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Trerithick, Polyphant, Altarnun, Cornwall Radiocarbon wiggle-matching of oak timbers

Alison Arnold, Robert Howard, Cathy Tyers, Michael Dee, Sanne Palstra, and Peter Marshall

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SUMMARY
Independent validation of tentative tree-ring dating for a group of previously undated samples from the west range roof of Trerithick, Altarnun, Cornwall has been obtained by radiocarbon wiggle-matching and it can now be considered as a radiocarbon-supported dendrochronological date, the site chronology spanning AD 1557–1726$_{DR}$. Dendrochronological and radiocarbon analysis has now demonstrated that the roofs of both the extant hall range and west range are replacements dating to the late seventeenth and early-eighteenth centuries respectively.

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INTRODUCTION

Trerithick is a Grade-II* listed (List Entry Number 1328056), two storey, medieval hall house, located approximately 1.5km west of Polyphant in the parish of Altarnun, near Launceston, Cornwall (Fig 1).

This sixteenth-century house, thought to have been radically remodelled and extended in the eighteenth century, currently comprises the hall range aligned broadly north-south and facing east, incorporating the original open hall, with a short parlour wing at its northern end and two ranges to the rear, one extending broadly westwards from the parlour wing forming a courtyard. A further range is set to the front to the southern end of the hall range. The information below is summarised from the official list entry (List Entry Number 1328056), Berry (2006), and the handbook of the Vernacular Architecture Group 2019 Spring Conference.

The principle phase of the house is of late sixteenth-century date, having been built for John Hecks, but there is uncertainty as to what preceded this. The core plan of the hall range is of a three-room and cross-passage hall house with the inner room to the north, later the parlour wing, probably having a stair in the rear wall, whilst the hall, and probably the lower end to the south of the passage, were open to the roof. It is thought that much of the walling dates to around AD 1575 when it has been suggested that the northern end of the hall range was projected forward from the original line of the front, or east face, of the building as seen now as the parlour wing. Around AD 1585 a gabled two-storey porch was added to the front of the cross-passage, this having a lintel with 'AN DO 1585 BY M + IH' carved into it (Fig 2).

The range immediately to the rear of the parlour wing, referred to here as the west range, is thought to date to the late-sixteenth century and is potentially coeval with the modification of the northern end of the hall range, but it is believed to have been partly rebuilt in the early eighteenth century when the house was substantially remodelled and extended. At 90° to this and running parallel to the hall range is another range which is disused. It has some late sixteenth-century features and has previously been described as incorporating a shippon barn dating to the early eighteenth century.

The range to the front of the main range at its southern end is set at a slight angle and is thought to be seventeenth century, possibly early eighteenth century, although potentially comprising two phases of construction. The end wall of this range has a reset four-light mullion window with the lintel carved 'ANNO DOMINI 1575 BY JOHN HECKS' (Fig 3).

A programme of ring-width dendrochronology was undertaken in AD 2006 on the roofs of the extant hall and west range to inform statutory advice in the context of an application for Listed Building Consent while access was provided by refurbishment work (Arnold and Howard 2007a). This analysis produced two site chronologies, TRKHSQ01 and TRKHSQ02. All seven of the hall range samples matched each other at a minimum *t*-value of 6.8 and were combined at the relevant offset positions to form TRKHSQ01, a site sequence of 171 rings dated to AD 1503–1673 (Arnold and Howard 2007a, fig 13). Five of the 11 samples from the

West range matched each other at a minimum value of t = 12.1 and were combined at the relevant offset positions to form TRKHSQ02, a site sequence of 126 rings (Arnold and Howard 2007a, fig 14). However, attempts to date TRKHSQ02 and the remaining ungrouped samples by dendrochronology were unsuccessful.

DENDROCHRONOLOGY

Since the original dendrochronological analysis in AD 2006 (Arnold and Howard 2007a), the reference data for south-west England has been enhanced. Subsequent reanalysis of the ring-width data from the undated west range roof samples, undertaken as part of a wider reanalysis of undated material from sites in Devon and those sites close to the county boundary with Devon in Cornwall, identified a tenuous end date of AD 1726 for the previously undated site chronology TRKHSQ02. In addition, a potential match (t = 6.9) between TRK-H17 and TRK-H18 was identified but with only a 34-year overlap between the two ring series (Fig 4). These two individual series produced low but significant t-values (t = 4.2 and t = 3.8 respectively) at consistent relative positions with TRKHSQ02. Samples TRK-H17 and TRK-H18 were therefore initially combined to form a new 146 ring site chronology TRKHSQ03. This newly formed site master, TRKHSQ03, matched (t = 5.2) with TRKHSQ02 (Fig 5) and produced some significant t-values at an end date of AD 1702 with reference chronologies, a date consistent with its cross-matching position with TRKHSQ02. Site chronologies TRKHSQ02 and TRKHSQ03 also produced t-values of 3.1 and 4.2 respectively with the previously dated site chronology TRKHSQ01 at these tenuous end dates. However, this dating evidence was again considered inconclusive due to the limited range and strength of the cross-dating produced.

A new combined site chronology comprising all seven individual components of both TRKHSQ02 and TRKHSQ03 was produced, this new site chronology (TRKHSQ23) being 170 years long (Fig 6). The cross-matching between the seven individual series is presented in Table 1. The new site chronology, TRKHSQ23, was compared with oak reference chronologies from the British Isles and elsewhere in Europe. The level and number of significant t-values at the previously identified end date of AD 1726 were enhanced (Table 2) but were still considered insufficient for secure dating.

RADIOCARBON DATING

In order to provide independent scientific dating support for the site chronology TRKHSQ23, sample TRK-H09 was selected for radiocarbon dating and wiggle-matching as this was the core with the longest ring sequence (109 annual growth-rings) in this site master chronology (Table 3; Fig 6).

Radiocarbon dating is based on the radioactive decay of ^{14}C, which trees absorb from the atmosphere during photosynthesis and store in their growth-rings. The radiocarbon from each year is stored in a separate annual ring. Once a ring has formed, no more ^{14}C is added to it, and so the proportion of ^{14}C versus other carbon isotopes reduces in the ring through time as the radiocarbon decays. Radiocarbon ages, like those in Table 4, measure the proportion of ^{14}C in a sample and are expressed in radiocarbon years BP (before present, 'present' being a constant, conventional date of AD 1950).

Radiocarbon measurements have been obtained from ten single annual tree-rings from timber TRK-H09 (Table 4; Fig 7). Dissection was undertaken by Alison Arnold and Robert Howard at the Nottingham Tree-Ring Dating Laboratory. Prior to sub-sampling, the core was checked against the tree-ring width data. Then each annual growth ring was split from the rest of the tree-ring sample using a chisel or scalpel blade. Each radiocarbon sample consisted of a complete annual growth ring, including both earlywood and latewood. Each annual ring was then weighed and placed in a labelled bag. Rings not selected for radiocarbon dating as part of this study have been archived by Historic England.

Radiocarbon dating was undertaken at the Centre for Isotope Research, University of Groningen, the Netherlands in 2021. Each ring was converted to α-cellulose using an intensified aqueous pretreatment (Dee *et al* 2020) and 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 (Wijma *et al* 1996; Aerts-Bijma *et al* 1997). The graphite was then pressed into aluminium cathodes and dated by AMS (Synal *et al* 2007; Salehpour *et al* 2016). Data reduction was undertaken as described by Wacker *et al* (2010).

The facility maintains a continual programme of quality assurance procedures (Aerts-Bijma *et al* 2021), in addition to participation in international inter-comparison exercises (Scott *et al* 2017; Wacker *et al* 2020). These tests demonstrate the reproducibility and accuracy of these measurements.

The results are conventional radiocarbon ages, corrected for fractionation using $\delta^{13}C$ values measured by Accelerator Mass Spectrometry (Stuiver and Polach 1977; Table 4). The quoted $\delta^{13}C$ values were measured by Isotope Ratio Mass Spectrometry, and more accurately reflect the natural isotopic composition of the sampled wood.

WIGGLE-MATCHING

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 TRK-H09, derived from the probability method (Stuiver and Reimer 1993), are shown in outline in Figures 7–8.

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 Figure 7–8 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).

Figure 7 illustrates the chronological model for TRKHSQ023. 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-26255) was laid down 28 years before the carbon in ring 29 of the series (GrM-26256), with the radiocarbon measurements (Table 4) calibrated using the internationally agreed radiocarbon calibration data for the northern hemisphere, IntCal20 (Reimer *et al* 2020).

The model has good overall agreement (Acomb: 145.8, An: 22.4, n: 10; Fig 7), with all the radiocarbon dates having good individual agreement (A > 60). It suggests that the final ring of TRKHSQ23 formed in *cal AD 1722–1733* (*95% probability*; *ring 170 (AD 1726)*; Fig 7), probably in *cal AD 1725–1731* (*68% probability*), compatible with the last measured ring being formed in AD 1726 (Table 2). Furthermore, when the last ring of the wiggle-match is constrained to be AD 1726, the model has good overall agreement (Acomb: 146.8, An: 21.3, n: 11; Fig 8), with all the radiocarbon dates have good individual agreement (A > 60).

Radiocarbon wiggle-matching provides confirmation of the ring-width dendrochronology and it to be considered as a radiocarbon-supported dendrochronological date, that spans AD 1557–1726$_{DR}$, with the final ring of TRKHSQ23 having been formed in AD1726$_{DR}$ (Table 2) The superscript $_{DR}$ indicates that this is not a date determined independently by ring-width dendrochronology, and that the master sequence, TRKHSQ23, should not be utilised as a ring-width master sequence for dating other sites.

INTERPRETATION AND DISCUSSION

One of the samples, TRK-H14, within the site sequence TRKHSQ23 has complete sapwood and the last measured ring dates to AD 1726$_{DR}$, the felling date of the timber represented. Five other samples from the west range roof have heartwood/sapwood boundary rings ranging in date from AD 1702$_{DR}$ (TRK-H17) to AD 1707$_{DR}$ (TRK-H11), thus encompassing the AD 1705$_{DR}$ heartwood/sapwood boundary date of TRK-H14. This small variation in heartwood/sapwood boundary dates strongly suggests that these five timbers were also felled in, or around, AD

1726_{DR}. The remaining dated sample, one of the two dated hip rafters (TRK-H18), comprises heartwood only but with a *terminus post quem* date for felling of AD 1679, allowing for the minimum number of expected sapwood rings (15 as per Arnold and Howard 2007a), it is also possible, and appears likely, that this timber is coeval with the other dated timbers from this west-range roof.

Prior to tree-ring and radiocarbon analysis being undertaken both the hall and west range of Trerithick had been dated to the late-sixteenth century on the basis of inscriptions and structural features, although it had previously been mooted that the roof structures of the complex dated to the seventeenth and eighteenth centuries, with the exception of the rear range, incorporating the shippon barn, which is believed to have been renewed in the twentieth century. Dendrochronological analysis has indicated that the roof of the hall is constructed of timbers felled in AD 1673 (Arnold and Howard 2007a) and the west-range roof of timbers felled in, or around, AD $1726_{DR.}$ The dendrochronological analysis and radiocarbon analysis thus show that the hall and west-range roofs are of different date, being constructed around half a century apart even though stylistically they are very similar. These roofs both appear to be later replacements dating to the late-seventeenth and early eighteenth centuries and are thus potentially associated with modifications to the original ranges.

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TABLES

Table 1: Cross-matching of the individual ring series combined to form site sequence TRKHSQ23 (t-values over 3.5 are statistically significant)

Sample	TRK-H08	TRK-H09	TRK-H11	TRK-H12	TRK-H14	TRK-H17	TRK-H18
TRK-H08	*	12.8	11.9	11.5	11.4	3.1	2.4
TRK-H09	*	*	13.9	25.7	9.0	4.3	3.6
TRK-H11	*	*	*	14.4	10.2	4.3	1.6
TRK-H12	*	*	*	*	8.8	4.7	3.5
TRK-H14	*	*	*	*	*	3.2	2.1
TRK-H17	*	*	*	*	*	*	6.9
TRK-H18	*	*	*	*	*	*	*

Table 2: Results of the cross-dating of site sequence TRKHSQ23 and relevant reference chronologies when the first-ring date is AD 1557 and the last-ring date is AD 1726

Reference chronology	Span of chronology	*t*-value	Reference
Pound Farm, Luppit, Devon	AD 1557–1664	5.4	Tyers *et al* forthcoming
Trerithick, Altarnun, Cornwall	AD 1503–1673	5.3	Arnold and Howard 2007a
Natton Hall, Drewsteignton, Devon	AD 1530–1625	5.3	Tyers *et al* forthcoming
Widhayes linhay, Uplowman, Devon	AD 1676–1786	5.3	Tyers *et al* forthcoming
Upwich, Droitwich, Worcestershire	AD 1685–1742	5.2	Tyers *et al* forthcoming
Hulme Hall, Allostock, Cheshire	AD 1574–1689	4.6	Arnold *et al* 2003
Poltimore House, Poltimore, Devon	AD 1534–1725	4.6	Arnold *et al* 2005a
Treludick, Egloskerry, Devon	AD 1516–1630	4.4	Arnold and Howard 2007b
Drascombe Barton, Drewsteignton, Devon	AD 1520–1691	4.3	Tyers *et al* forthcoming
Bolsover Castle Riding School, Derbyshire	AD 1494–1744	4.1	Arnold *et al* 2005b

Table 3: Tree-ring and radiocarbon-supported tree-ring dating for samples from Trerithick

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
Roof above extant hall range						
TRK-H01	East principal rafter, truss 2	87	h/s	1557	1643	1643
TRK-H02	East principal rafter, truss 3	80	18	1586	1647	1665
TRK-H03	West principal rafter, truss 3	144	h/s	1503	1646	1646
TRK-H04	East principal rafter, truss 4	83	h/s	1554	1636	1636
TRK-H05	West principal rafter, truss 4	115	30C	1559	1643	1673
TRK-H06	East principal rafter, truss 5	127	h/s	1510	1636	1636
TRK-H07	West principal rafter, truss 5	126	h/s	1516	1641	1641
Roof above west range						
TRK-H08	North principal rafter, truss 1	96	20	1629DR	1704DR	1724DR
TRK-H09	South principal rafter, truss 1	109	06	1601DR	1704DR	1709DR
TRK-H10	Collar, truss 1	NM	--	----	----	----
TRK-H11	North principal rafter, truss 2	79	16	1645DR	1707DR	1723DR
TRK-H12	South principal rafter, truss 2	106	08	1608DR	1705DR	1713DR
TRK-H13	Collar, truss 2	51	19	----	----	----
TRK-H14	North principal rafter, truss 3	82	21C	1645DR	1705DR	1726DR
TRK-H15	Collar, truss 3	NM	--	----	----	----
TRK-H16	North principal rafter, truss 5	NM	--	----	----	----
TRK-H17	North-west hip rafter	72	h/s	1631DR	1702DR	1702DR
TRK-H18	South-west hip rafter	108	--	1557DR	----	1664DR

h/s = the heartwood/sapwood ring is the last ring on the sample.
C = complete sapwood is retained on the sample, the last measured ring date is the felling date of the tree
NM = sample not measured
DR = radiocarbon supported ring-width dendrochronology date (not a date determined independently by ring-width dendrochronology)

Table 4: Radiocarbon measurements and associated $\delta^{13}C$ values from oak sample TRK-H09 (south principal rafter, truss 1)

Laboratory number	Sample	Radiocarbon age (BP)	$\delta^{13}C_{IRMS}$ (‰)
GrM-26255	TRK-H09, ring 1, *Quercus* sp., heartwood. TRKHSQ02 relative year 45	383±17	−23.6±0.15
GrM-26256	TRK-H09, ring 29 *Quercus* sp., heartwood. TRKHSQ02 relative year 73	309±18	−24.6±0.15
GrM-26257	TRK-H09, ring 34 *Quercus* sp., heartwood. TRKHSQ02 relative year 78	315±17	−23.8±0.15
GrM-26259	TRK-H09, ring 43 *Quercus* sp., heartwood. TRKHSQ02 relative year 87	255±18	−24.4±0.15
GrM-26260	TRK-H09, ring 49 *Quercus* sp., heartwood. TRKHSQ02 relative year 93	252±18	−23.9±0.15
GrM-26305	TRK-H09, ring 73 *Quercus* sp., heartwood. TRKHSQ02 relative year 117	172±17	−24.6±0.15
GrM-26393	TRK-H09, ring 78 *Quercus* sp., heartwood. TRKHSQ02 relative year 122	168±17	−23.4±0.15
GrM-26262	TRK-H09, ring 91 *Quercus* sp., heartwood. TRKHSQ02 relative year 135	148±17	−23.3±0.15
GrM-26265	TRK-H09, ring 95 *Quercus* sp., heartwood. TRKHSQ02 relative year 139	136±17	−23.4±0.15
GrM-26394	TRK-H09, ring 105 *Quercus* sp., heartwood. TRKHSQ02 relative year 149	110±18	−23.4±0.15

FIGURES

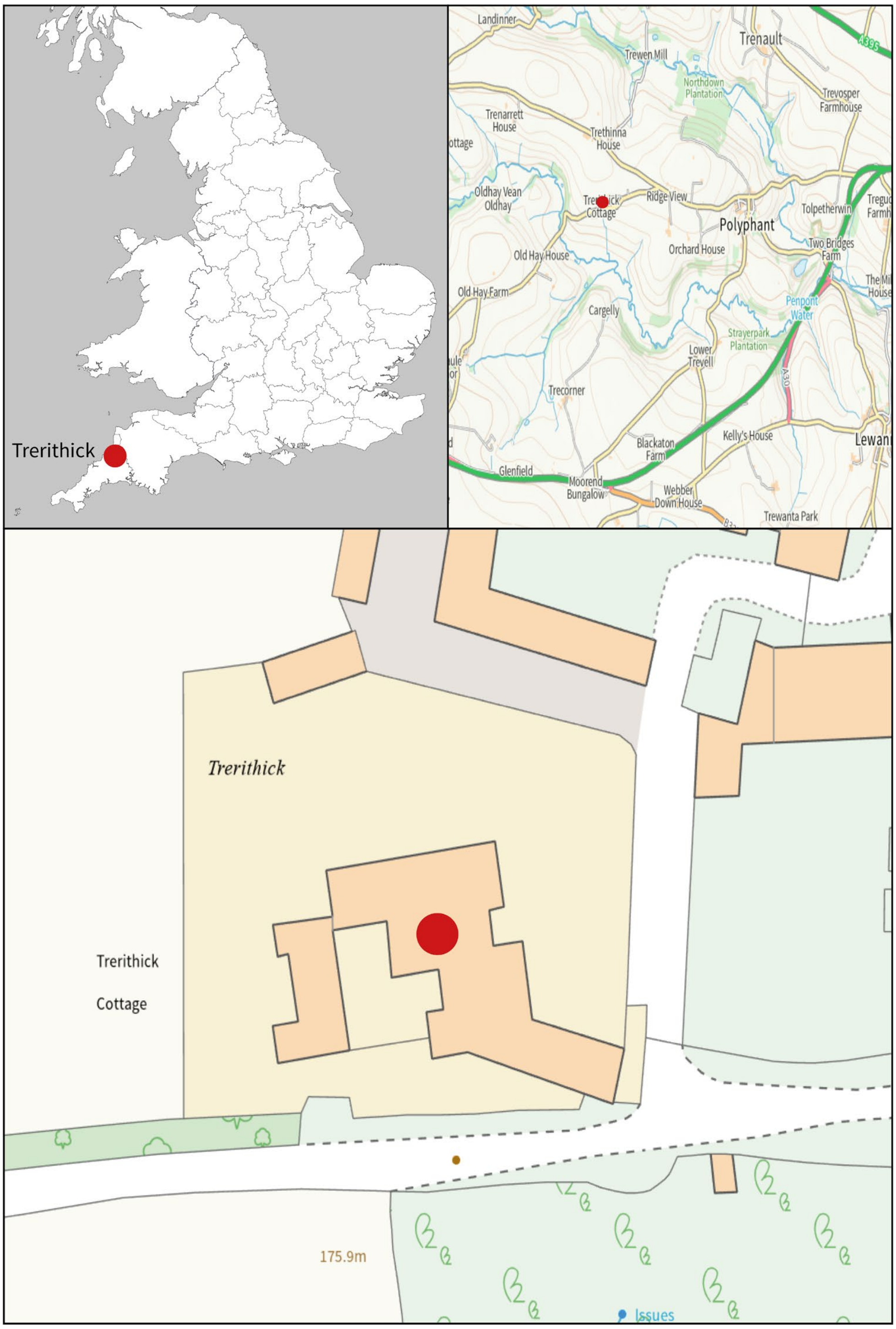


Figure 1: Maps to show the general location of Trerithick, Cornwall (red dot), Trerithick (red dot) and Trerithick (red dot). Scale: top right 1:20000; bottom 1:500.

Figure 2: The carved inscription on the lintel of the two storey porch to the front of the main range (photograph Cathy Tyers)

Figure 3: The carved inscription on the lintel of the reset four-light mullion window in the front range (photograph Cathy Tyers)

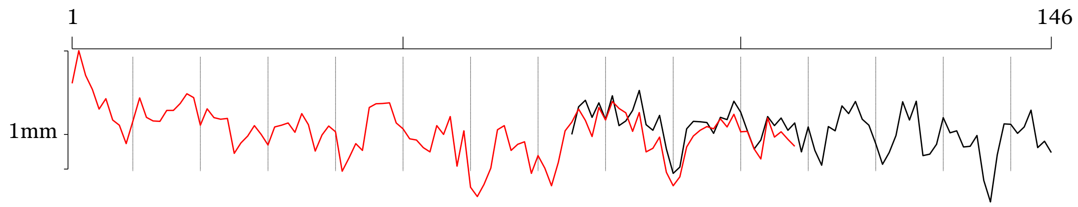


Figure 4: Plots of the ring-width series TRK-H17 (black) and TRK-H18 (red) showing the matching position identified. The y-axis is ring width (mm) on a logarithmic scale, the x-axis is relative years

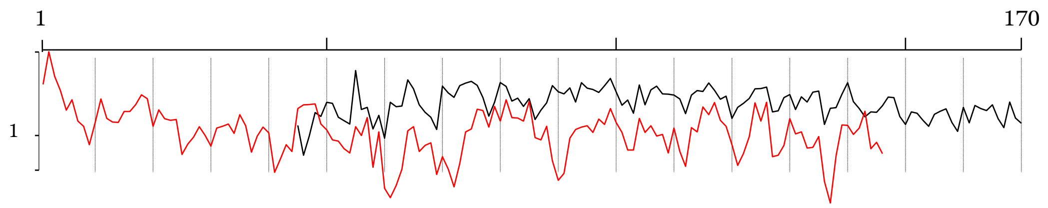


Figure 5: Plots of the ring-width series of site chronologies TRKHSQ02 (black) and TRKHSQ03 (red) showing the matching position identified. The y-axis is ring width (mm) on a logarithmic scale, the x-axis is relative years

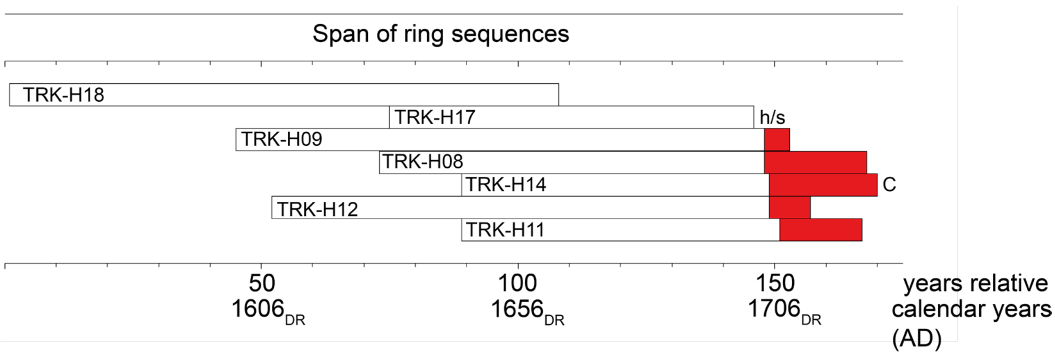


Figure 6: Bar diagram of samples in site sequence TRKHSQ23. White bars = heartwood; red bars = sapwood; h/s = the heartwood/sapwood ring is the last ring on the sample; C = complete sapwood is retained on the sample, the last measured ring date is the felling date of the tree, $_{DR}$ = radiocarbon supported ring-width dendrochronology date (not a date determined independently by ring-width dendrochronology)

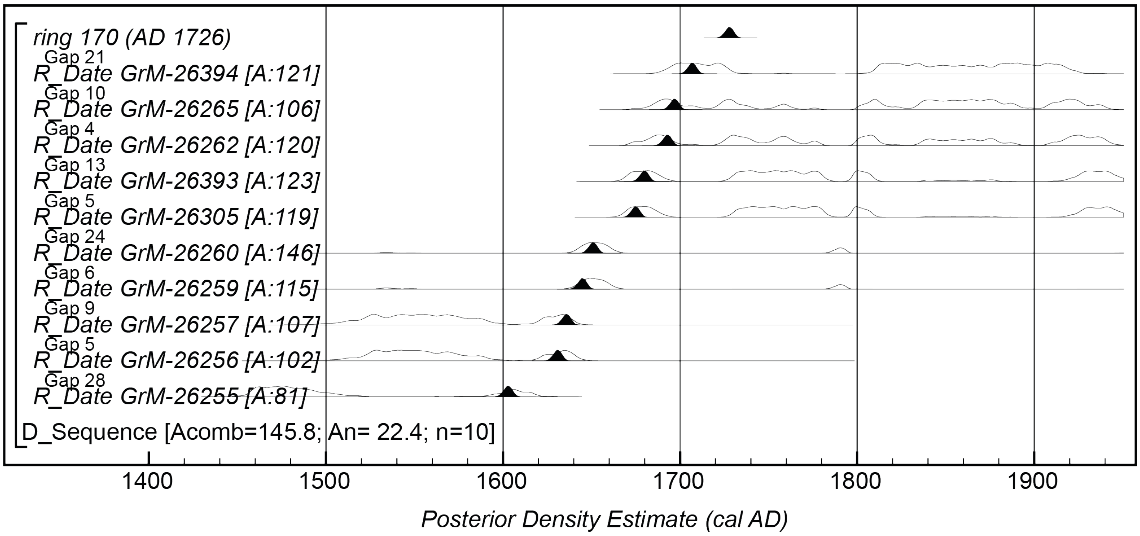


Figure 7: Probability distributions of dates from the undated site sequence TRKHSQ23. Each distribution represents the relative probability that an event occurs at a particular time. For each of the dates two distributions have been plotted: one in outline, which is the simple radiocarbon calibration, 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

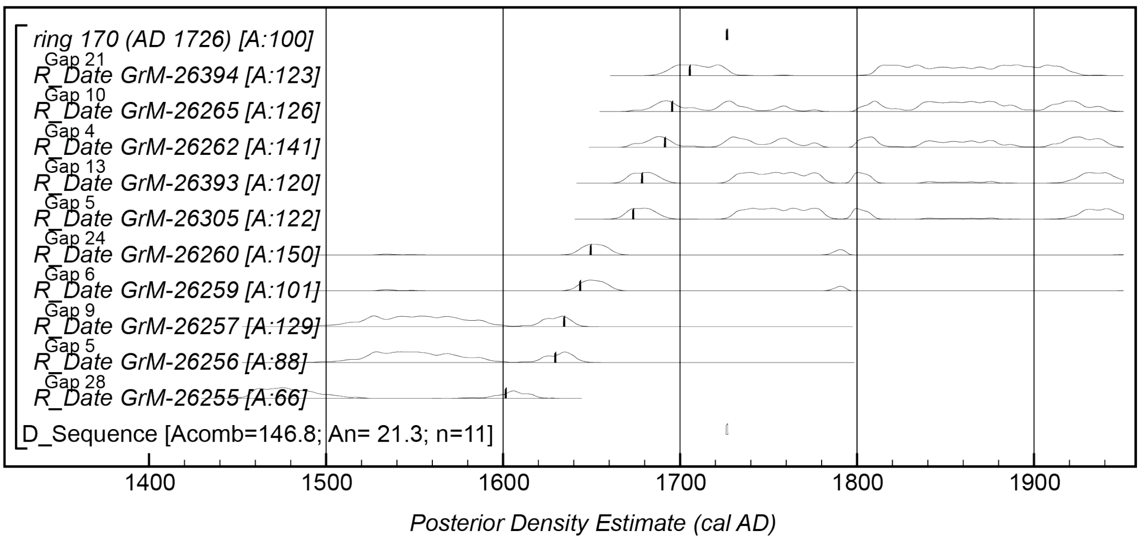
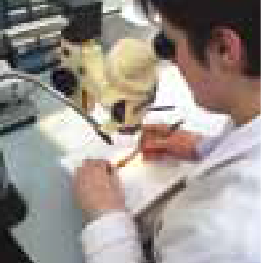
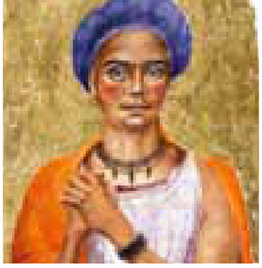
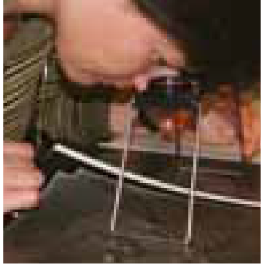


Figure 8: Probability distributions of dates from the undated site sequence TRKHSQ23, including the tree-ring date of AD 1726 for ring 170. The format is identical to Figure 7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