Radiocarbon results

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Introduction

Nine radiocarbon age determinations have been obtained on samples of charcoal and human bone from Longstone Edge.

Objectives

The objectives of the radiocarbon dating programme were:

- To determine the date and duration of mortuary activity prior to the construction of the barrow 1 mound.
- To provide a date for human remains below barrow 1.
- To date the Food Vessel cremation burial associated with the construction of the barrow 1 mound.
- To date the mortuary activity from barrow 2, as a comparison with that beneath barrow 1.

Methods

Eight samples were processed by the Oxford Radiocarbon Accelerator Unit in 2004. The two charcoal samples were prepared using the methods outlined in Hedges et al (1989), the five human bones according to Bronk Ramsey et al 2004a, and the cremated bone sample as outlined in Lanting et al (2001). The samples were all measured using Accelerator Mass Spectrometry (Bronk Ramsey et al 2004b.).

One sample of cremated bone was submitted to the Centre for Isotope Research of the University of Groningen, The Netherlands, for Accelerator Mass Spectrometry (AMS) radiocarbon dating in 2004. The sample pre-treatment followed the method described by Lanting *et al* (2001), and was processed according to the procedures set out in Aerts-Bijma *et al* (1997; 2001) and van der Plicht *et al* (2000).

Both these laboratories maintain continual programmes of quality assurance procedures, in addition to participation in international inter-comparisons (Scott 2003). These tests indicate no laboratory offsets and demonstrate the validity of the precision quoted.

Results

The radiocarbon results are given in Table 1, and are quoted in accordance with the international standard known as the Trondheim convention (Stuiver and Kra 1986). They are conventional radiocarbon ages (Stuiver and Polach 1977).

Calibration

The calibrations of the results, relating the radiocarbon measurements directly to calendar dates, are given in Table 1 and in outline in Figure 1. All have been calculated using the calibration curve of Reimer *et al* (2004) and the computer program OxCal v4.0.5 (Bronk Ramsey 1995; 1998; 2001; 2008). The calibrated date ranges cited in the text are those for 95% confidence. They are quoted in the form recommended by Mook (1986), with the end points rounded outwards to 10 years. The ranges quoted in italics are *posterior density estimates* derived from mathematical modelling of archaeological problems (see below). The ranges in plain type in Table 1 have been calculated according to the maximum intercept method (Stuiver and Reimer 1986). All other ranges are derived from the probability method (Stuiver and Reimer 1993).

Methodological Approach

A Bayesian approach has been adopted for the interpretation of the chronology from this site (Buck *et al* 1996). Although the simple calibrated dates are accurate estimates of the dates of the samples, this is usually not what archaeologists really wish to know. It is the dates of the archaeological events, which are represented by those samples, which are of interest. In the case of Longstone Edge, it is the chronology of the use of the site for funerary activity that is important, not just the dates of individual burials. The dates of this activity can be estimated not only using the absolute dating information from the radiocarbon measurements on the samples, but also by using the stratigraphic relationships between samples.

Fortunately, a methodology is now available which allows the combination of these different types of information explicitly, to produce realistic estimates of the dates of archaeological interest. It should be emphasised that the *posterior density estimates* produced by this modelling are not absolute. They are interpretative *estimates*, which can and will change as further data become available and as other researchers choose to model the existing data from different perspectives.

The technique used is a form of Markov Chain Monte Carlo sampling, and has been applied using the program OxCal v4.0.5 (http://c14.arch.ox.ac.uk/). Details of the algorithms employed by this program are available from the on-line manual or in Bronk Ramsey (1995; 1998; 2001; 2008). The algorithm used in the models described below can be derived from the structure shown in Figure 1.

This section concentrates on describing the archaeological evidence, which has been incorporated into the chronological model, explaining the reasoning behind the interpretative choices made in producing the models presented. These archaeological decisions fundamentally underpin the choice of statistical model.

The sequence

The enclosure defined by a circular dry stone wall contained numerous small human bones and crushed or broken fragments of larger bones in association with Neolithic pottery. Originally interpreted as an excarnation platform, analysis of the human remains suggested they did not represent excarnation. An alternative interpretation was that the remains might be contemporary with the disturbed burials in the rock-cut graves (see below). Two measurements on human bone from the purported excarnation platform ([72572] OxA-13447 4283±32 BP and [72776] OxA-14086; 4832±31 BP) are not statistically consistent (T'=151.2; T'(5%)=3.8; v=1, Ward and Wilson 1978), and clearly represent material of two different ages. However, both are considerably older than the inhumations from the graves.

The enclosure was later re-used as a burial site, marked by the presence of three rock-cut graves, all covered by large limestone flags. Apart from a single fragment in one of the others, only the main or "central" grave contained human remains. Measurements on the two inhumations from the grave (skeleton 75502: OxA-13449; 3771±29 BP; skeleton 75501: OxA-13448; 3691±29 BP), the latter largely displaced by a recent fissure through the barrow, are statistically consistent (T'=3.8; T'(5%)=3.8; v=1, Ward and Wilson 1978), and could thus be of the same age.

A Food Vessel cremation burial was subsequently placed on the edge of the mound that covered the cist burials, and was in turn sealed by the main barrow mound. Replicate samples of charred hazelnut fragments and cremated human bone were submitted as part of a wider programme to assess the accuracy of the dating of cremated bone (Lanting *et al* 2001). The four measurements are not statistically consistent (T'=11384.2; T'(5%)=7.8; v=3, Ward and Wilson 1978) and clearly represent more than one phase of activity. The two replicate measurements on cremated bone [3030] are statistically consistent (T'=0.0; T'(5%)=3.8; v=1, Ward and Wilson 1978), and thus a weighted mean can be taken before calibration (3558±28 BP). The two measurements on charred hazelnut fragments [5136A and B) from the cremation deposit (OxA-13393; 7519±40 BP and OxA-13394; 8475±40 BP) are not statistically consistent (T'=283.9; T'(5%)=3.8; v=1, Ward and Wilson 1978), and the material thus represents the remains of two distinct periods of activity.

Barrow 2 was the smaller of the two barrows and demonstrated a single phase of construction with a rock-cut grave at its centre, previously excavated by Thomas Bateman. The partial remains of a child skeleton found on the ground surface beneath the mound and outside the grave may be the remains of an individual removed from the cist by Bateman. However, other finds from the deposit suggest the bones may be *in-situ*, given they are not in Bateman's backfill. The child inhumation (72634; OxA-13450; 3704±29 BP) and measurements from the central grave of barrow 1 are statistically consistent (T'=4.4; T'(5%)=6.0; v=2, Ward and Wilson 1978), and could all be of the same actual age.

The model

In the model in Figure 2 the two measurements on charred hazelnut fragments from the Food Vessel cremation burial have been excluded from the analysis because they are clearly residual and probably relate to Mesolithic activity in the vicinity of the site. The model shows good agreement between the radiocarbon results and stratigraphy, ($A_{overall}$=99.8%) and provides an estimates for the start of mortuary activity of *3880-3540 cal BC (68% probability; Boundary_Start*; Fig 1*).* The burials in the cist grave date to the end of the 3rd millennium BC following which they were covered by the first mound that is estimated to have been constructed *2070-1930 cal BC (68% probability; mound construction*; Fig 1*).* The estimate for the date of the

Food Vessel cremation is *2020-1770 cal BC (95% probability; R_Combine 3030*; Fig 1*)* and probably *1950-1850 cal BC (68% probability)*. This estimate date of the cremation also provides a *terminus post quem* for the construction of the main barrow mound.

The two individuals dated from below barrow 1 are clearly Neolithic in date and indicate the presence of a much earlier mortuary phase, though there remains no positive evidence for excarnation. The presence of (undated) burnt bone in the mortuary deposit shows that at least some of these remains have been redeposited.

Stable Isotopes

The ratio of carbon isotopes is used to distinguish between a marine protein diet (expected consumer 's $\delta^{13}C$ -12‰) and a C3 plant protein duet (most vegetables, fruits, and wheat) expected consumer 's $\delta^{13}C$ -20‰) (Schwarcz and Schoeninger, 1991). Carbon isotope values between -12‰ and -20‰ indicate consumption of a mixture of marine and terrestrial resources.

Nitrogen isotopes are primarily used to determine the input of plant vs. animal protein in the diet, although there is some evidence that $\delta^{15}N$ values are also influenced by the nitrogen balance of an organism (Fuller *et al* 2004). In an ecosystem each step up the food train results in consumer tissue, in this case bone collagen being enriched in $\delta^{15}N$ by approx. 3-4% relative to diet (Schoeninger and DeNiro 1984). Thus people who eat more animal protein compared to plant protein will display higher $\delta^{15}N$ values (O'Connell and Hedges, 1999).

The $\delta^{13}C$ stable isotope values (Table 1 and Figure 3) are consistent with a very largely terrestrial diet and are not likely to have any effect on the radiocarbon dating (Chisholm *et al* 1982). As no faunal samples are available from Longstone Edge it is not possible to make a direct trophic level comparison of human $\delta^{15}N$ values with domestic or wild animal $\delta^{15}N$ values. The $\delta^{15}N$ values for the young child from barrow 2 (OxA-13450; +12.3‰) and child from the mortuary deposit below barrow 1 (OxA-14086; +11.7‰) are though significantly enhanced compared with the adults. These values might be evidence that these children were breastfed (Richards *et al* 2002), but as these children died at a young age they might have been fed different diets or died of malnutrition, potentially altering the expected $\delta^{15}N$ values (Hobson *et al* 1993).

The C:N ratios suggest that bone preservation was sufficiently good to have confidence in the radiocarbon determinations (Masters, 1987; Tuross *et al* 1988).

Conclusions

The radiocarbon programme has confirmed the existence of Neolithic mortuary activity pre-dating barrow 1, though the formation processes of this assemblage remain unclear. Subsequent mortuary activity prior to the completion of barrow 1 comprised open cist burials just before 2000 cal BC, and a Food Vessel cremation burial just after 2000 cal BC. The radiocarbon results from graves beneath barrow 1 and 2 suggest that the Early Bronze Age burial activity at each site may have been contemporary.

References

Aerts-Bijma, A T, Meijer, H A J, and van der Plicht, J, 1997 AMS sample handling in Groningen, *Nuclear Instruments and Methods in Physics Research B*, **123**, 221–5

Aerts-Bijma, A T, van der Plicht, J, and Meijer, H A J, 2001 Automatic AMS sample combustion and CO_2 collection, *Radiocarbon*, **43(2A)**, 293–8

Bronk Ramsey, C, 1995 Radiocarbon calibration and analysis of stratigraphy, *Radiocarbon*, **36**, 425–30

Bronk Ramsey, C, 1998 Probability and dating, *Radiocarbon*, **40**, 461–74

Bronk Ramsey, C, 2001, Development of the Radiocarbon Program OxCal, *Radiocarbon*, **43** (2A) 355-363

Bronk Ramsey, C, 2008 Deposition models for chronological records, *Quaternary Science Reviews* **27**, 42-60

Bronk Ramsey, C, Higham, T F G, Bowles, A, and Hedges, R E M, 2004a Improvements to the pretreatment of bone at Oxford, *Radiocarbon,* **46**, 155-63

Bronk Ramsey, C, Ditchfield, P, Humm, M, 2004b Using a Gas ion source for radiocarbon AMS and GC-AMS, *Radiocarbon* **46**, 25-32

Buck, C E, Cavanagh, W G, and Litton, C D, 1996 *Bayesian Approach to Interpreting Archaeological Data*. Chichester: Wiley

Chisholm, B S, Nelson, D E, and Schwarcz, H P 1982 Stable carbon isotope ratios as a measure of marine versus terrestrial protein in ancient diets, *Science,* **216**, 1131-32

Fuller, B T, Fuller, J L, Sage, N E, Harris, D A, O'Connell, T C, Hedges, R E M, 2004 Nitrogen balance and $\delta^{15}N$: why you're not what you eat during pregnancy, *Rapid Commun Mass Spectrom* **18**, 2889–2896.

Hedges, R E M, Law, I A, Bronk, C R, and Housley, R A, 1989 The Oxford Accelerator Mass Spectrometry facility: technical developments in routine dating, *Archaeometry*, **31**, 99-113

Hobson K A, Alisauskas R T, Clark R G, 1993 Stable nitrogen isotope enrichment in avian tissues due to fasting and nutritional stress: implications for isotopic analyses of diet, *Condor* **95**, 388–394

Lanting, J N, Aerts-Bijma, A T, and van der Plicht, J, 2001 Dating of cremated bones, *Radiocarbon*, **43(2A)**, 249–54

Masters, P M, 1987 Preferential preservation of non-collagenous protein during bone diagenesis: implications for chronometric and stable isotope measurements*, Geochimica et Cosmochimica Acta*, **51**, 3209-14

Mook, W G, 1986 Business Meeting: recommendations/resolutions adopted by the twelfth international radiocarbon conference, *Radiocarbon* **28**, 799

O'Connell, T C, Hedges, R E M, 1999 Investigations into the effects of diet on modern human hair isotopic values, *Am J Phys Anthropol* **108**, 409–425.

Reimer, P J, Baillie, M G L, Bard, E, Bayliss, A, Beck, J W, Bertrand, C, Blackwell, P G, Buck, C E, Burr, G, Cutler, K B, Damon, P E, Edwards, R L, Fairbanks, R G, Friedrich, M, Guilderson, T P, Hughen, K A, Kromer, B, McCormac, F G, Manning, S, Bronk Ramsey, C, Reimer, R W, Remmele, S, Southon, J R, Stuiver, M, Talamo, S, Taylor, F W, van der Plicht, J, and Weyhenmeyer, C E, 2004 IntCal04 Terrestrial radiocarbon age calibration, 0–26 Cal Kyr BP *Radiocarbon* **46**,1029-1058

Richards, M P, Mays, S, and Fuller, B T, 2002 Stable carbon and nitrogen values of bone and teeth reflect weaning age at the medieval Wharram Percy site, Yorkshire, UK, *Amer J Phys Anthropol* **119**, 205-10
Schoeninger, M J, DeNiro M J, 1984 Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals, *Geochim Cosmochim Acta* **48**, 625–639.
Schwarcz, H P, Schoeninger M J, 1991 Stable isotopic analyses in human nutritional ecology, *Yrbk Phys Anthropol* **34**, 283–321
Scott, E M, 2003 The third international radiocarbon intercomparison (TIRI) and the fourth international radiocarbon intercomparison (FIRI) 1990 – 2002: results, analyses, and conclusions, *Radiocarbon*, **45**, 135-408
Stuiver, M, and Kra, R S, 1986 Editorial comment, *Radiocarbon*, **28(2B)**, ii
Stuiver, M and Polach, H J, 1977 Discussion: reporting of ^{14}C data, *Radiocarbon*, **19**, 355–63
Stuiver, M, and Reimer, P J, 1986 A computer program for radiocarbon age calculation, *Radiocarbon*, **28**, 1022–30
Stuiver, M, and Reimer, P J, 1993 Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program, *Radiocarbon*, **35**, 215–30
van de Plicht, J, 1993 The Gröningen radiocarbon calibration program, *Radiocarbon*, **35**, 231-7
van der Plicht, J, Wijma, S, Aerts, A T, Pertuisot, M H, and Meijer, H A J, 2000 Status report: the Groningen AMS facility, *Nuclear Instruments and Methods in Physics Research B*, **172**, 58–65
Ward, G K, and Wilson, S R, 1978 Procedures for comparing and combining radiocarbon age determinations: a critique, *Archaeometry*, **20**, 19-31

Table 1 Longstone Edge Radiocarbon Results

<table>
<tr><th>Lab Number</th><th>Context/Sample Number</th><th>Description</th><th>Material</th><th>Radiocarbon Age (BP)</th><th>Weighted mean</th><th>δ^{13}C (‰)</th><th>δ^{15}N (‰)</th><th>C:N ratio</th><th>Calibrated date range (95% confidence)</th><th>Posterior Density Estimate (95% probability)</th></tr>
<tr><td>OxA-13393</td><td>3030, 5136A</td><td>Barrow 1, cremation</td><td>Hazelnut shell fragment</td><td>7519±40</td><td></td><td>-22.4</td><td></td><td></td><td>6450-6240 cal BC</td><td>-</td></tr>
<tr><td>OxA-13394</td><td>3030, 5136B</td><td>Barrow 1, cremation</td><td>Hazelnut shell fragment</td><td>8475±40</td><td></td><td>-24.7</td><td></td><td></td><td>7590-7480 cal BC</td><td>-</td></tr>
<tr><td>OxA-14087</td><td>3030</td><td>Barrow 1, cremation</td><td>Human bone, cremated</td><td>3560±40</td><td rowspan="2">3558±28 BP (T'=0.0; T'(5%)=3.8; v=1, Ward and Wilson 1978),</td><td></td><td></td><td></td><td rowspan="2">2010-1770 cal BC</td><td rowspan="2">2020-1770 cal BC</td></tr>
<tr><td>GrA-26548</td><td>3030</td><td>Barrow 1, cremation</td><td>Human bone, cremated</td><td>3555±40</td><td></td><td></td><td></td></tr>
<tr><td>OxA-13447</td><td>1057, 72572</td><td>Barrow 1, inhumation</td><td>Human bone, proximal end of right ulna</td><td>4832±31</td><td></td><td>-20.8</td><td>9.0</td><td>3.2</td><td>3660-3530 cal BC</td><td>3700-3620 (39%) or 3940-3520 (56%)</td></tr>
<tr><td>OxA-14086</td><td>1082, 72776</td><td>Barrow 1, inhumation</td><td>Human bone</td><td>4283±32</td><td></td><td>-22.1</td><td>11.7</td><td>3.2</td><td>2930-2870 cal BC</td><td>3010--2870 cal BC</td></tr>
<tr><td>OxA-13448</td><td>75501</td><td>Barrow 1 (cist grave), inhumation</td><td>Human bone, left femur base</td><td>3691±29</td><td></td><td>-20.6</td><td>10.4</td><td>3.2</td><td>2200-1970 cal BC</td><td>2200-1980 cal BC</td></tr>
<tr><td>OxA-13449</td><td>75502, 72711/2</td><td>Barrow 1 (cist grave), inhumation</td><td>Human bone, left femur distal shaft</td><td>3771±29</td><td></td><td>-20.5</td><td>10.8</td><td>3.3</td><td>2290-2040 cal BC</td><td>2290-2130 (91%) or 2090-2050 (4%) cal BC</td></tr>
<tr><td>OxA-13450</td><td>2058, 72634</td><td>Barrow 2, inhumation</td><td>Human bone, left femur mid-shaft fragment</td><td>3704±29</td><td></td><td>-21.2</td><td>12.3</td><td>12.3</td><td>2200-1980 cal BC</td><td>2200-2020 (94%) or 2000-1980 (1%) cal BC</td></tr>
</table>

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

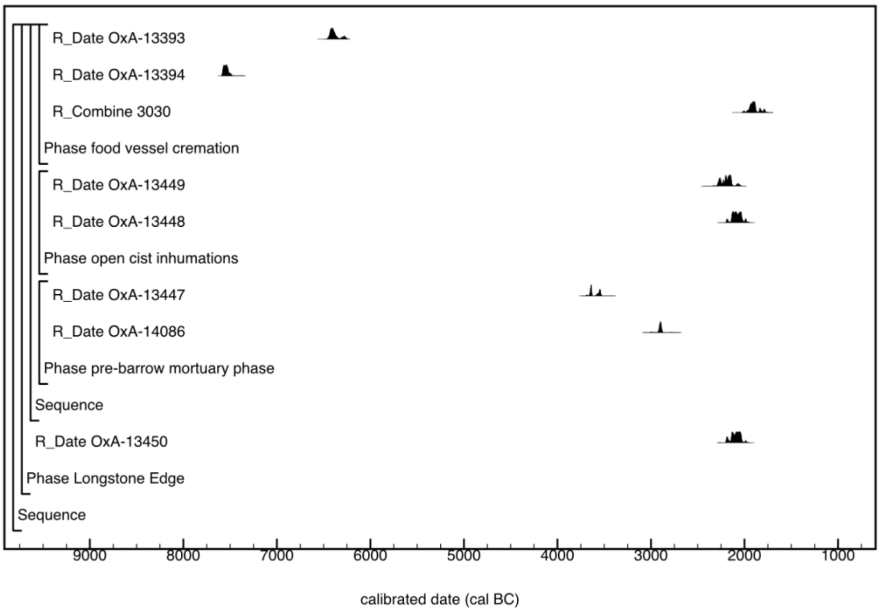

Figure 2: Probability distributions of simulated dates from Longstone Edge: each distribution represents the relative probability that an event occurred at some particular time. For each of the simulated radiocarbon measurements two distributions have been plotted, one in outline, which is the result of simple radiocarbon calibration, and a solid one, which is based on the chronological model used. The other distributions correspond to aspects of the model. For example, the distribution '*mound construction*' is the estimated date for the construction of the first mound at Longstone Edge. The large square brackets down the left hand side along with the OxCal keywords define the overall model exactly.

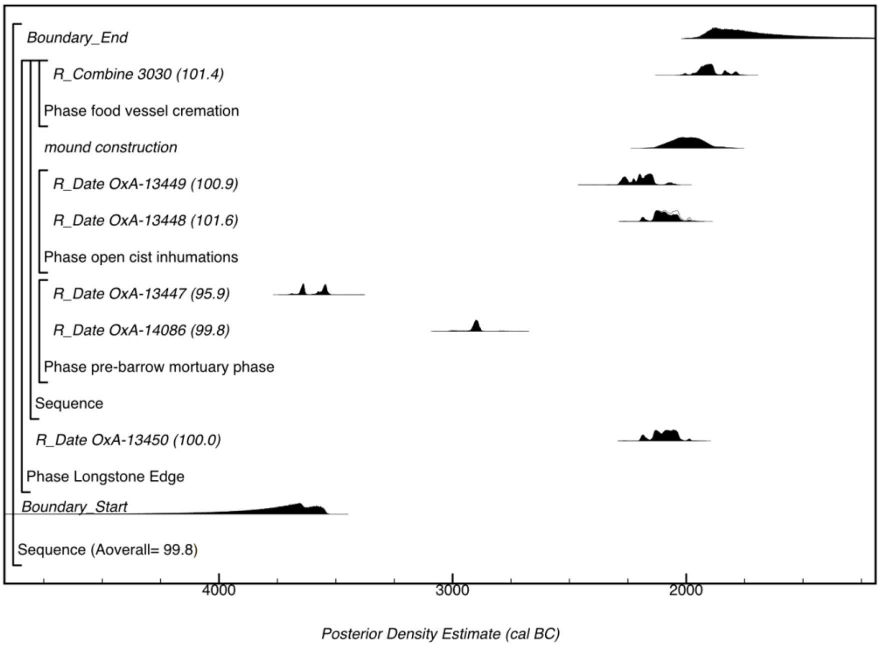

Figure 3: Human bone isotope data from Longstone Edge