UNIVERSITY OF OXFORD

RESEARCH LABORATORY FOR ARCHAEOLOGY
AND THE HISTORY OF ART

Dyson Perrins Building, South Parks Road
Oxford OX1 3QY

Tel: + 44 (0)1865 285229 Fax: + 44 (0)1865 285220
Email: orau@rlaha.ox.ac.uk Web: http://c14.arch.ox.ac.uk

UNIVERSITY OF OXFORD
RADIOCARBON
ACCELERATOR UNIT

Dr Dan Miles
Mill Farm
Mapledurham
Oxon
RG4 7TX

19th Dec, 2011

Our ref: **C14/3777**

Dear Dan

The following radiocarbon measurements have been made on samples from this project.

OxA	**Sample**	**Material (species)**	**δ^{13}C**	**Date**
Trefadog, Anglesey, UK				
OxA-25581	trf 01a	wood (oak)	-24.85	559 ± 25
OxA-25582	trf 01b	wood (oak)	-25.12	348 ± 24

The dates are uncalibrated in radiocarbon years BP (Before Present - AD 1950) using the half life of 5568 years. Isotopic fractionation has been corrected for using the measured δ^{13}C values measured on the AMS. The quoted δ^{13}C values are measured independently on a stable isotope mass spectrometer (to ±0.3 per mil relative to VPDB). For details of the chemical pretreatment, target preparation and AMS measurement see *Radiocarbon* **46** (1) 17-24, **46** (1): 155-63, and *Archaeometry* **44** (3 Supplement 1): 1-149. The attached calibration plots, showing the calendar age ranges, have been generated using the Oxcal computer program (v4.1) of C. Bronk Ramsey, using the 'INTCAL09' dataset (*Radiocarbon* **51** (4), 2009).

As you may know we publish all dates measured at Oxford in a datelist which appears in the journal *Archaeometry*. When you have had the chance to consider the implications of the results I wonder if you would be kind enough to send your brief comments to me.

Yours sincerely

Hayley Sula

Interpretation of C14 Dates OxA-25581 and OxA-25582 from Trefadog, Anglesey

Dr Peter Marshall, Assistant Scientific Dating Co-ordinator, English Heritage
December 2011

Radiocarbon wiggle-matching

Wiggle-matching is the process of matching a series of radiocarbon determinations 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 different blocks of wood submitted for dating is known precisely by counting the rings in the timber.

Recent advances in the accuracy and precision of radiocarbon measurements produced by Accelerator Mass Spectrometry (eg Bronk Ramsey *et al* 2004; Dellinger *et al* 2004) now make this approach feasible for small wood samples, such as those available from cores taken for tree-ring dating. An excellent summary of the history and variety of approaches employed for wiggle-matching is provided by Galimberti *et al* (2004) and recent applications can be found in Hamilton *et al* (2008) and Tyers *et al* (2009).

A variety of the wiggle-matching approach has also been applied to validate, or choose between, different matching positions of a floating tree-ring sequence against the absolutely dated master chronologies (Bayliss *et al* 1999). This is useful in situations where possible cross-matching positions have been identified by the tree-ring analysis, but where these are not strong enough statistically to be accepted without independent, confirmatory, evidence.

A Bayesian approach to wiggle-matching

The first method of wiggle-matching which has been applied to these data, is using a Bayesian approach to combine the radiocarbon dates with the relative dating provided by the tree-ring analysis. This is a probabilistic approach, which determines which parts of the calibrated radiocarbon date are most likely given the tree-ring evidence. This results in a reduced date range, known as a *posterior density estimate*, which is shown in black in Figure 1, and given in italics in the text.

The technique used is a form of numerical integration, and has been applied using the program OxCal v4.1 (http://www.rlaha.ox.ac.uk/orau/) and the calibration data of Reimer *et al* (2009). Details of the algorithms employed for this application are available from the on-line manual or in Bronk Ramsey (1995; 1998; 2001; 2009). The algorithms used in the models described below can be derived from the structure shown in Figures 1and 2.

A general introduction to the Bayesian approach to interpreting archaeological data is provided by Buck *et al* (1996) and for dating buildings (Bayliss 2007). The approach to wiggle-matching adopted here is described by Christen and Litton (1995) and Bronk Ramsey *et al* (2001).

The chronological model for the dating of samples from trf01 is shown in Figure 1. This includes the radiocarbon measurements on each of the five year blocks of wood from the cores, the information that the centre ring of block A is 75 years earlier than the centre ring of block B, and the information that after the centre point of block B there were two and half years to the bark edge.

This analysis suggests that sample trfo1, was felled in *cal AD 1465-1505 (95% probability; bark edge*; Fig 1), or *cal AD 1475–1495 (68% probability)*. This model has good overall agreement (A_{comb} = 97.9%, A_n= 50%, n-2; Bronk Ramsey 1995). This means that the radiocarbon measurements are compatible with the tree-ring sequence of the timber samples.

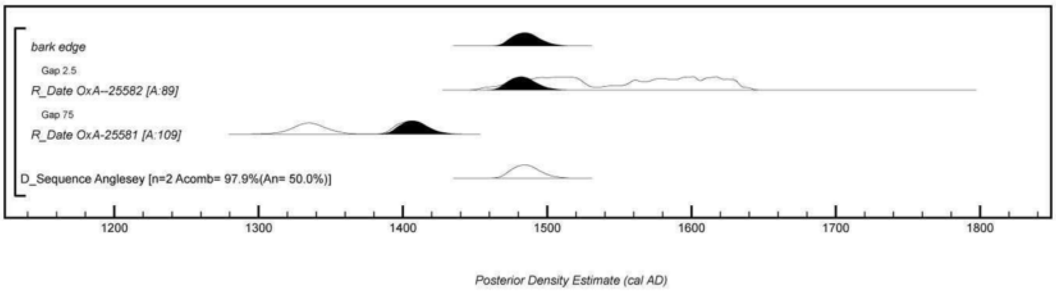


Figure 1: Probability distributions of dates from core trf01. Each distribution represents the relative probability that an event occurs at a particular time. For each of the dates two distributions have been plotted: one in outline, which is the result of simple radiocarbon calibration, and a solid one, based on the wiggle-match sequence. Distributions other than those relating to particular samples, correspond to aspects of the model. For example, the distribution '*bark edge*' is the estimated date when the timber was felled. The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly.

A Bayesian approach to validating tentative tree-ring matches

Despite exhaustive cross-checking for potential matches with an extensive set of reference data from Great Britain, conclusive dating of the tree-ring series from Trefadog by dendrochronology has not been possible. A potential tree-ring match was suggested by the dendrochronology for the site sequences - AD 1468 - although the match is not sufficiently strong for acceptance in absence of confirmatory evidence.

Figure 2 shows the chronological model for the dating of samples where the last ring of the sequence is constrained to be AD 1468, as tentatively suggested by the tree-ring analysis. This model includes the radiocarbon results on each of the five year blocks of wood from the core, the information that the centre of one block is 75 years earlier than the centre of the next block in the sequence, and the information that the centre point of block B is two and a half years earlier than the bark edge date of AD 1468. This model has poor overall agreement (A_{comb} =35.0%; A_n=40.8%, n=3; Bronk Ramsey 1995). This suggests that the dating of this sequence, cautiously suggested by tree-ring analysis, may be in-correct.

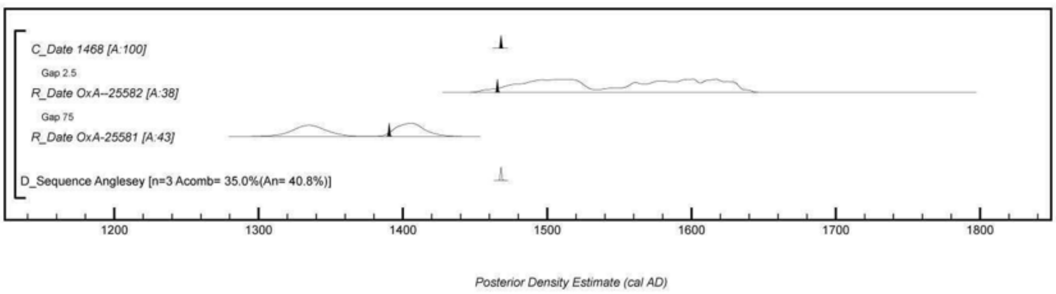


Figure 2: Probability distributions of dates from core trf01. The format is identical to that of Figure 1. *C_Date AD 1468* has been included to test whether the radiocarbon dates agree with the weak match provided by tree-ring analysis at this date. The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly

Discussion

The radiocarbon calibration curve for the late fifteenth century and early sixteenth century is complex (see Fig 3) and accounts for the wide and bi-modal distribution for sample B (shown in outline in Figs 1 and 2).

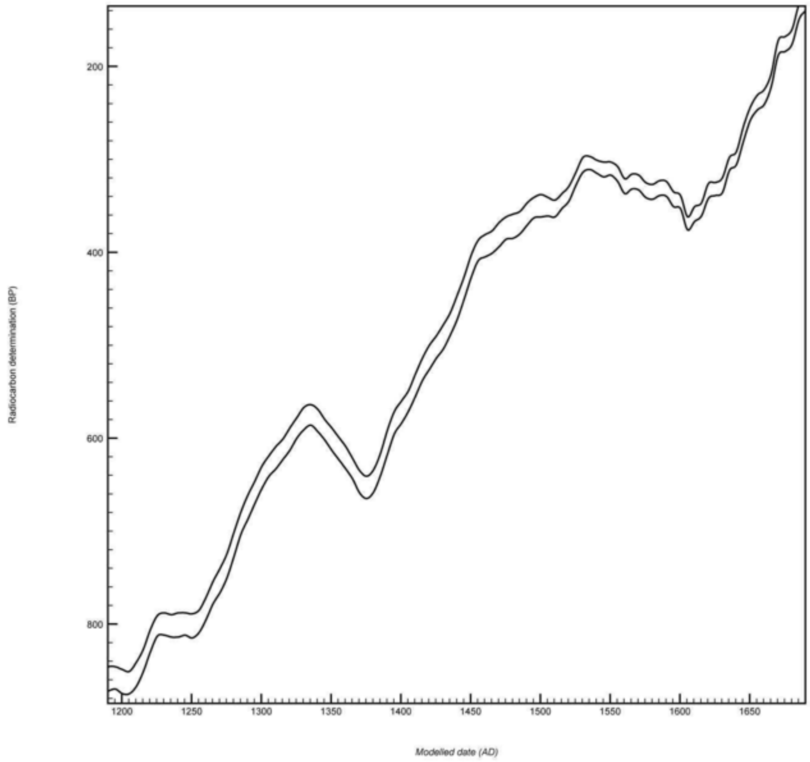


Figure 3: Radiocarbon calibration curve c AD 1200-1700 (Reimer *et al* 2009)

In order to refine the estimated date for the last ring in the core we have run a simulation (Fig 4) that exploit the steep piece of the calibration curve in the mid-fifteenth century (Fig 3). This simulation model includes an additional radiocarbon sample (R_Simulate). This simulation suggests that sample trfo1, was felled in *cal AD 1465-1490 (95% probability; bark edge*; Fig 1), or *cal AD 1470–1485 (68% probability)*. This model has good overall agreement (A_{comb} = 82.1%, A_n= 40.8%, n-3; Bronk Ramsey 1995). This means that the radiocarbon measurements are compatible with the tree-ring sequence of the timber samples.

Thus the submission of an additional sample will improve the precision of the estimated felling date, however, it will never confirm the tentative tree-ring date because of where sample B falls on the calibration curve.

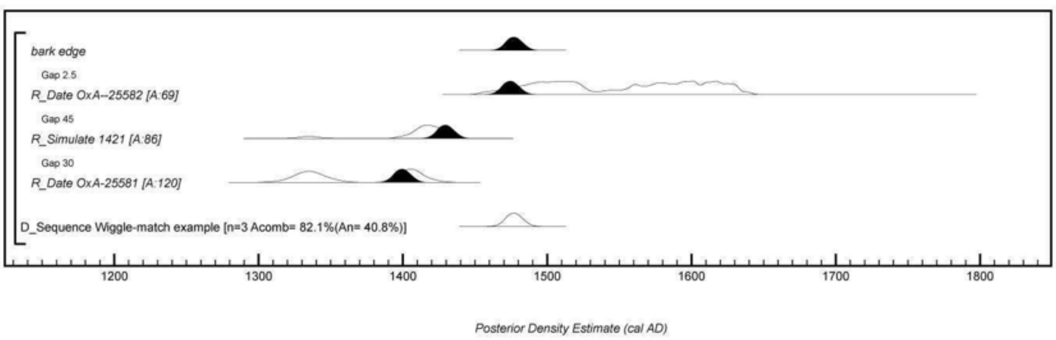


Figure 4: Probability distributions of dates from core trf01. The format is identical to that of Figure 1. *R_Simulate 1421* has been included to determine whether an additional radiocarbon dates increases the precision of the estimated felling date (*bark edge*). The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly

References

Bayliss, A, 2007 Bayesian buildings: an introduction for the numerically challenged. *Vernacular Architecture* **38**, 75–86.

Bayliss, A, and Tyers, I, 2004 Interpreting radiocarbon dates using evidence from tree rings. *Radiocarbon* **42**, 939□46.

Bayliss, A, Groves, C, McCormac, G, Baillie, M, Brown, D, and Brennard, M, 1999 Precise dating of the Norfolk timber circle, *Nature*, **402**, 479

Bronk Ramsey, C, 1995 Radiocarbon calibration and analysis of stratigraphy: The OxCal program, *Radiocarbon,* **37,** 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**, 355–363

Bronk Ramsey, C, 2009 Bayesian analysis of radiocarbon dates, *Radiocarbon*, **51**, 337–60

Bronk Ramsey, C, van der Plicht, J, and Weninger, B. 2001 ‘Wiggle matching’ radiocarbon dates. *Radiocarbon* **43**, 381–9.

Buck, C E, Cavanagh, W G, and Litton, C D, 1996 *Bayesian approach to interpreting archaeological data*. Chichester: Wiley.

Christen, J A, and Litton, C D 1995. A Bayesian approach to wiggle-matching. *Journal of Archaeological Science* **22**, 719–25.

Dellinger, F, Kutschera, W, Nocolussi, K, Schiessling, P, Steier, P, and Wild, E M, 2004 A ^{14}C calibration with AMS from 3500 – 3000 BC, derived from a new high-elevation stone-pine tree-ring chronology, *Radiocarbon*, **46**, 969-78

Galimberti M, Bronk Ramsey C, Manning S. 2004 Wiggle-match dating of tree-ring sequences. *Radiocarbon* **46**, 914–927.

Hamilton W D, Bayliss A, Menuge A, Bronk Ramsey C, Cook G. 2007 “*Rev Thomas Bayes: Get Ready To Wiggle*” – Bayesian Modelling, Radiocarbon Wiggle-matching, and the North Wing of Baguley Hall. *Vernacular Architecture* **38**, 84–96.

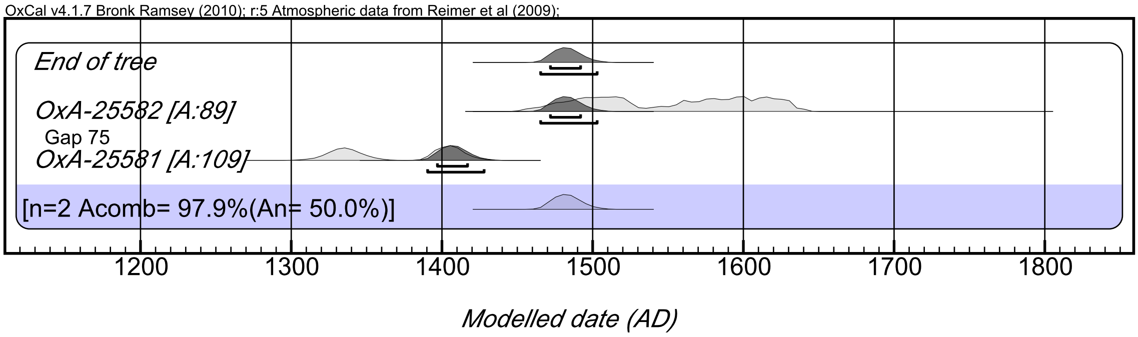
Reimer, P J, Baillie, M G L, Bard, E, Bayliss, A, Beck, J W, Blackwell, P G, Bronk Ramsey, C, Buck, C E, Burr, G S, Edwards, R L, Friedrich, M, Grootes, P M, Guilderson, T P, Hajdas, I, Heaton, T J, Hogg, A G, Hughen, K A, Kaiser, K F, Kromer, B, McCormac, F G, Manning, S W, Reimer, R W, Richards, D A, Southon, J R, Talamo, S, Turney, C S M, van der Plicht, J, and Weyhenmeyer, C E, 2009 IntCal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years cal BP, *Radiocarbon*, **51**, 1111–50

Stuiver, M, and Reimer, P J, 1986 A computer program for radiocarbon age calculation, *Radiocarbon*, **28**, 1022–30

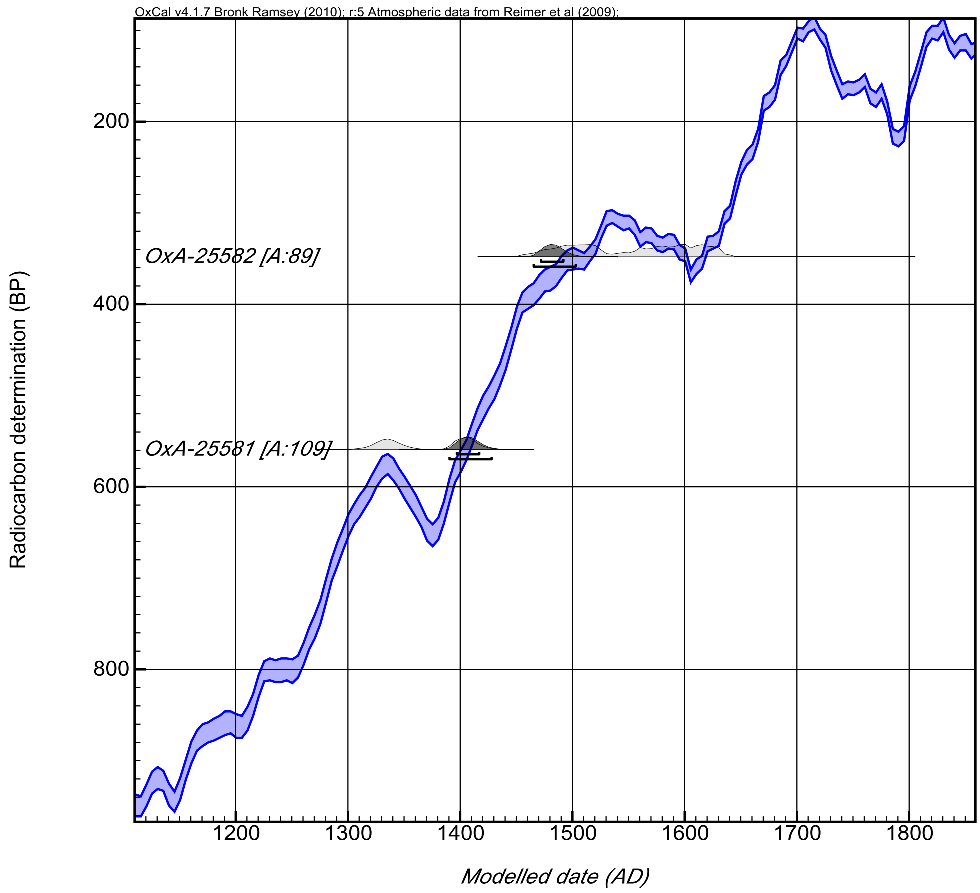
Stuiver, M, and Reimer, P J, 1993 Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program, *Radiocarbon*, **35**, 215–30

Tyers, C, Sidell, J, van der Plicht, J, Marshall, P, Cook, G, Bronk Ramsey, C, and Bayliss, A, 2009 Wiggle-matching using known-age pine from Jermyn Street, London, UK, *Radiocarbon* **51***,* 385–396.

Trefadog Miles_wigglematch[1]



Trefadog Miles_wigglematch[2]



Trefadog Miles-P30618-19_cal[1]