Research Report Series 17/2024

Higher Uppacott, Widecombe in the Moor, Devon

Dendrochronological and radiocarbon analysis of oak timbers

Ian Tyers, Michael Dee and Peter Marshall

Scientific Dating

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NGR: SX 70131 72879

Print: ISSN 2398-3841
Online: ISSN 2059-4453

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Summary

A tree-ring dating and radiocarbon wiggle-match programme was undertaken on oak timbers from Higher Uppacott. The results have demonstrated that the only original raised cruck truss from the roof of the longhouse, in the shippon, was constructed from timber felled in either the mid-fourteenth or early fifteenth centuries. The hall roof contains timbers felled at the beginning and end of the sixteenth century.

Contributors

Ian Tyers, Michael Dee and Peter Marshall

Acknowledgements

We would like to than Nigel Pratt (former Building Conservation Officer for the Dartmoor National Park Authority) for facilitating access to the building and Richard Parker (Oakford Archaeology) for permission to reproduce Figures 2, 3, and 5.

Front cover photo

View towards the shippon end of Higher Uppacott looking north, photo taken on the 22/03/2018 by Ian Tyers.

Archive location

Historic England, The Engine House, Fire Fly Avenue, Swindon, SN2 2EH. Devon HER number MDV113178.

Historic environment record

Dartmoor National Park Historic Environment Record, Parke, Haytor Road, Bovey Tracey, Newton Abbot, Devon, TQ13 9JQ

Date of research

The dendrochronological sampling was undertaken on the 22 February AD 2018 and the radiocarbon dating programme undertaken in AD 2022. The final report was written in AD 2024.

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Introduction

Higher Uppacott is an exceptionally well preserved grade I listed longhouse (https://historicengland.org.uk/listing/the-list/list-entry/1241837) just north of the hamlet of Poundsgate, Widecombe in the Moor, Devon (Fig. 1). The building, which is owned by the Dartmoor National Park Authority, is a rare example of a traditional Dartmoor longhouse.

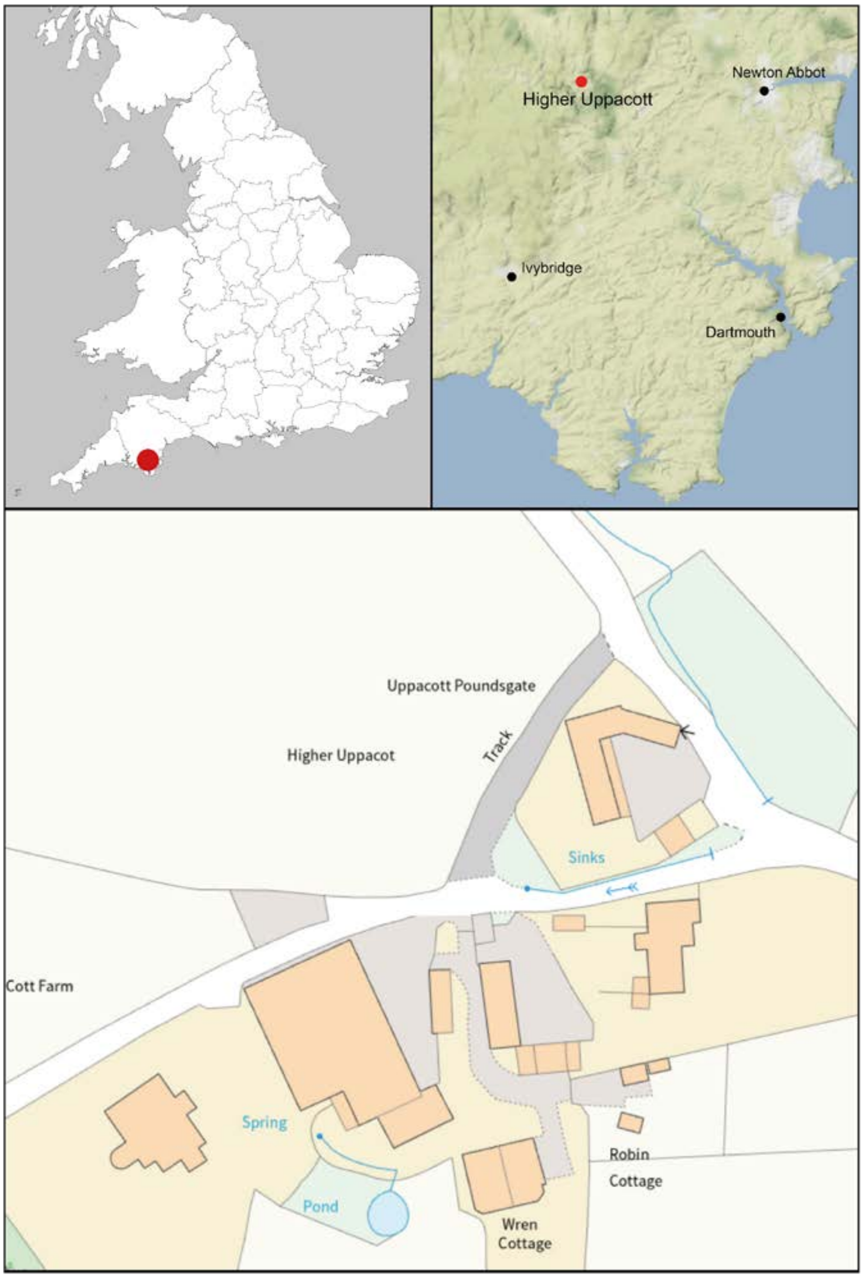

Figure 1: Maps to show the location of Higher Uppacott. © Crown Copyright and database right 2024. All rights reserved. Ordnance Survey Licence number 100024900. ggmap package (v3.0.0; Kahle and Wickham 2013)

Original dendrochronological analysis

Ten samples, were obtained in AD 2002 (Tyers 2003, table 1; fig 3) from the two trusses over the hall and parlour, to inform a conservation programme to re-configure the living accommodation, to inform the presentation of the building to the public, and to strengthen the spatial and temporal extent of tree-ring data for Devon (see Groves 2005).

Two site sequences were calculated, UPP_PRIN formed from three principal rafter samples (**1–3**) with a combined length of 82 years and UPP_RAFT from the two common rafter samples (**5–6**) with a combined length of 65 years. The two site sequences and the five individual sequences were then compared with dated chronologies from throughout the British Isles and northern Europe, but no absolute dating evidence was produced (Tyers 2003).

Further dendrochronological sampling and analysis

A Heritage Lottery Funded project to preserve and enhance Higher Uppacott in AD 2018 (https://www.moorthanmeetstheeye.org/projects/dartmoor-through-the-ages/projects/higher-uppacott-a-dartmoor-longhouse) included removal of the lining of the internal walls so that the historic fabric could be exposed and repaired. The opportunity was thus taken to revisit the site in the expectation that further suitable material for dendrochronological sampling and analysis would be available.

Eleven further samples (11–21; Table 1; Figs 2–5) taken from throughout the structure were recorded using the Keystone (Thorp 2002) numbering scheme (Fig. 2) and for the first time this included samples from the shippon.

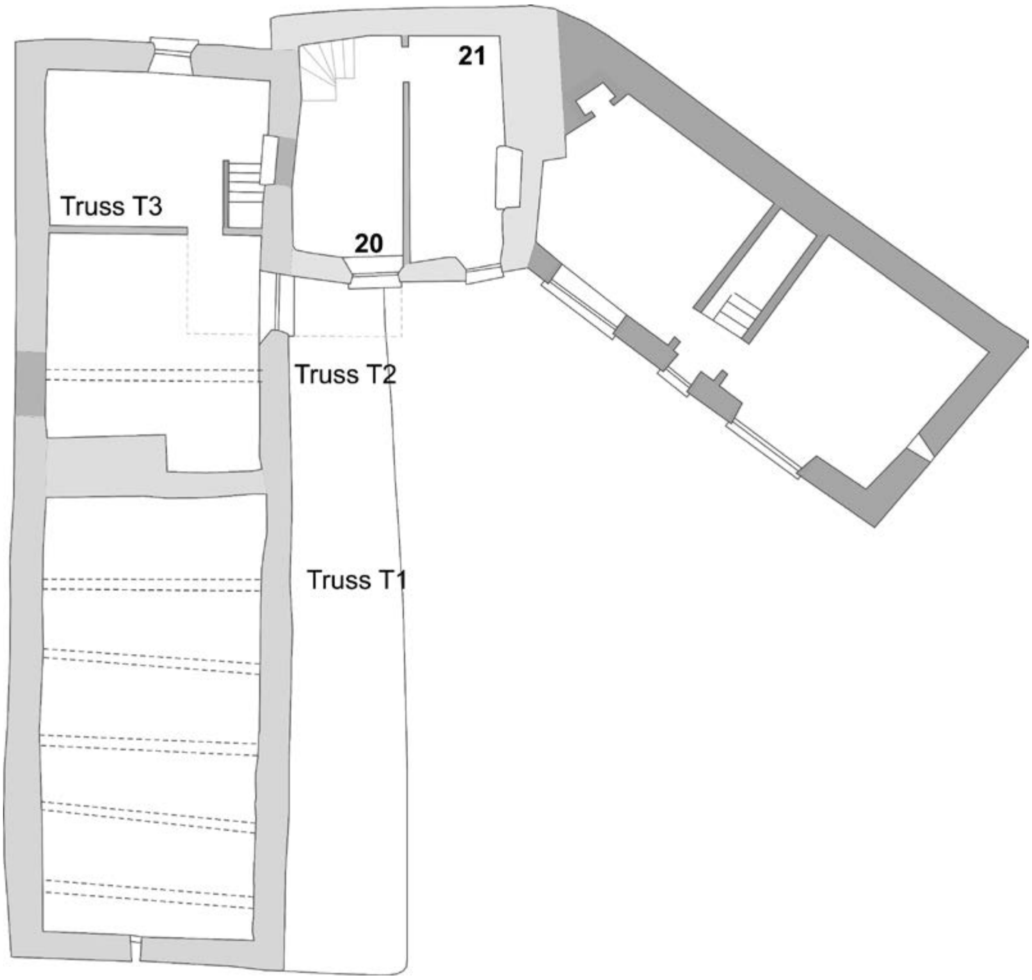

Figure 2: Plan of first floor (adapted from Parker and Steinmetzer 2016, fig 5) showing the approximate location of sampled timbers **20** and **21**. The truss numbering scheme follows Thorp (2002).

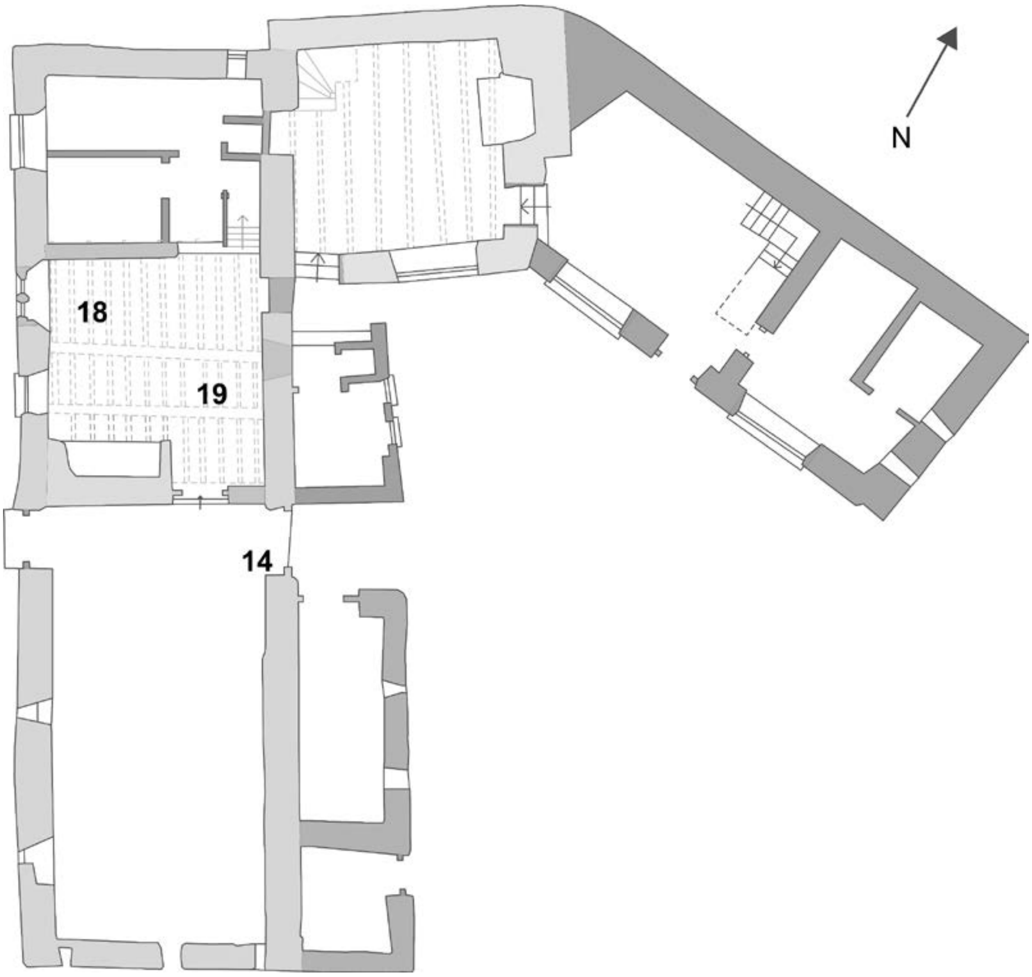

Figure 3: Plan of ground floor (adapted from Parker and Steinmetzer 2016, fig 4 showing the approximate location of sampled timbers **14**, **18** and **19**

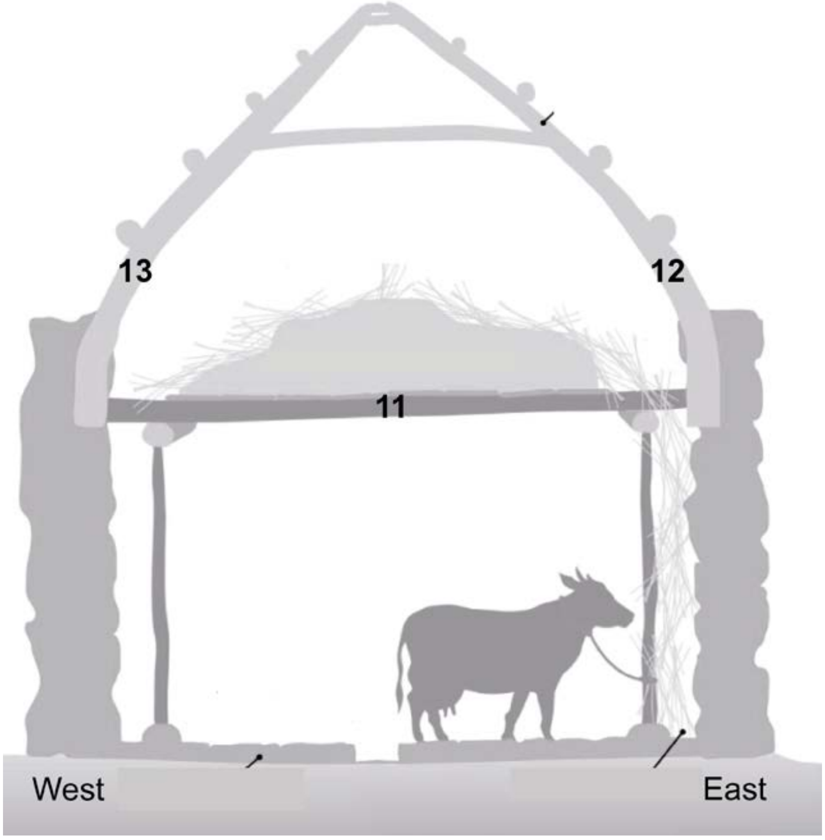

Figure 4: South face of truss 1, shippon. (adapted from Devonshire Magazine 2015/6, 74) showing the approximate location of sampled timbers **11–13**

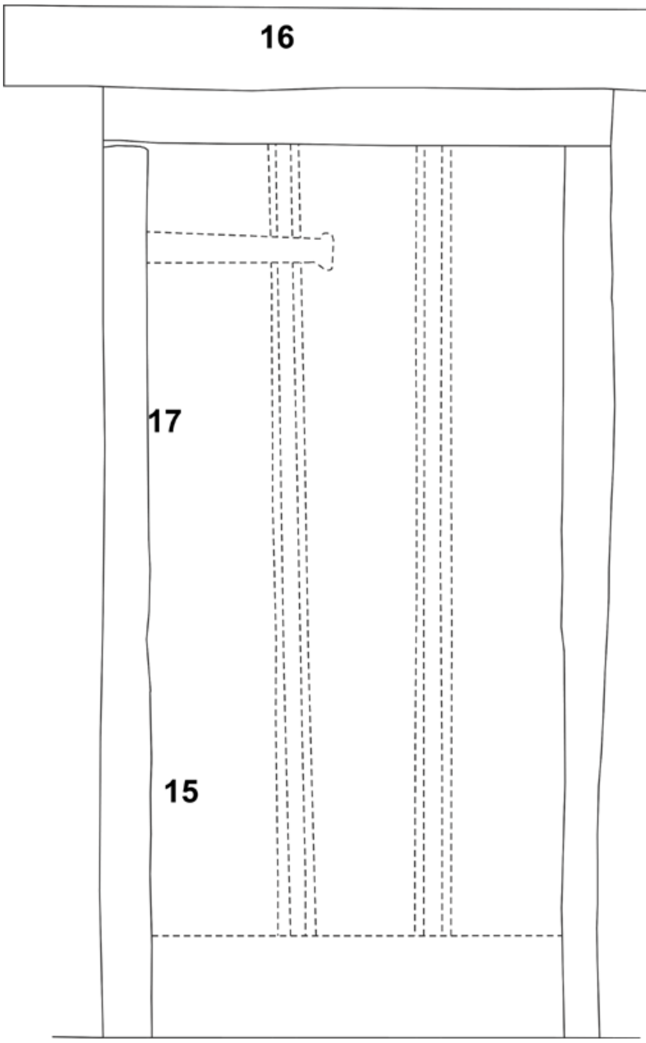

Figure 5: Elevation showing door in blocking (adapted from Parker and Steinmetzer 2016, fig 7 showing the approximate location of sampled timbers **15–17**

Methodology

Tree-ring dating employs the patterns of tree-growth to determine the calendar dates for the period during which the sampled trees were alive. The amount of wood laid down in any one year by most trees is determined by the climate and other environmental factors. Trees over relatively wide geographical areas can exhibit similar patterns of growth, and this enables dendrochronologists to assign dates to some samples by matching the growth pattern with other ring-sequences that have already been linked together to form reference chronologies.

The building was visited on 22 February AD 2018 for an assessment to identify whether additional oak timbers with sufficient numbers of rings for analysis existed in any part of the building. Given technical advances in both dendrochronology and the radiocarbon wiggle-matching of tree-ring sequences it was now feasible that timbers previously rejected for sampling, because of low ring counts, could be considered for sampling and analysis. This assessment concluded that timbers in a number of areas (Figs 2–5) contained some suitable oak material, although the timbers were generally characterised by low ring counts and the dendrochronological potential was not high. However, following discussions, it was decided to proceed with sampling.

The sampling took place on the same visit. The selected timbers were sampled using a 15mm diameter corer attached to an electric drill. The cores were taken as closely as possible along the radius of the timbers so that the maximum number of rings could be obtained for subsequent analysis. The ring sequences in the cores were revealed by sanding.

This preparation revealed the width of each successive annual tree ring. Each prepared sample could then be accurately assessed for the number of rings it contained, and at this stage it was also possible to determine whether the sequence of ring widths within it could be reliably resolved. Dendrochronological samples need to be free of aberrant anatomical features, such as those caused by physical damage to the tree, which may prevent or significantly reduce the chances of successful dating.

Standard dendrochronological analysis methods (see eg English Heritage 1998) were applied to each suitable sample. The complete sequence of the annual growth rings in the suitable samples was measured to an accuracy of 0.01mm using a micro-computer based travelling stage. Cross-correlation algorithms (eg Baillie and Pilcher 1973) were employed to search for positions where the ring sequences were highly correlated. The ring sequences with highly correlated positions were, in addition, plotted on the computer screen to allow visual comparisons to be made, this providing a measure of quality control identifying any potential errors in the measurements. Where such matching positions were satisfactory, new composite sequences were constructed from the synchronised sequences. Any *t*-values reported below were derived from the original CROS algorithm (Baillie and Pilcher 1973). A *t*-value of 3.5 or over is usually indicative of a good match, although this is with the proviso that high *t*-values at the same relative or absolute position need to have been obtained from a range of independent sequences, and that these positions are supported by satisfactory visual matching.

Not every tree can be correlated by the statistical tools or the visual examination of the graphs. There are thought to be a number of reasons for this: genetic variations; site-specific issues (for example a tree growing in a stream bed will be less responsive to rainfall); or some traumatic experience in the tree's lifetime, such as injury by pollarding, defoliation events by caterpillars, or similar. These could each produce a sequence dominated by a non-climatic signal. Experimental work with modern trees shows that 5–20% of all oak trees cannot be reliably cross-matched, even when enough rings are obtained.

Converting the date obtained for a tree-ring sequence into a useful date requires a record of the nature of the outermost rings of the sample. If bark or bark-edge survives, a felling date precise to the year or season can be obtained. If no sapwood survives, the date obtained from the sample gives a *terminus post quem* for its use. If some sapwood survives, an estimate for the number of missing rings can be applied to the end-date of the heartwood.

Where bark-edge or bark survives, the season of felling can be determined by examining the completeness or otherwise of the terminal ring lying directly under the bark. Complete material can be divided into three major categories:

- ‘early spring’, where only the initial cells of the new growth have begun - this is equivalent to a period in March/April, when the oaks begin leaf-bud formation;
- ‘later spring/summer’ where the early wood is evidently complete but the late wood is evidently incomplete, which is equivalent to May-through-September of a normal year, and
- ‘winter’ where the latewood is evidently complete and this is roughly equivalent to September-to-March (of the following year) since the tree is dormant throughout this period and there is no additional growth put on the trunk.

These categories can overlap as, for example, not all oaks simultaneously initiate leaf-bud formation. It should also be noted that slow growing or compressed material cannot always be safely categorised.

Timber technology studies demonstrate that many of the tool marks recorded on ancient timbers can only have been done on green timber. There is little evidence for long-term storage of timber or of widespread use of seasoned, rather than green, timber in the medieval period (see eg English Heritage 1998, 11–12).

Reused timbers can only provide tree-ring dates for the original usage date, not their reuse. Identifying reused timbers requires careful timber recording which notes the presence of features which are not functional in the structure. It is always possible that some timbers exhibit no evidence of earlier usage and are thus ‘hidden reused’ timbers.

The dendrochronological impact of this problem is particularly acute where only single timbers have been dated from a structure.

The analysis may highlight potential same-tree identifications if two or more tree-ring sequences are obtained that are exceptionally highly correlated. Such pairs, or sometimes more, are then used as a same-tree group and each can be given the interpreted date of the most complete of the samples. They are most useful where several timbers date but only one has any sapwood or where same-tree identifications yield linkages between different areas.

Results

Each sample was assessed for the wood type, the number of rings it contained, and whether the sequence of ring widths could be reliably resolved. This assessment confirmed that all the sampled timbers were oak (*Quercus* spp.) and that ten of the cores were suitable for dendrochronological analysis. The exception being a single core, **17**, from a hall door post that had too few rings for analysis. The details of the samples are provided in Table 1.

The ten new suitable oak samples from the building were prepared for analysis and measured, the ring-width series being given in Appendix 1. The resultant ring series were initially compared with other material obtained from the building in AD 2002 (see Table 1). One further site sequence, UPP_4+14, was calculated, in addition to the two from the original analysis (see above). UPP_4+14 was formed from the truss 2 west principal rafter (**4**) and cross-passage door head (**14**) with a combined length of 84 years (Table 2).

The three site sequences and the 13 measured individual sequences were then compared with dated chronologies from throughout the British Isles and northern Europe, with the only absolute dating evidence produced for UPP_4+14 when it spans AD 1406–1489 (Table 3; Fig. 6). The remaining two site sequences and 13 individual sequences remained undated.

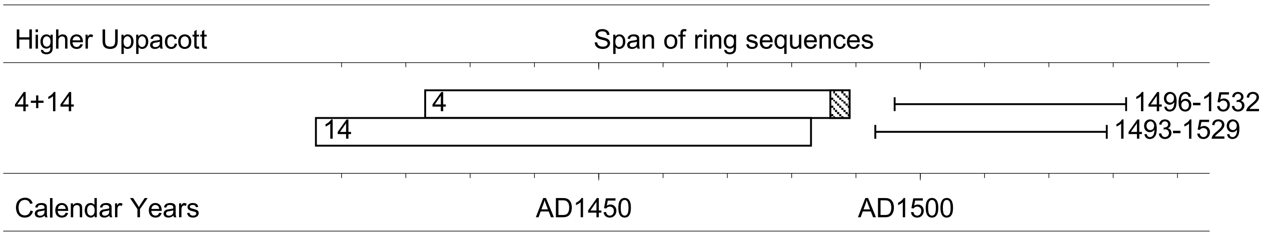

Figure 6: Bar diagram showing dated oak tree-ring sequences from the Higher Uppacott

Felling date for cores 4+14

The small variation in the relative date of the heartwood/sapwood boundaries of the two timbers in UPP_4+14, which vary by only three years, suggests that these timbers were derived from trees cut down as part of a single episode of felling. The date of this felling episode can be estimated by combining the felling date for each timber (as they both retain the heartwood/sapwood transition). Firstly, we estimate the felling date of these timbers by adding the probability distribution of the expected number of sapwood rings in ancient oak timbers from England (Arnold et al. 2019, fig 9) to the date of the last ring of these timbers. For core **4** we apply this probability distribution truncated to allow for the surviving sapwood rings (Bayliss and Tyers 2004, 960–1). Secondly, we combine the two felling date estimates (Fig. 7). The model shown in Figure 7 has good overall agreement (Acomb: 111.6, An: 50.0, n: 2; Fig. 7), with each prior distribution having good individual agreement. This analysis suggests the timbers of the west principal rafter of truss 2 (**4**) and cross passage door head (**14**) were felled in *AD 1492–1513* (*95% probability*; **4+14**; Fig. 7), probably in *AD 1495–1506* (*68% probability*).

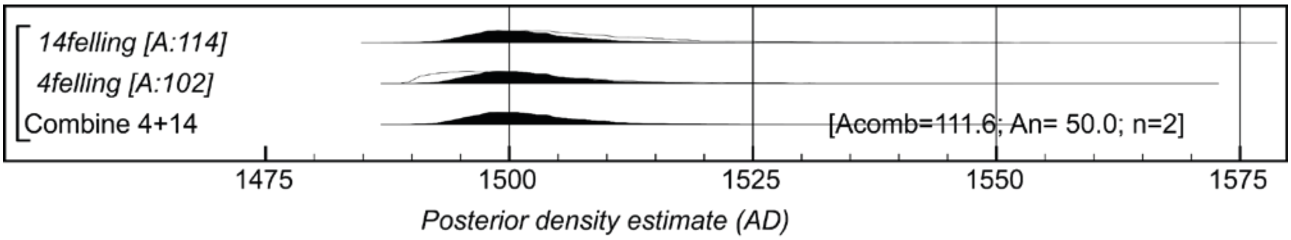

Figure 7: Combined probability distribution estimating the felling date of the timbers in site sequence UPP_4+14, if they are interpreted as representing a single felling event

Table 1: Samples from timbers from Higher Uppacott (AD 2002 samples 1–10 and AD 2018 samples 11–21). H/S is the heartwood/sapwood edge; Bw is winter felled bark edge; Bs is spring felled bark edge in the following year.

Core No.	Origin of core	Total rings	Sapwood rings	ARW (mm/yr)	Date of measured sequence	Notes
1	T3 east principal rafter	61	12	1.84	-	+ sap frags
2	T3 west principal rafter	65	H/S	2.20	-	-
3	T2 east principal rafter	65	17+Bw	1.54	-	-
4	T2 west principal rafter	67	3	2.05	AD 1423–1489	-
5	East rafter, 2 south of T2	65	5	1.46	-	-
6	West rafter, 3 south of T2	60	H/S	1.66	-	-
7	T2 collar	48	H/S	2.76	-	-
8	East rafter, 2 south of T3	56	19	1.58	-	-
9	West purlin, T2–T3	44	H/S	1.93	-	-
10	Stud under T3	66	3	1.14	-	-
11	T1 tiebeam	133	+HS	1.29	-	-
12	T1 cruck	31	+HS	3.17	-	+sap frags
13	T1 cruck	30	9	3.48	-	+sap frags
14	Cross passage door head	78	+HS	1.95	AD 1406–1483	-
15	Hall door post	26	16	2.94	-	-
16	Hall door post/screen	50	+HS	1.80	-	-
17	Hall door post	~10 rings	none	-	-	-
18	Hall ceiling joist	36	-	2.47	-	-
19	Hall ceiling joist	31	14+Bs	2.90	-	-
20	Wing principal	30	+?HS	1.96	-	+sap frags

Core No.	Origin of core	Total rings	Sapwood rings	ARW (mm/yr)	Date of measured sequence	Notes
21	Wing principal	44	8	1.74	-	-

Table 2: *t*-value matrix for timbers from Higher Uppacott, Widecombe on the Moor, Devon, forming the dated chronology UPP_4+14

	14
4	6.85

Table 3: Results of the cross-matching of site sequence UPP_4+14 and the reference chronologies when the first-ring date is AD 1423 and the last-measured ring date is AD 1489

Site reference	***t* – value**	**Span of chronology**	**Reference**
Devon: Townsend Farm, Barn, Stockland	7.11	AD 1387–1478	Tyers and Groves 2003
Devon: Hole Farm, Hockworthy	5.81	AD 1306–1468	McDermott and Miles 2004
Devon: St Andrews, Church, Feniton	5.66	AD 1386–1477	Arnold et al. 2009
Devon: Leigh Barton, Churchstow	5.62	AD 1345–1484	Groves 2006
Somerset: Lancin Farmhouse, Wambrook	5.82	AD 1374–1533	Tyers 1994
Cornwall: St Ildierna/Ildiana Church, Lansallos	8.09	AD 1355–1514	Arnold and Howard 2006
Cornwall: Cotehele Cupboard front	5.74	AD 1327–1509	Miles pers comm
Cornwall: Boconnoc House, nr Lostwithiel	5.56	AD 1302–1503	Arnold and Howard 2007
Cornwall: Harlyn House Harlyn, Padstow	5.54	AD1351–1672	Arnold and Howard pers comm
Cornwall: St Martins Church, East Looe	5.39	AD 1363–1518	Arnold et al. 2006

Radiocarbon dating

Given the very small number of dendrochronologically dated samples and the importance of understanding the chronology of this significant heritage asset, not least for its public presentation, a programme of radiocarbon wiggle-matching was undertaken (see below). Dissection was undertaken by Ian Tyers at the Dendrochronological Consultancy Ltd laboratory. Prior to sub-sampling, each 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.

UPP_PRIN

In order to determine whether samples **1–3** do actually cross-match (UPP_PRIN), they have unusually low-correlations (Tyers 2003, table 2) for samples that have visual similarities in overall shape and branching patterns that suggest they originate from the same tree, samples from all three were selected for radiocarbon dating and wiggle-matching. Two samples were selected from cores **1** and **2**, and five from core **3** that had bark surviving (Table 4) in order to date the principal rafters of trusses 2 and 3 and determine if they are contemporary with the tree-ring dated west principal rafter (**4**) of truss 2.

Table 4: Radiocarbon measurements and associated δ^{13}C values from, oak samples **1–3** part of site sequence UPP_PRIN

Laboratory Number	Sample	Radiocarbon Age (BP)	δ^{13}C$_{IRMS}$ (‰)
GrM-29331	Core 1 ring 2 (*Quercus* spp., heartwood), UPP_PRIN relative ring 15	315±18	−26.6±0.15
GrM-29333	Core 1 ring 12 (*Quercus* spp., heartwood) UPP_PRIN relative ring 25	326±17	−26.1±0.15
GrM-29334	Core 2 ring 2 (*Quercus* spp., heartwood) UPP_PRIN relative ring 2	357±18	−25.0±0.15
GrM-29335	Core 2 ring 12 (*Quercus* spp., heartwood) UPP_PRIN relative ring 12	313±18	−24.8±0.15
GrM-29336	Core 3 ring 5 (*Quercus* spp., heartwood) UPP_PRIN relative ring 22	320±17	−24.3±0.15
GrM-29337	Core 3 ring 20 (*Quercus* spp., heartwood) UPP_PRIN relative ring 37	293±17	−24.8±0.15

Laboratory Number	Sample	Radiocarbon Age (BP)	$\delta^{13}C_{IRMS}$ (‰)
GrM-29338	Core 3 ring 35 (*Quercus* spp., heartwood) UPP_PRIN relative ring 52	291±17	−25.6±0.15
GrM-29341	Core 3 ring 50 (*Quercus* spp., sapwood) UPP_PRIN relative ring 67	315±18	−25.7±0.15
GrM-29342	Core 3 ring 65 (*Quercus* spp., sapwood) UPP_PRIN relative ring 82	321±17	−25.7±0.15

The shippon

Of the three samples from the shippon sample **11** with 133 rings ending at the heartwood/sapwood boundary would normally make an ideal sequence for radiocarbon wiggle-matching, however, in this instance it was not selected as it is very slow grown, making sub-sampling of single years very challenging. Core **13** with 30 rings, including nine sapwood rings was therefore chosen although this sequence is plainly very short.

Radiocarbon measurements were obtained from six single annual tree-rings from core **13** (Table 5) in order to provide a felling date estimate for one of the crucks of truss 1 from the shippon.

Table 5: Radiocarbon measurements and associated $\delta^{13}C$ values from, oak sample **13**. 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 Number	Sample	Radiocarbon Age (BP)	$\delta^{13}C_{IRMS}$ (‰)
GrM-29343	Core 13 ring 2 (*Quercus* spp., heartwood)	625±17	−23.4±0.15
GrM-29636	Replicate of GrM-29343	642±17	−23.6±0.15
ring 2	^{14}C: 634±13 BP; T'=0.5; $\delta^{13}C$: −23.6±0.1; T'=0.9		
GrM-29344	Core 13 ring 7 (*Quercus* spp., heartwood)	598±17	−24.4±0.15
GrM-29345	Core 13 ring 12 (*Quercus* spp., heartwood)	547±20	−23.9±0.15
GrM-29346	Core 13 ring 17 (*Quercus* spp., heartwood)	577±17	−22.9±0.15
GrM-29350	Replicate of GrM-29346	559±17	−22.9±0.15
ring 17	^{14}C: 568±13 BP; T'=0.6; $\delta^{13}C$: −22.9±0.1; T'=0.0		
GrM-29347	Core 13 ring 22 (*Quercus* spp., heartwood)	578±18	−23.7±0.15
GrM-29348	Core 13 ring 27 (*Quercus* spp., heartwood)	554±18	−24.0±0.15

Hall ceiling

The first-floor joists supporting the hall ceiling are lightly chamfered oak timbers, with straight cut stops, running from north to south. Given one of the beams is seated in the blocking of the earlier hall window, in the east room, it is clear that the hall ceiling is a later insertion into the original open house (Parker and Steinmetzer 2016, 7). Radiocarbon measurements were obtained from six single annual tree-rings from core **19** (Table 6) in order to provide a felling date estimate for the addition of the hall ceiling.

Table 6: Radiocarbon measurements and associated δ^{13}C values from, oak sample **19**

Laboratory Number	**Sample**	**Radiocarbon Age (BP)**	**δ^{13}C$_{IRMS}$ (‰)**
GrM-29629	Core 19 ring 1 (*Quercus* spp., heartwood)	300±18	−25.5±0.15
GrM-29630	Core 19 ring 6 (*Quercus* spp., heartwood)	327±18	−24.4±0.15
GrM-29632	Core 19 ring 11 (*Quercus* spp., heartwood)	316±17	−24.4±0.15
GrM-29633	Core 19 ring 16 (*Quercus* spp., heartwood)	333±18	−24.3±0.15
GrM-29634	Core 19 ring 21 (*Quercus* spp., sapwood)	324±17	−25.5±0.15
GrM-29631	Core 19 ring 26 (*Quercus* spp., sapwood)	349±17	−24.8±0.15

Methodology

Radiocarbon dating was undertaken by the Centre for Isotope Research, University of Groningen, the Netherlands in 2022. 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 Centre for Isotope Research 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 δ^{13}C values measured by Accelerator Mass Spectrometry (Stuiver and Polach 1977; Tables 4–6). The quoted δ^{13}C values were measured by Isotope Ratio Mass Spectrometry, and more accurately reflect the natural isotopic composition of the sampled wood.

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 Tables 4–6, 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).

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 the dated tree-ring sequences, derived from the probability method (Stuiver and Reimer 1993), and are shown in outline in Figures 8–9 and 12.

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 8–9 and 12 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). The models are defined by the OxCal CQL2 keywords and by the brackets on the left-hand-side of Figures 8, 9, and 12 (the full code is given in Appendix 2).

UPP_PRIN wiggle-match

Figure 8 illustrates the chronological model for the undated site sequence UPP_PRIN. This model incorporates the gaps between each dated annual ring known from tree-ring counting (eg that the carbon in ring 2 of core **1** (relative year 15 of UPP_PRIN) in the measured tree-ring series (GrM-29331) was laid down 7 years before the carbon in ring 5 of core **3** (relative year 22 of UPP_PRIN) of the tree ring series (GrM-29336; Fig 8), 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 for the undated site sequence UPP_PRIN shown in Figure 8 has good overall agreement (Acomb: 83.7, An: 23.6, n: 9; Fig. 8), with only one of the radiocarbon dates (GrM-29335; A: 54) having poor individual agreement (A < 60). This therefore indicates that the cross-matching of samples **1–3** suggested by dendrochronology is correct. It suggests that the final ring of UPP_PRIN formed in *cal AD 1573–1601* (*95% probability*; *GrM-29342*; Fig. 8), probably in *cal AD 1577–1588* (*68% probability*). As the final ring of UPP_PRIN is also the last sapwood ring below the bark on sample 3 this is also the felling date of the timbers in UPP_PRIN.

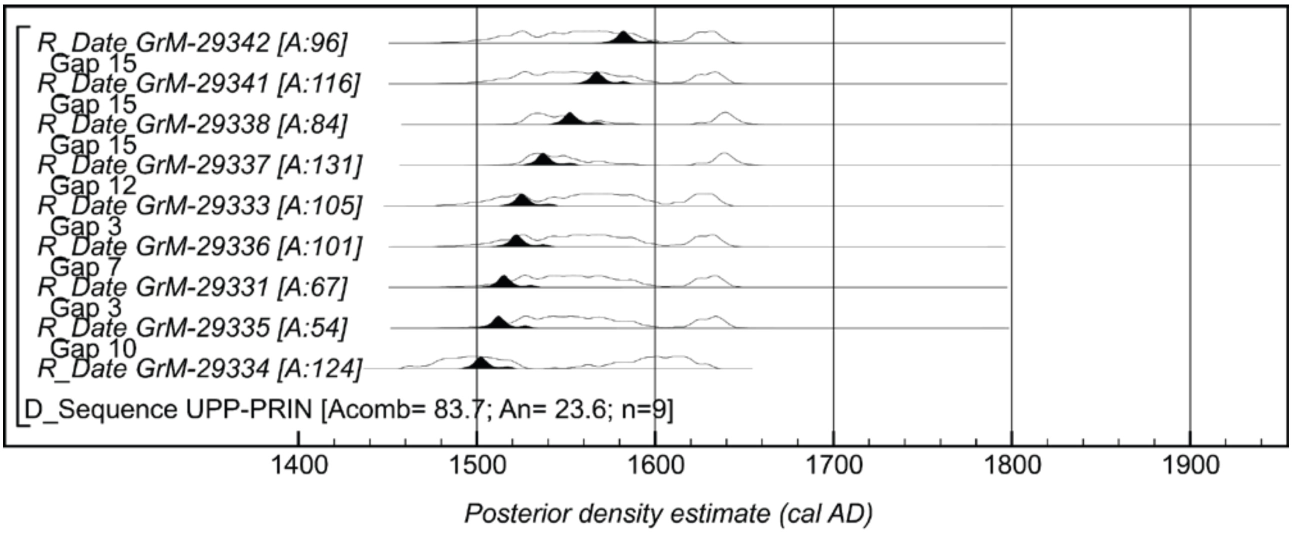

Figure 8: Probability distributions of dates from timbers **1–3**, part of site sequence UPP_PRIN. Each distribution represents the relative probability that an event occurs at a particular time. For each of the dates two distributions have been plotted: one in outline, which is the simple radiocarbon 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 and the description of the sapwood estimates in the text defines the overall model exactly

The shippon wiggle-match

Figure 9 illustrates the chronological model for core **13** from the cruck of truss in the shippon. This model incorporates the gaps between each dated annual ring known from tree-ring counting (eg that the carbon in ring 22 of the measured tree-ring series (GrM-29347) was laid down 5 years before the carbon in ring 27 of the tree ring series (GrM-29348; Fig. 9), 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 for core **13** shown in Figure 9 has good overall agreement (Acomb: 75.5, An: 28.9, n: 6; Fig. 8), with only one of the radiocarbon dates (GrM-29345; A: 49) having poor individual agreement (A < 60). It suggests that the final ring, 30, of core **13** formed in *cal AD 1342–1352* (*42% probability*; *Core13ring30*; Fig. 9) or *cal AD 1410–1420* (*53% probability)*, probably in *cal AD 1345–1350* (*27% probability*) or *cal AD 1412–1418* (*41% probability*).

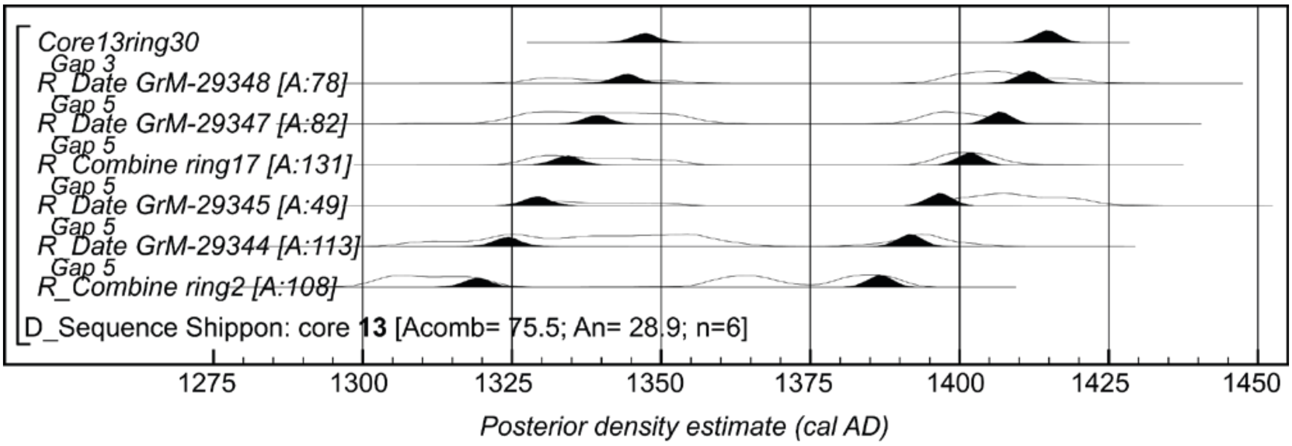

Figure 9: Probability distributions of dates from core **13**. The format is identical to Figure 8

Although core **13** does not have complete sapwood (Table 1), it does retain nine sapwood rings. We can estimate the felling date of this timber by adding the probability distribution of the expected number of sapwood rings in ancient oak timbers from England (Arnold *et al* 2019, fig 9) to the estimated date of the last ring of this timber. For core **13** we apply this probability distribution truncated to allow for the surviving sapwood rings (Bayliss and Tyers 2004, 960–1). This analysis suggests the one of the crucks used in the roof of shippon was felled in *cal AD 1346–1379* (*42% probability*; *Shippon13felling*; Fig. 10) or *cal AD 1414–1448* (*53% probability)*, probably in *cal AD 1351–1365* (*27% probability*) or *cal AD 1417–1435* (*41% probability*).

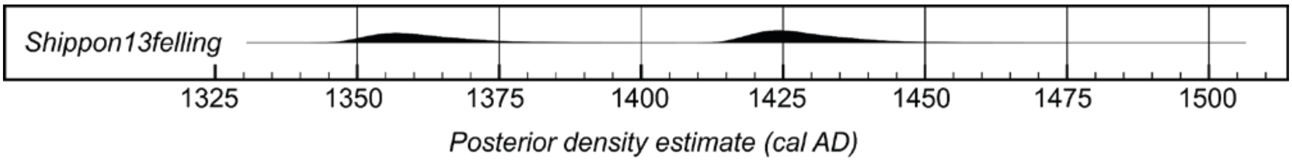

Figure 10: Probability distribution estimating the felling date of timber **13**

The bimodality in the felling date estimate for the shippon cruck is due to the shape of the radiocarbon calibration curve in the mid fourteenth–mid fifteenth centuries (Fig.11) and resolving whether the cruck is either fourteenth or fifteenth century in date would require submission of samples from a longer tree-ring sequence.

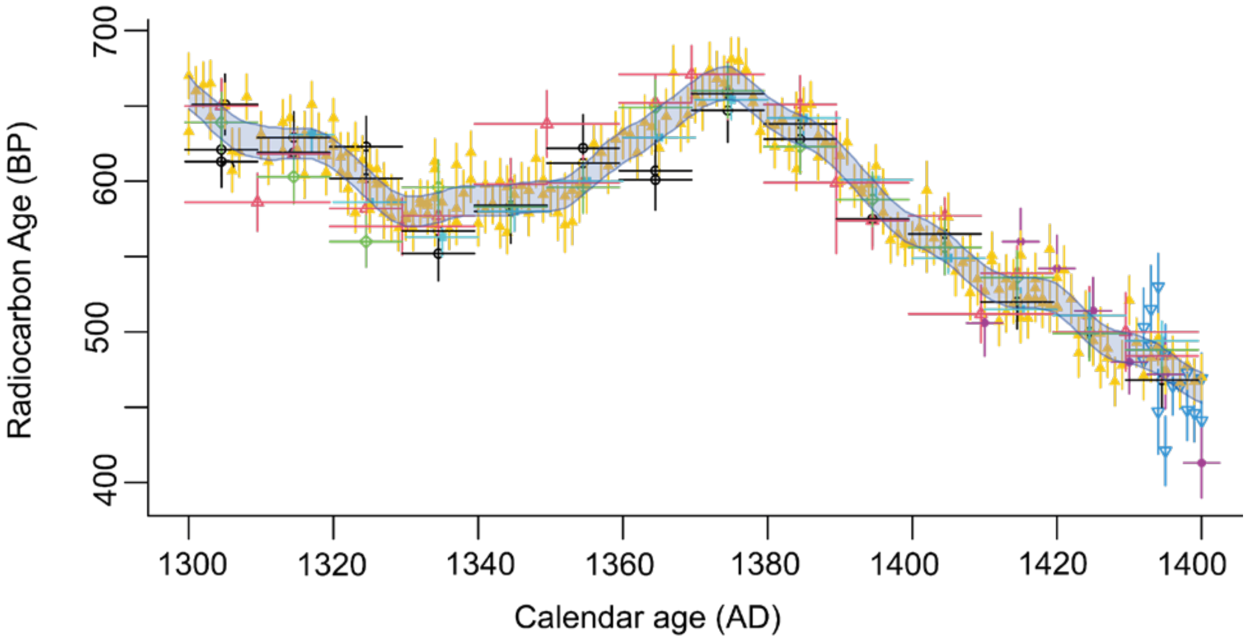

Figure 11: IntCal20 calibration curve and data points (Reimer et al. 2020). rintcal (Blaauw 2022)

Hall ceiling wiggle-match

Figure 12 illustrates the chronological model for core **19** from the hall ceiling. 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-29629) was laid down 5 years before the carbon in ring 6 of the tree ring series (GrM-29630; Fig. 11), 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 for core **19** shown in Figure 12 has good overall agreement (Acomb: 124.6, An: 28.9, n: 6; Fig. 12), with all the radiocarbon dates) having good individual agreement (A > 60). It suggests that the final ring, 30, of core **19** formed in *cal AD 1563–1606* (*95% probability*; *Core19ring31*; Fig. 12), probably in *cal AD 1345–1350* (*68% probability*). As the final ring of core **19** is also the last sapwood ring below the bark on this sample is also provides a felling date for the timber.

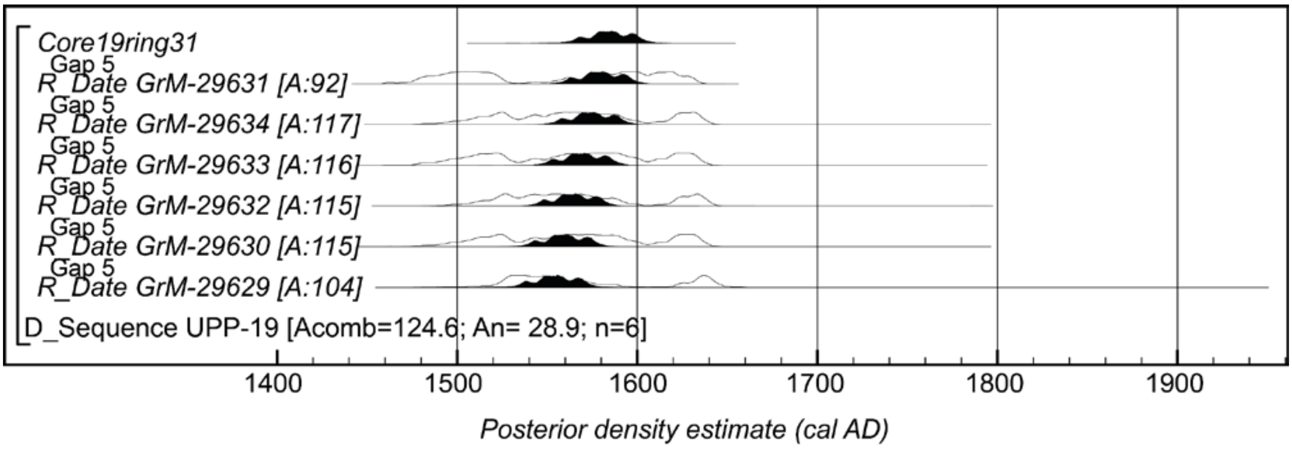

Figure 12: Probability distributions of dates from core 19. The format is identical to Figure 8

Discussion

Only one truss from the roof of the original longhouse consisting of a shippon to the south and house to the north entered through a shared cross passage survives. One of the raised crucks of this roof is estimated to have been felled in *cal AD 1346–1379* (*42% probability*; *Shippon13felling*; Fig. 10) or *cal AD 1414–1448* (*53% probability)*, probably in *cal AD 1351–1365* (*27% probability*) or *cal AD 1417–1435* (*41% probability*). Based on stylistic comparisons with other roofs of similar form dated by dendrochronology it is thought to be early fourteenth century in date.

The original building analysis (Thorp 2002) had postulated that in the late fifteenth- or early sixteenth-century the domestic end of the building, ie north of the shippon, was reconstructed with a higher roof level, supported by A-frame trusses with short wall posts and notch-lap-jointed collars. But further building analysis undertaken as part of the AD 2018 conservation programme suggested that the roof was in fact mid-seventeenth century in date and appeared to be contemporary with the flooring over the hall to create the hall chamber.

The limited scientific dating evidence does not provide conclusive support for either of these scenarios as the three dated principal rafters from trusses 2 and 3 (*GrM-29342*; Fig. 13), that appear to derive from the same tree date to the second half of the sixteenth century along with a single dated timber from hall ceiling (*Core19ring31felling*; Fig 13), while the west principal rafter of truss 2 dates to the decades around AD 1500 and therefore more than 50 years earlier, along with the cross-passage door head.

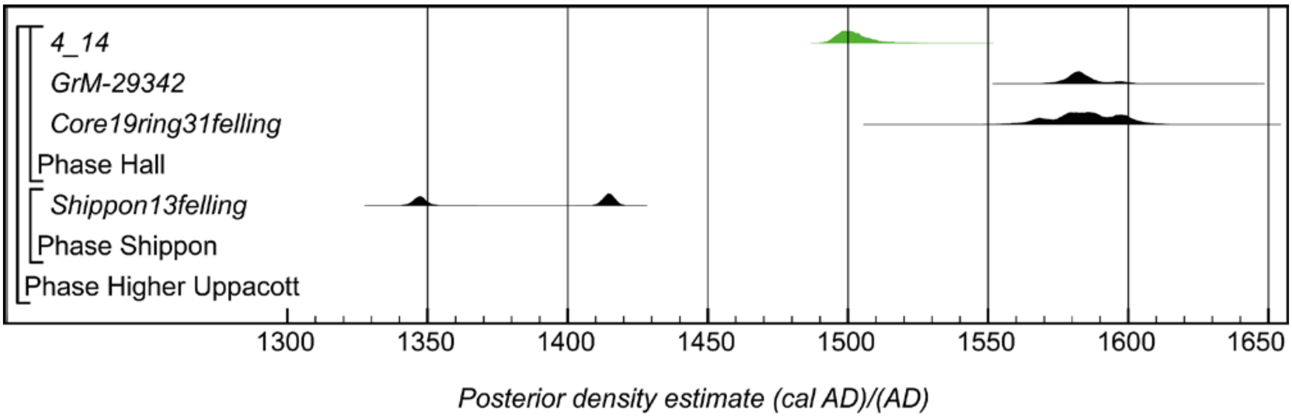

Figure 13: Summary of scientific dating evidence for the development of Higher Uppacott (green = dendrochronology, black = radiocarbon wiggle-match)

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Appendix 1: Tree-ring data

UPP01

316	249	316	210	202	173	126	127	123	178
353	204	239	191	121	144	206	178	95	84
122	93	126	152	102	125	153	190	236	168
301	281	230	240	123	85	104	142	113	137
131	167	245	257	186	178	183	191	204	154
253	186	193	278	180	145	154	183	246	257
220									

UPP02

235	243	343	397	324	410	475	338	338	269
161	174	495	415	345	460	298	182	152	138
136	143	159	223	196	223	145	127	116	207
142	157	269	230	191	197	262	154	214	219
276	245	220	230	230	196	151	72	81	68
77	80	114	124	154	229	246	139	158	243
164	165	214	305	239					

UPP03

177	150	142	106	89	145	230	203	204	89
99	78	160	72	63	112	120	145	165	173
116	177	140	254	270	147	145	180	181	135
86	88	97	130	161	140	104	140	182	142
130	218	215	189	225	192	237	214	286	332
216	165	150	237	203	277	285	85	57	34
42	46	55	93	101					

UPP04

204	203	217	267	188	193	198	284	319	317
209	192	194	196	293	225	96	122	169	131
231	280	206	250	262	222	194	88	64	64
85	129	121	156	162	175	116	226	135	153
206	136	143	221	247	386	189	189	124	178
212	258	527	366	204	132	192	163	271	251
278	195	261	272	244	228	144			

UPP05
214 231 248 238 266 171 215 225 220 191
151 149 126 180 201 140 147 122 183 196
123 88 67 101 137 134 132 129 171 169
114 152 178 184 161 166 163 170 163 175
217 122 107 106 81 78 87 108 116 112
127 109 127 84 92 53 94 120 159 143
114 116 140 110 109

UPP06
228 206 196 236 159 278 276 291 226 190
191 133 171 189 153 138 138 196 210 133
82 74 69 93 76 96 112 169 191 160
177 202 233 196 227 192 251 219 207 244
116 116 121 114 89 137 156 146 124 148
143 154 119 121 127 136 171 186 163 144

UPP07
261 239 323 372 333 241 190 197 202 284
277 263 351 246 230 225 177 368 254 363
355 287 321 303 347 314 318 305 314 427
391 342 245 320 272 305 309 343 261 219
207 232 221 169 162 194 148 212

UPP08
114 79 94 134 112 167 273 252 121 321
224 190 197 193 272 135 154 216 270 139
158 195 177 213 106 106 93 165 196 176
146 182 183 158 99 111 68 112 147 150
167 96 124 151 185 97 86 123 147 167
150 168 162 187 138 96

UPP09
180 253 197 203 158 160 61 125 164 115
206 195 218 182 93 161 270 137 178 172
227 189 168 218 171 153 222 242 163 152
215 186 132 243 230 134 189 207 378 302
259 236 260 201

UPP10
168 231 166 150 118 116 110 128 161 234
217 172 112 112 91 135 130 155 178 161
115 132 132 117 123 77 65 91 96 125
139 162 143 97 59 79 75 155 177 126
124 79 71 77 98 121 142 118 136 97
113 69 82 63 59 89 89 71 70 53
54 65 53 61 62 66

UPP11
128 150 158 158 202 225 220 249 272 302
276 269 282 239 160 160 182 173 184 184
228 134 127 134 144 102 138 165 207 221
176 194 118 116 129 121 152 211 174 150
236 174 183 137 76 82 75 84 85 110
72 95 114 87 102 103 69 98 93 99
121 96 60 70 49 65 68 67 77 79
85 85 99 112 54 57 63 63 67 62
99 120 94 98 64 75 120 141 125 161
139 148 177 142 103 99 87 95 96 151
136 155 163 104 115 114 115 115 121 115
104 107 120 100 117 84 124 135 139 119
82 83 72 72 98 138 128 181 131 127
83 76 98

UPP12
299 313 394 308 347 249 456 535 523 509
445 343 347 375 316 353 367 454 301 301
261 320 244 126 158 235 298 283 153 121
105

UPP13
447 373 477 435 406 621 464 411 437 388
314 237 239 275 273 319 343 319 263 256
183 206 314 444 524 412 310 210 309 235

UPP14
206 198 177 222 134 118 119 199 273 258
201 270 184 112 111 130 107 204 261 311
295 160 149 156 266 279 213 203 192 279
244 242 158 101 113 175 175 260 221 177
259 269 282 226 129 91 211 248 283 194
223 219 218 167 210 208 246 167 133 139
162 203 195 142 147 100 220 145 163 229
203 158 110 193 185 236 243 211

UPP15
369 364 395 416 315 313 240 308 347 598
270 193 292 623 301 208 161 134 115 84
152 288 274 288 320 268

UPP16
229 203 191 119 140 176 280 272 242 199
215 287 319 232 315 295 212 243 325 203
281 190 239 187 161 204 134 123 160 104
114 136 208 169 115 103 111 80 131 113
104 127 179 148 118 91 103 108 121 131

UPP18
210 201 197 196 248 210 204 283 336 372
348 309 240 261 253 279 294 212 186 226
224 291 230 217 199 220 291 377 269 261
256 227 189 243 133 184

UPP19
343 384 409 415 390 206 341 513 441 354
197 272 386 304 227 173 140 205 362 314
301 312 334 261 234 292 183 135 139 230
194

UPP20
319 337 326 308 336 237 201 221 269 138
290 199 152 165 158 158 178 142 210 152
185 97 148 124 150 138 105 124 142 168

UPP21
190 79 116 132 155 169 180 98 143 181
136 79 62 57 49 42 64 58 47 55
72 80 96 195 301 297 360 322 318 264
149 228 329 265 279 302 255 84 124 282
284 250 258 174

Appendix 2: CQL2 code for chronological models

UPP_PRIN timbers **1–3** (Fig. 8)

```
Options(“Higher Uppacott”)
 {
  Resolution=1;
 };
 Plot()
 {
  D_Sequence("UPP-PRIN")
  {
   R_Date("GrM-29334",357,18);
   Gap(10);
   R_Date("GrM-29335",313,18);
   Gap(3);
   R_Date("GrM-29331",315,18);
   Gap(7);
   R_Date("GrM-29336",320,17);
   Gap(3);
   R_Date("GrM-29333",326,17);
   Gap(12);
   R_Date("GrM-29337",293,17);
   Gap(15);
   R_Date("GrM-29338",291,17);
   Gap(15);
   R_Date("GrM-29341",315,18);
   Gap(15);
   R_Date("GrM-29342",321,17);
  };
 };
```

Shippon core **13** (Fig. 9)

```
Options()
 {
  Resolution=1;
 };
 Plot(“Higher Uppacott”)
 {
  D_Sequence("UPP-13")
  {
   R_Combine("ring2")
   {
    R_Date("GrM-29343",625,17);
    R_Date("GrM-29636", 642, 17);
   };
   Gap(5);
   R_Date("GrM-29344",598,17);
   Gap(5);
   R_Date("GrM-29345",547,20);
   Gap(5);
   R_Combine("ring17")
   {
    R_Date("GrM-29346",577,17);
    R_Date("GrM-29350", 559, 17);
   };
   Gap(5);
   R_Date("GrM-29347",578,18);
   Gap(5);
   R_Date("GrM-29348",554,18);
   Gap(3);
   Date("Core13ring30");
  };
 };
```

Hall ceiling core **19** (Fig. 12)

```
Options()
 {
  Resolution=1;
 };
 Plot(“Higher Uppacott”)
 {
  D_Sequence("Hall ceiling core 19")
  {
   R_Date("GrM-29629",300,18);
   Gap(5);
   R_Date("GrM-29630",327,18);
   Gap(5);
   R_Date("GrM-29632",316,17);
   Gap(5);
   R_Date("GrM-29633",333,18);
   Gap(5);
   R_Date("GrM-29634",324,17);
   Gap(5);
   R_Date("GrM-29631",349,17);
   Gap(5);
   Date("Core19Ring31");
  };
 };
```

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ISSN 2398-3841 (Print)
ISSN 2059-4453 (Online)
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