a Bayesian model which assumes that sample age increases with depth. The format is identical to that in Figure 9.

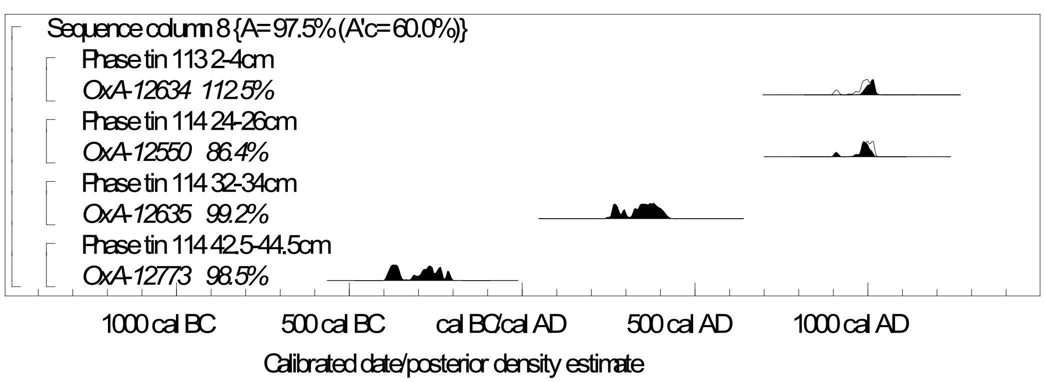

Table 1: radiocarbon results, Birstall Watermeads

Laboratory Code	Sample	Sample	$\delta^{13}C$ (‰)	Radiocarbon age BP	Calibrated date (95% confidence)
Series A					
GrA-23698	[236] 86A	charcoal, *Corylus avellana*	-26.3	3850±40	2470–2140 cal BC
OxA-12573	[236] 86B	charcoal, *Prunus spinosa*	-25.6	3877±34	2470–2200 cal BC
GrA-24519	[236] 86C	charcoal, Pomoideae	-27.2	3890±50	2490–2200 cal BC
GrA-24516	[236] 86D	charcoal, *Prunus spinosa*	-25.3	3850±50	2470–2140 cal BC
OxA-12959	[236] 86E	charcoal, *Alnus glutinosa*	-24.5	3913±36	2490–2290 cal BC
GrA-23700	[248] 92A	charcoal, *Corylus avellana*	-26.1	3835±40	2470–2140 cal BC
OxA-12484	[248] 92B	charcoal, *Alnus glutinosa*	-25.4	932±28	cal AD 1020–1210
GrA-24520	[248] 92C	charcoal, *Alnus glutinosa*	-27.8	3700±50	2280–1940 cal BC
OxA-12958	[248] 92D	charcoal, *Alnus glutinosa*	-28.3	3765±34	2290–2030 cal BC
OxA-12957	[248] 92E	charcoal, *Alnus glutinosa*	-26.6	3725±34	2280–1980 cal BC
GU-5986	[246] 111	charcoal, *Alnus* sp. and bark	-25.5	3940±100	2860–2140 cal BC
GU-5985	[317] 108	charcoal, *Corylus avellana* and *Alnus glutinosa*	-25.9	3890±50	2490–2200 cal BC
GU-5987	[147] 67A	charcoal, *Corylus/Alnus* sp.	-26.9	3870±50	2470–2140 cal BC
GU-5988	[147] 67B	charcoal, *Corylus avellana*, *Alnus glutinosa*, and *Corylus/Alnus* sp.	-27.5	3770±50	2400–2030 cal BC

GU-5994	timber 15	wood, *Alnus glutinosa* wide roundwood	-29.6	3640±50	2150–1830 cal BC
GU-5983	timber 17	wood, *Alnus*?	-23.9	3890±50	2490–2200 cal BC
GU-5984	timber 18	wood, *Alnus*?	-29.4	3800±50	2460–2040 cal BC
GU-5995	timber 20	wood, *Alnus glutinosa* wide roundwood	-29.7	3730±50	2290–1970 cal BC
OxA-12998	withy 30	wood, *Alnus glutinosa* roundwood, including bark	-28.8	4039±31	2830–2610 cal BC
OxA-12644	withies 31/32	wood, *Corylus/Alnus* roundwood, 3 rings	-27.6	3741±38	2290–1980 cal BC
OxA-12586	[101] 56	waterlogged stem/leaf, monocotyledon	-28.8	4172±34	2890–2600 cal BC
OxA-12548	[229] 89	waterlogged seeds of *Carex* sp., *Ranunculus* subgen *Ranunculus*, *Cirsium* sp.	-25.2	2042±25	120 cal BC–cal AD 30
OxA-12585	pollen tin 107A	waterlogged bark fragments	-28.1	3971±34	2580–2350 cal BC
GrA-23745	pollen tin 107B	waterlogged bark fragments	-28.4	4100±40	2870–2490 cal BC

Series B					
GU-5980	timber 01	wood, *Quercus* sp. roundwood, 14 rings	-27.5	1580±50	cal AD 380–610
GU-5981	timber 03	wood, *Quercus* sp. roundwood, 9 rings	-27.5	1530±50	cal AD 420–650
GU-5982	timber 04	wood, *Quercus* sp. roundwood, 17 rings	-25.9	1510±50	cal AD 420–650
GrA-23584	bone 111	bone, cattle skull	-22.3	2105±45	350 cal BC–cal AD 1
GrA-23572	bone 114	bone, horse skull	-22.6	2165±45	380 cal BC–50 cal BC
GrA-23585	bone 03	bone, male aurochs femur with butchery marks	-23.1	3925±45	2570–2230 cal BC

GrA-23589	bone 190	bone, female aurochs femur	-23.4	3840±50	2470–2130 cal BC
Series C					
GrA-23586	small find 47	bone, human skull, male, $\delta^{15}N$ = 11.8‰	-21.2	4280±45	3010–2760 cal BC
GrA-23588	small find 55	bone, human femur, possibly female, $\delta^{15}N$ = 10.9‰	-21.2	4290±45	3020–2790 cal BC
Series D					
OxA-12549	WPB/4/20cm	waterlogged seeds, *Schoenoplectus* sp.	-24.2	1237±25	cal AD 680–890
OxA-12999	WPB/4/33–35cm	waterlogged seeds, *Schoenoplectus*, *Prunella*?, *Ranunculus sceleratus*, *Lychnis flos-cuculi*, *Oenanthe* sp., *Potentilla* sp., *Carex* sp., *Eleocharis* sp.	-25.0	1207±27	cal AD 720–900
GrA-24528	WPB/4/44–46cm	*Prunus/Crataegus* twigs	-26.9	1620±45	cal AD 260–550
OxA-12826	WPB/4/54cm	waterlogged seeds, *Apium* sp., *Lychnis* sp., *Silene* sp., *Persicaria* sp., *Eleocharis* sp.	-26.4	1625±50	cal AD 260–550
OxA-12973	WPB/4/68–70cm	waterlogged seeds, *Ranunculus flammula*, *R. sceleratus*, *Ranunculus* sp., *Lychnis flos-cuculi*, *Polygonum lapathifolium*, *Isolepis setacea*, *Apium nodiflorum*, *Mentha* sp., *Carex* sp., *Chenopodium* cf *album*, *Rumex acetosella*, *Rumex* sp., *Stellaria media*, *Potentilla reptans*, *Cerastium fontanum*	-26.8	1682±33	cal AD 250–430
OxA-12482	WPB/4/81cm	waterlogged seeds, *Ranunculus* subgen *Ranunculus*, *Galium* sp., *Carex* subgenus *Carex*, *Apium* cf. *nodiflorum*, *Persicaria lapathifolia*, *Mentha* sp.	-23.9	4490±33	3360–3020 cal BC
OxA-12823	WPB/4/100–102cm	*Corylus avellana* nutshell, seeds of *Urtica dioica*, *Sambucus nigra*, *Ranunculus* subgen *Ranunculus*, *Viola* sp.	-27.4	2110±90	390 cal BC–cal AD 80
OxA-12634	col8 [113]	waterlogged stem/leaf, monocotyledon	-29.5	1048±28	cal AD 900–1030

OxA-12550	col8 [114]A top	waterlogged stem/leaf, monocotyledon	-27.9	1044±24	cal AD 900–1030
OxA-12635	col8 [114]B mid	waterlogged stem/leaf, monocotyledon	-29.3	1698±30	cal AD 250–430
OxA-12773	col8 [114]C bottom	waterlogged stem/leaf, monocotyledon	-27.7	2256±28	400–200 cal BC

1996 samples					
GU-5671	AS7 1996 31.1	bulk peat, humic acid fraction	-28.3	7790±80	6990–6450 cal BC
GU-5672	AS7 1996 31.3	bulk peat, humic acid fraction	-29.0	9330±80	8790–8290 cal BC
GU-5673	AS7 1996 31.5	bulk peat, humic acid fraction	-30.0	9780±70	9310–9140 cal BC
OxA-6831	AS7 1996 32	human bone, atlas vertebra C1, with cut marks	-20.4	2760±55	1020–800 cal BC