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Scientific Dating

The Ship Inn, Exeter, Devon
Tree-ring and Radiocarbon Analysis of Timbers

Nigel Nayling, Roderick Bale, Gordon Cook, Derek Hamilton and Peter Marshall

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THE SHIP INN
MARTIN'S LANE
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SUMMARY
A programme of dendrochronology was undertaken on timbers at the Ship Inn, Exeter, Devon. Cores from four of the eight sampled oak timbers proved suitable for analysis but the ring-width series obtained did not correlate with each other, nor did they correlate with oak reference chronologies from the British Isles or elsewhere in Europe. Following the failure of the ring-width dendrochronology to provide any calendar dating two samples were submitted for radiocarbon dating. Wiggle-matching of these dates suggests that a ground-floor ceiling joist was probably felled in the mid-fourteenth to mid-fifteenth centuries.

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INTRODUCTION

The Grade II listed Ship Inn (List Entry Number 1273589) stands in St Martin's Lane, a narrow street which links the centre of Exeter's High Street to the Cathedral Close (Fig 1). Although it is one of the city's best-known historic buildings, it has clearly undergone substantial modern alterations. The Ship Inn was built as a row of three small late medieval houses, each consisting of an unheated ground-floor room and a heated upper room, separated from its neighbours by timber-framed partitions incorporating jointed crucks. In numbers two and three the primary roof above the level of the jointed crucks was dismantled when a second floor was added in the seventeenth century. In number one, however, most of the rear slope of the roof was retained in later changes; thus each truss in this part of the building preserves not only a length of principal rising from the jointed crucks, but one half of the collar, and remnants of the upper and lower tier of plain unmoulded purlins. There is no wall plate and the roof apex does not survive. In addition, two features survive on the ground floor. First at the middle of each of the buildings gable ends is a jowled oak post supporting the principal joist of the floor above. The post in number one has been reset but the one in number three is *in situ*, since it is jointed to the beam above.

In 1994, when the building underwent a change of ownership, Exeter Archaeology took the opportunity to carry out a measured survey of the building (Matthews *et al* 2011). The date of primary construction of the building was, however, an outstanding question, and in 2010 English Heritage requested tree-ring dating to provide a precise date for its construction.

SAMPLING

Eight core samples from timbers thought to be associated with the primary construction of the building (Figs 2–5; Table 1) were obtained in 2010. These were given the tree-ring code Shipinn (for the Ship Inn) and numbered 01–08 (Table 1). The location of each core was noted at the time of sampling and is recorded on drawings taken from Matthews *et al* (2011).

TREE-RING ANALYSIS AND RESULTS

Methods employed at the Lampeter Dendrochronology Laboratory in general follow those described in *Dendrochronology: guidelines on producing and interpreting dendrochronological dates* (English Heritage 1998). The samples were cleaned using razor blades so that the ring sequence could be clearly discerned and measured. The complete sequence of growth rings of four samples was measured to an accuracy of 0.01mm using a micro-computer based travelling stage (Tyers 2004). The other four samples had too few rings for reliable dating by ring-width dendrochronology rings to merit analysis. Cross-correlation algorithms (Baillie and Pilcher 1973; Munro 1984) were employed to search for positions where the ring sequences were highly correlated against each other. 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 must be obtained from a range of independent sequences, and that satisfactory visual matching supports these positions. None of the measured samples correlated with each other and thus these individual ring sequences were tested against a range of reference chronologies from throughout the British Isles and elsewhere in Europe, but no conclusive dating evidence was obtained. Thus, it was not possible to provide any dating evidence relating to the construction of the Ship Inn using ring-width dendrochronology.

RADIOCARBON DATING

Following the failure of the ring-width dendrochronology to provide any calendar dating a single sample from the outer five rings of core Shipinn02 (that potentially had surviving bark edge) was submitted for radiocarbon dating.

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 2, 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 dating was undertaken at the Scottish Universities Environmental Research Centre (SUERC) in 2012. The block of five tree-rings was initially pre-treated using the acid-alkali-acid (ABA) method; an approach commonly employed for samples that are thought to have minimal contamination. The sample was placed in a beaker of hot (80°C approx.) dilute (0.5M) HCl for approximately two hours, after which, the acid was cooled and decanted off. The sample was then rinsed with distilled water, immersed in a 0.5M NaOH solution and again heated for approximately two hours. Again, the sample was allowed to cool, the alkali was decanted, and the sample again rinsed with distilled water. The sample was then given a final acid wash in hot 0.5M HCl for approximately two hours to ensure that any residual NaOH solution present in the sample was neutralised. A subsample was then combusted following the method described by Vandeputte *et al* (1996) and the CO_2 evolved was cryogenically purified and graphitised following Slota *et al* (1987). The graphite sample was then dated by Accelerator Mass Spectrometry (Freeman *et al* 2010).

The result (SUERC-37665), a conventional radiocarbon age, corrected for fractionation using a $\delta^{13}C$ value measured by conventional mass spectrometry (Stuiver and Polach 1977) is given in Table 2.

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 distribution of the calibrated radiocarbon date from ground-floor ceiling, joist, derived from the probability method (Stuiver and Reimer 1993), is shown in outline in Figure 6.

The calibrated radiocarbon date (Fig 6) is clearly at odds with the medieval age of the building, suggesting the dated timber was Roman in date! A fragment of the originally pretreated sample (GU-25794) was thus re-combusted and graphitised as outlined above and the sample redated by AMS. The conventional radiocarbon age (SUERC-37961; 2545±35 BP, corrected for fractionation using a $\delta^{13}C$ value measured by conventional mass spectrometry (Stuiver and Polach 1977) was even older than the original determination. The probability distributions of the calibrated radiocarbon dates from both determinations (Fig 6) clearly demonstrating significant contamination of this sample, given their expected medieval age, and that the contamination was not uniform.

Finally, the remainder of sample GU-25794 was pretreated using the method of Hoper *et al* (1998) isolating the α-cellulose fraction, that was then combusted, graphitised, and date by AMS as described above. The third measurement, SUERC-38346, produced a conventional radiocarbon age (550±30BP), corrected for fractionation using a $\delta^{13}C$ value measured by conventional mass spectrometry (Stuiver and Polach 1977) much more in-line with the expected medieval age of the timber (Fig 6).

In order to confirm that the third measurement on timber Shipinn02 had successfully removed all contaminant(s) a second sample was submitted from the middle of the core (rings 22–26), with the expectation that any chemicals would not have penetrated this far. Sample (GU-26483) was pretreated to α-cellulose (Hoper *et al* 1998), combusted (Vandeputte *et al* 1996), graphitised (Slota *et al.* 1987) and dated by AMS (Xu *et al* 2007). The measurement, SUERC-38345, produced a conventional radiocarbon age (570±30BP), corrected for fractionation using a $\delta^{13}C$ value measured by conventional mass spectrometry (Stuiver and Polach 1977) that suggested the ground-floor ceiling, joist timber was medieval in age (Fig 6).

WIGGLE-MATCHING

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 1995; Bronk Ramsey 2009a). The modelled dates are shown in black in Figures 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 timber Shipinn02 and incorporates the gap between the two dated blocks of five annual rings known from the tree-ring sequence (eg that the carbon in SUERC-38345 was laid down 37 years before the carbon in SUERC-38346; Fig 7). The radiocarbon measurements have been calibrated using the internationally agreed radiocarbon calibration data for the northern hemisphere, IntCal20 (Reimer *et al* 2020).

The model has poor overall agreement (Acomb: 49.5, An: 50.0, n: 2; Fig 7), with one of the radiocarbon dates having poor individual agreement (A < 60; SUERC-38345), it does, however, only just fall (0.5) below the threshold for good agreement. It provides an estimate for the felling of the Shipinn02 timber *of cal AD 1340–1369* (28% probability; Shipinn02_felling; Fig 9) or *cal AD 1384–1412 (39% probability)* or *cal AD 1416–1444 (28% probability),* probably *cal AD 1345–1366* (*17% probability*) or *cal AD 1390–1407* (*33% probability*) or *cal AD 1422–1426* (*4% probability*) or *cal AD 1415–1444* (*14% probability*).

Noisy data

The two main approaches for dealing with noisy date or 'outliers' in radiocarbon dating are either to eliminate them manually from the analysis or to use a more objective statistical approach (Bronk Ramsey 2009b; Christen 1994). The model averaging approach (Bronk Ramsey *et al* 2010) offers a more systematic approach than testing many different models individually by adding variable parameters to a model.

In order to deal with the potential problems of measurement offsets as a result of a sample being contaminated, we have used the OxCal model (`r-type`; Bronk Ramsey 2009b) for individual radiocarbon offsets. Each measurement is a given a prior probability of being an outlier (in this case 0.05) and the model then averages over cases where the shift is allowed and where it is not (Bronk Ramsey et al 2010). The model also provides a parameter defining whether the sample is an outlier (with an offset – see Fig 8). Neither of the samples is identified as an outlier and the model provides an estimate for the felling of the Shipinn02 of *cal AD 1340–1369* (*28% probability*; *Shippin2_felling*; Fig 8) or *cal AD 1382–1410 (39% probability) or cal AD 1414–1442 (28% probability)* and probably *cal AD 1345–1356* (*17% probability*) or *cal AD 1391–1407* (*32% probability*) or *cal AD 1421–1427* (*5% probability*) or *cal AD 1428–1438* (*14% probability*)

The fact that neither of the measurements is identified as an outlier and the estimates for the felling of Shipinn02 from both models are almost identical (Fig 9) simply illustrates the problematic nature of deciding whether or not to accept models that only very marginally fail to meet the threshold for 'good agreement'.

CONCLUSION

Tree-ring analysis was undertaken on cores from four of the eight timbers sampled at the Ship Inn, Exeter; four samples having too few rings for dating. The ring-width dendrochronological analysis neither identified any relative dating between the samples, nor produced any calendar dates for the four measured samples, and the radiocarbon dating was hampered by contamination of the wood by unknown contaminant(s).

Many common products used in the treatment of timbers are of synthetic origin and contain hydrocarbons that are devoid of ^{14}C. Although we have no idea of when or with what the radiocarbon dated timber sample was treated, there was no visual indication of any chemical treatment, we suggest it probably contained 'dead carbon', resulting in the apparent ageing of the dated material. The radiocarbon dating of the timber serves as a reminder of the importance of sample pretreatment and the need to remove contamination in order to produce accurate radiocarbon measurements.

Wiggle-matching of the two radiocarbon dates suggests that a ground floor ceiling joist (Shipinn02), was probably felled in the mid-fourteenth to mid-fifteenth centuries. But, is this estimate accurate? A wide variety of evidence (Matthews *et al* 2011, 173; 176) points to the fact that the Ship Inn was probably built in the later medieval period, ie fifteenth century. The results from the radiocarbon wiggle-matching are clearly not incompatible with such a suggested date of construction, however, further dating of timbers, identification of the contaminant(s) potentially used on some of them and demonstration of its removal is required before a more robust independent scientifically derived estimate for the construction of the Ship Inn can be determined.

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TABLES

Table 1: Sample details, Ship Inn, Exeter

Sample code	Origin of core	Cross-section	Dimensions (mm)	Total rings	Sapwood	ARW mm/year	Date of sequence
Shipinn01	Number one, ground floor ceiling, joist	Quartered	140 x 110	50	H/S?	2.68	Undated
Shipinn02	Number one, ground floor ceiling, joist	Quartered	140 x 120	63	12+Bw?	2.16	Undated
Shipinn03	Number one, ground floor ceiling, jowled post	Quartered	300 x 180	18	-	4.7	Unmeasured
Shipinn04	Number one, ground floor ceiling, joist	Quartered	140 x 140	40	-	2.1	Unmeasured
Shipinn05	Number two, ground floor ceiling, main beam	Quartered	340 x 260	29	-	2.58	Unmeasured
Shipinn06	Number one end truss, truncated collar	Quartered	250 x 70	64	H/S?	2.04	Undated
Shipinn07	Number one, purlin	Quartered	230 x 180	102	H/S?	1.25	Undated
Shipinn08	Number two principal rafter mid truss	Halved	260 x 180	17	-	8.23	Unmeasured

Key: H/S = heartwood/sapwood boundary; Bw = bark edge, felled winter; ARW = average ring width

Table 2: Radiocarbon measurements and associated δ¹³C values from oak samples ground floor ceiling, joist (Shipinn02), number 1 St Martin's Lane (The Ship Inn) Exeter

Laboratory Number	Sample	Radiocarbon Age (BP)	$\delta^{13}C_{IRMS}$ (‰)
SUERC-37665	Wood, *Quercus* sp. sapwood, rings 59–63	1880±30	−24.2±0.2
SUERC-37961	Replicate of SUERC-37665	2545±35	−24.5±0.2
SUERC-38346	Replicate of SUERC-37665	550±30	−23.4±0.2
SUERC-38345	Wood, *Quercus* sp. heartwood, rings 22–26	570±30	−23.8±0.2

FIGURES

Figure 1: Maps to show the location of the Ship Inn, St Martin's Lane, Exeter, Devon, marked in red. Scale: top right 1:50,000; bottom 1:2500. © Crown Copyright and database right 2020. All rights reserved. Ordnance Survey Licence number 100024900. © British Crown and SeaZone Solutions Ltd 2020. All rights reserved. Licence number 102006.006. © Historic England

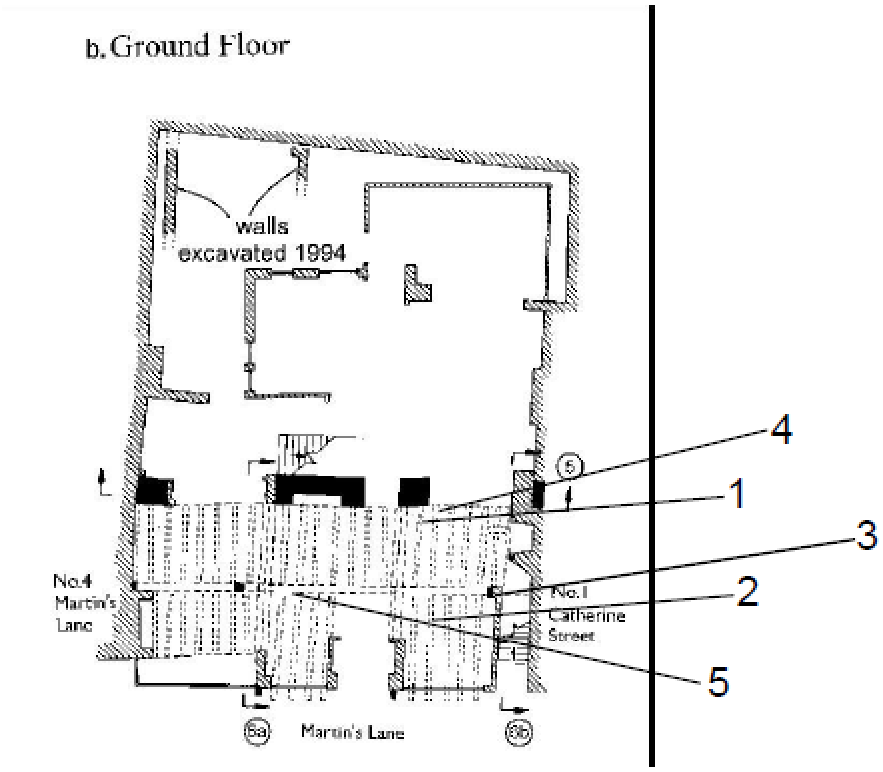

Figure 2: Sample locations 1–5. (Figure from Exeter Archaeology)

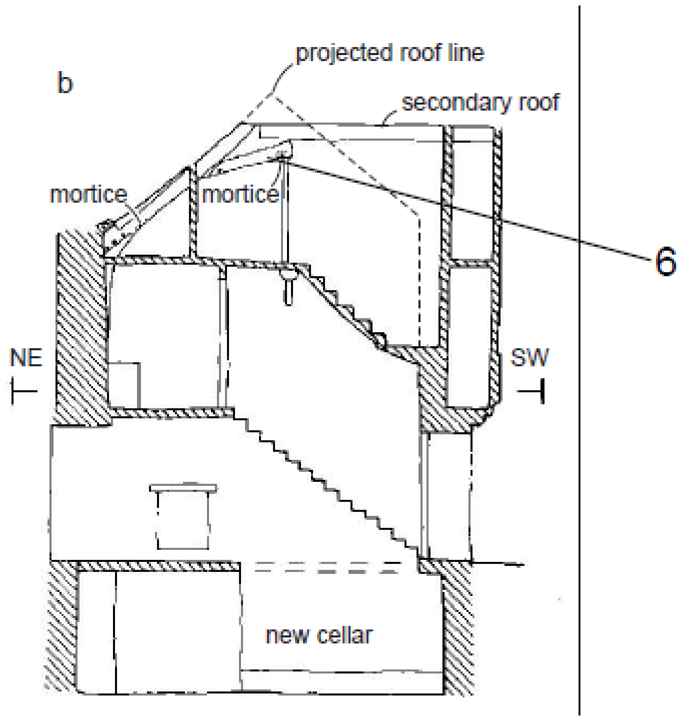

Figure 3: Sample 6 location. (Figure from Exeter Archaeology)

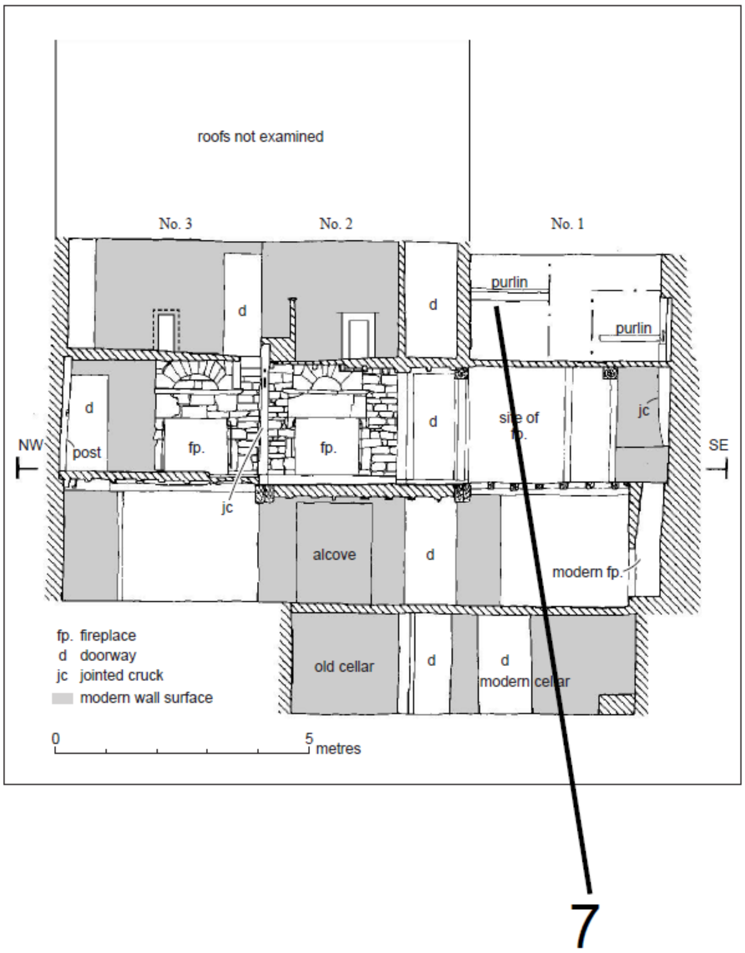

Figure 4. Sample 7 location. (Figure from Exeter Archaeology)

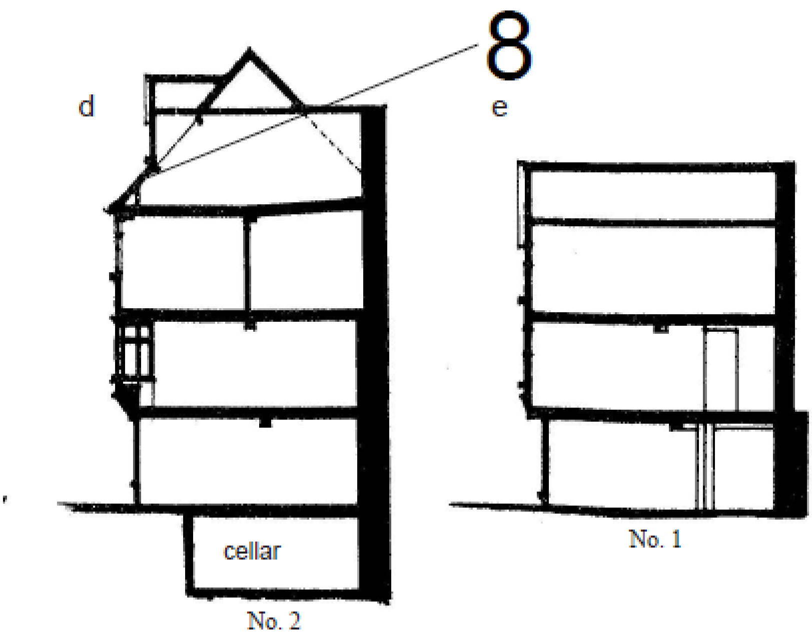

Figure 5. Sample 8 location (Figure from Exeter Archaeology)

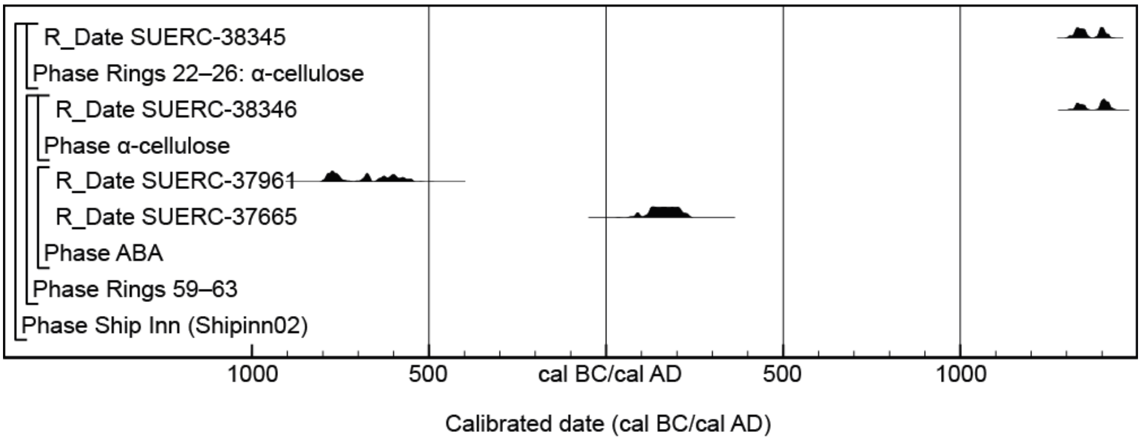

Figure 6: Probability distributions of dates from Shipinn02. Each distribution represents the relative probability that an event occurs at a particular time

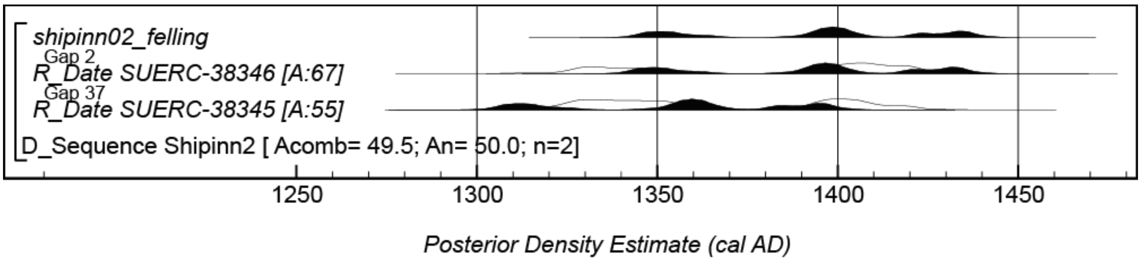

Figure 7: Probability distributions of dates from Shipinn02. Each distribution represents the relative probability that an event occurs at a particular time. For each of the dates two distributions have been plotted: one in outline, which is the simple radiocarbon calibration, and a solid one, based on the wiggle-match sequence. The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly

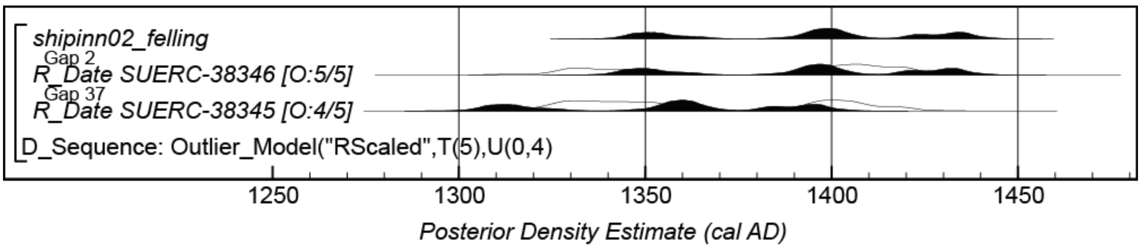

Figure 8: Probability distributions of dates from Shipinn02 (outlier model). The format is identical to that of Figure 7. The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly

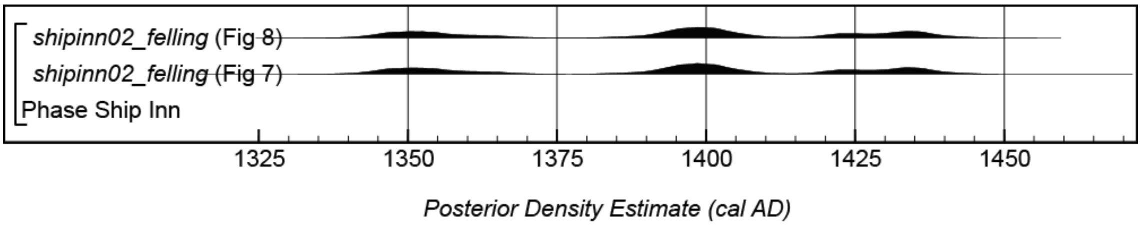

Figure 9: Probability distributions of estimated dates for the felling of Shipinn02. The distributions are derived from the models shown in Figures 7–8

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