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Scientific Dating

Headstone Manor, Pinner View, Harrow, London
Radiocarbon wiggle-matching of oak timbers

Robert Howard, Cathy Tyers, Silvia Bollhalder, Lukas Wacker, and Peter Marshall

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SUMMARY
Radiocarbon wiggle-matching of undated ring-width site chronology HEDMSQ02 from Headstone Manor, Pinner View, Harrow, London suggests its final ring formed in *cal AD 1630–1650* (*95% probability*), probably in *cal AD 1634–1645* (*68% probability*). Its timbers are likely to represent two phases of felling; the first with an estimated felling date in the range *cal AD 1607–1626 (95% probability),* probably in *cal AD 1611–1621 (68% probability)* and the second in the range *cal AD 1647–1665 (95% probability), probably in cal AD 1651–1660 (68% probability).* A total of 24 of the 99 sampled timbers from the large multi-phase building have now been dated by ring-width dendrochronology and radiocarbon wiggle-matching. The relatively small number of dated samples combined with the extensive evidence for the reuse of timbers means a robust interpretation of its chronological development is still wanting.

CONTRIBUTORS
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INTRODUCTION

Headstone Manor

Headstone Manor is a Grade I listed (List Entry Number 1285855) timber framed aisled hall house with a contemporary cross-wing in Harrow, London (Fig 1) which today forms part of the Headstone Manor and Museum. Both parts are believed to be contemporary and to date from the fourteenth century. The Manor of Harrow was amongst the estates owned by the see of Canterbury, Archbishop John Stratford purchasing the surrounding land in AD 1344. Standing on a moated site (List Entry Number 1005558) adjacent to a tithe barn (List Entry Number 1358623), the Manor is believed to have been partially demolished and then extended in the sixteenth century, these works particularly impacting the great hall and high end. Upon the dissolution in AD 1546 the site was sold to Sir Edward North (later Lord North).

Tree-ring analysis

The Manor has been the subject of two programmes of analysis by dendrochronology undertaken by Nottingham University Tree-ring Dating Laboratory. In AD 1995 timbers from the extant part of the present building, the open hall, and cross-wing were sampled (Howard *et al* 1996) and in AD 2000 timbers from the hall range, east-wing roof, porch, tower, west wing, outshut roof, cross wing, and open hall were sampled (Howard *et al* 2000, table 1).

The tithe barn that stands outside the moat, adjacent and to the west of the Manor house was sampled for dendrochronological analysis in June AD 2000 (Arnold *et al* 2002).

Analysis of 99 samples from the two sampling campaigns on the Manor resulted in seven groups of samples being formed (HEDMSQ01–07; Howard *et al* 2000, figs 5–11). Of these only two were dated by ring-width dendrochronology, HEDMSQ01 and HEDMSQ07. The first of these, HEDMSQ01, has 107 rings that span the period AD 1439–1545. None of the samples included in HEDMSQ01 has complete sapwood (Howard *et al* 2000, fig 5; table 1), but six retain the heartwood/sapwood boundary and one 14 sapwood rings. The estimated felling dates of these timbers can be determined by the addition of the probability distribution for the expected number of sapwood rings in ancient oak timbers from England (Arnold *et al* fig 9) to the dates of the last rings of the respective timbers. For HED-M55 the probability distribution has been shortened to allow for the 14 surviving sapwood rings (Bayliss and Tyers 2004, 960–1). These distributions are shown in outline in Figure 2.

The relative positions of the heartwood/sapwood boundaries on the samples in HEDMSQ01 lie within fairly narrow limits, having a 16-year difference (Howard *et al* 2000, fig 5; table 1). It is thus possible that these timbers have the same, or at least a very similar felling date. The date of this felling episode can be estimated by combining the probability distributions for the felling of each timber that has a heartwood/sapwood boundary. The model shown in Figure 2 that combines the felling dates for the seven timbers in HEDMSQ01 that have heartwood/sapwood boundaries has good overall agreement (Acomb: 102.7, An: 26.7, n: 7; Fig 2), with each prior distribution having good individual agreement (A:>60). This analysis suggests the timbers in HEDMSQ01 were felled in *AD 1555–1565* (*95% probability*; *HEDMSQ01 felling*; Fig 2), probably in *AD 1557–1562* (*68% probability*).

The second of these, HEDMSQ07, consisting of eight samples, all from the open hall and cross-wing of the Manor House, spans the period AD 1234–1305. None of the samples included in HEDMSQ07 has complete sapwood (Howard *et al* 2000, fig 11; table 1), but three retain the heartwood/sapwood boundary and five between two and 20 sapwood rings. Using the same methodology outlined above distributions for the estimated felling dates of these eight timbers are shown in outline in Figure 3.

The eight samples in site chronology HEDMSQ07 also lie within fairly narrow limits, having an 18-year difference (Howard *et al* 2000, fig 11; table 1). It is again plausible that these timbers also have the same, or at least a very similar felling date. The model shown in Figure 3 that combines the felling dates for all eight timbers in site chronology HEDMSQ07 has good overall agreement (Acomb: 102.7, An: 26.7, n: 7; Fig 3), with only *HED_M86_felling* having slightly low individual agreement (A: 44). This is within statistical expectation. The analysis suggests the timbers in HEDMSQ07 were felled in *AD 1306–1311* (*95% probability*; *HEDMSQ07 felling*; Fig 3), probably in *AD 1305–1314* (*68% probability*).

The felling date estimates given above for site chronologies HEDMSQ01 and HEDMSQ07 vary very slightly to those in Howard *et al* (2000) as they are derived from a different methodology (see Laxton *et al* 2001, 11–13 for full details of the methodology that originally employed a 95% confidence limit for the amount of sapwood on mature oaks from southern England of 15–45 rings).

RADIOCARBON DATING

Given the very high proportion of undated timbers and the need to better understand the chronology of the Manor, the longest and best replicated of the undated site chronologies, HEDMSQ02, containing seven samples that has 88 rings was selected for radiocarbon dating and wiggle-matching (Howard *et al* 2000, 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 1, 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).

Six radiocarbon measurements have been obtained from single annual tree-rings from timber HED-M59 (Table 1). 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 by the Laboratory of Ion Beam Physics, ETH Zürich, Switzerland in 2021. Cellulose was extracted from each ring using the base-acid-base-acid-bleaching (BABAB) method described by Němec et al (2010), combusted and graphitised as outlined in Wacker *et al* (2010a), and dated by Accelerator Mass Spectrometry (Synal *et al* 2007; Wacker *et al* 2010b). Data reduction was undertaken as described by Wacker *et al* (2010c). The facility maintains a continual programme of quality assurance procedures (Sookdeo *et al* 2020), 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 1).

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 Headstone Manor, derived from the probability method (Stuiver and Reimer 1993), are shown in outline in Figure 4 (lower).

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 4 (lower) 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 4 (lower) illustrates the chronological model for HEDMSQ02. This model incorporates the gaps between each dated annual ring known from tree-ring counting (eg that the carbon in ring 2 of the measured tree-ring series (ETH-112783) was laid down 13 years before the carbon in ring 15 of the series (ETH-112784); Fig 4 (lower)), with the radiocarbon measurements (Table 1) calibrated using the internationally agreed radiocarbon calibration data for the northern hemisphere, IntCal20 (Reimer *et al* 2020).

The model has good overall agreement (Acomb: 142.1, An: 28.9, n: 6; Fig 4 (lower)), with all six radiocarbon dates having good individual agreement (A:>60). It suggests that the final ring of HEDMSQ02 formed in *cal AD 1630–1650* (*95% probability*; *HED_M09_HS ring 88*; Fig 2), probably in *cal AD 1634–1645* (*68% probability*).

INTERPRETATION

It is possible, although unlikely, that the timbers in site chronology HEDMSQ02 have the same felling date. This is because the relative positions of the heartwood/sapwood boundaries vary widely, with a difference of 38 years between sample HED-M18 (ring 50) and sample HED-M09 (ring 88). The provenance of the samples also varies with the tower, west wing, and east wing being represented.

Indeed, it appears more likely that two phases of felling are represented by this site chronology. Samples HED-M18, M41, and M59 may represent one phase of felling because the relative positions of their heartwood/sapwood boundaries are similar to each other varying by only 11 years (Howard *et al* 2000, fig 6). Samples HED-M09, M13, M45, and M46 which also have relative heartwood/sapwood boundary positions similar to each other, varying by only eight years (Howard *et al* 2000, fig 6) may represent a different later phase of felling.

None of the three samples, HED-M18, M41, and M59, included in the first felling phase in site chronology HEDMSQ07 has complete sapwood (Howard *et al* 2000, fig 6; table 1), but have ten, 20, and 23 sapwood rings respectively. Using the same methodology outlined above (§ Tree-ring analysis) distributions for the estimated felling dates of these three timbers are shown in outline in Figure 4 (upper).

A model that combines the felling dates for these three timbers, shown in Figure 4 (upper), has good overall agreement (Acomb: 136.7, An: 40.8, n: 3; Fig 4 (upper)), with each prior distribution having good individual agreement (A:>60). The analysis suggests that timbers HED-M18, M41, and M59 were felled in *cal AD 1607–1626* (*95% probability; HED-M18/M41/M59 felling*; Fig 4 (upper)), probably in *cal AD 1611–1621* (*68% probability*).

The four samples included in the second felling phase in site chronology HEDMSQ07 (HED-M09, M13, M45, and M46) do not have complete sapwood (Howard *et al* 2000, fig 6; table 1), but three retain the heartwood/sapwood boundary and one (HED-M13) has three sapwood rings. Using the same methodology outlined above (§ Tree-ring analysis) distributions for the estimated felling dates of these four timbers are shown in outline in Figure 4 (upper).

A model that combines the felling dates for these four timbers, shown in Figure 4 (upper), has good overall agreement (Acomb: 140.6, An: 35.4, n: 4; Fig 4 (upper)), with each prior distribution having good individual agreement (A:>60). The analysis suggests that timbers HED-M46, M13, M45, and M09 were felled in *cal AD 1647–1665* (*95% probability; HED-M46/M13/M45/M09 felling*; Fig 4 (upper)), probably in *cal AD 1651–1660* (*68% probability*).

DISCUSSION

A summary of both the ring-width dendrochronological and radiocarbon wiggle-matching dating evidence is shown in Figure 5.

Ring-width dendrochronology was only able to provide estimates for a modest, number of samples from Headstone Manor (17 out of 99). Samples from dated timbers from what is believed to be on stylistic and structural evidence to be the earliest extant portions of the Manor house, the open hall, and cross-wing, suggest a felling date of *AD 1306–1311* (*95% probability*; *HEDMSQ07 felling*; Fig 3), probably of *AD 1305–1314* (*68% probability*). Other timbers from a variety of locations are dated by ring-width dendrochronology as being felled in the later sixteenth century, having an estimated felling date range of *AD 1555–1565* (*95% probability*; *HEDMSQ01 felling*; Fig 2), probably of *AD 1557–1562* (*68% probability*). These timbers derive from throughout the Manor house and support the interpretation that much reconstruction work took place around this time.

Radiocarbon wiggle-matching has additionally dated a further seven timbers from a wide range of locations to felling episodes in the early and mid-seventeenth century. But given the evidence for the widespread reuse of timber all over the Manor House (Howard *et al* 2000) and the limited number of dated timbers, the present evidence does little to provide a firm chronology for its construction and development.

Headstone Manor is a large complex multi-phase building, and with less than a quarter of the sampled timbers dated by ring-width dendrochronology and radiocarbon wiggle-matching (24 out of 99), allied to the evidence for extensive reuse of timber in the building, providing a meaningful interpretation for its chronological development is still sketchy. Given the remaining four undated site chronologies all only contain two samples each, two with the heartwood/sapwood boundary (HEDMSQ03–04) and two without (HEDMSQ05–06) radiocarbon wiggle-matching of these is unlikely to make interpretation of the dating evidence any more straightforward.

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TABLES

Table 1: Radiocarbon measurements and associated $\delta^{13}C$ values from oak samples HED-M59, part of site chronology HEDMSQ02

Laboratory Number	Sample	Radiocarbon Age (BP)	$\delta^{13}C_{AMS}$ (‰)
ETH-112783	HED-M59, ring 2, *Quercus* sp., heartwood, HEDMSQ02 relative year 2	300±14	−24.3
ETH-112784	HED-M59, ring 15, *Quercus* sp., heartwood, HEDMSQ02 relative year 15	326±15	−23.8
ETH-112785	HED-M59, ring 32, *Quercus* sp., heartwood, HEDMSQ02 relative year 32	341±14	−24.5
ETH-112786	HED-M59, ring 49, *Quercus* sp., heartwood, HEDMSQ02 relative year 49	363±14	−24.2
ETH-112787	HED-M59, ring 63, *Quercus* sp., sapwood, HEDMSQ02 relative year 63	350±15	−24.3
ETH-112788	HED-M59, ring 77, *Quercus* sp., sapwood, HEDMSQ02 relative year 77	319±14	−25.3

FIGURES

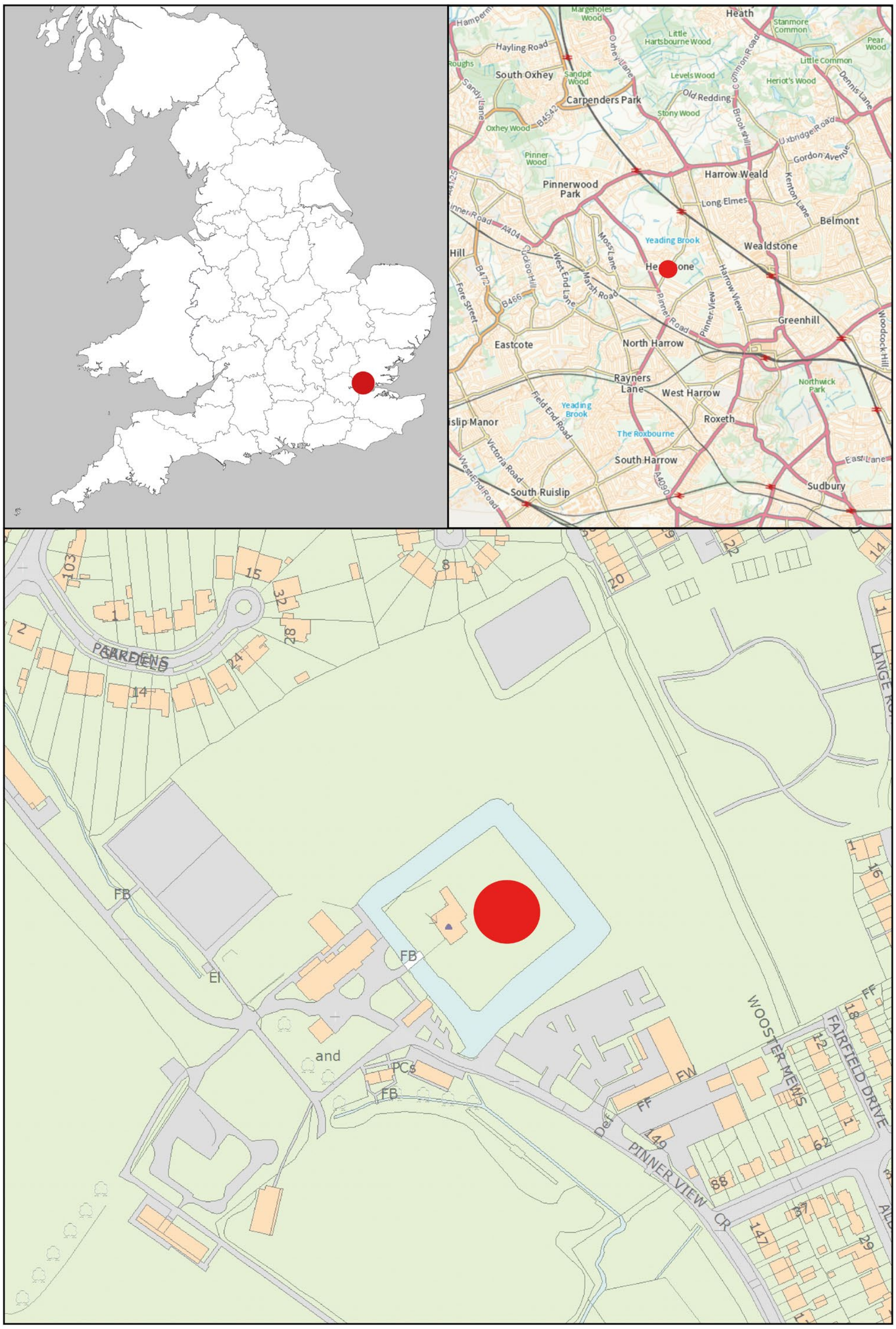


Figure 1: The location of the Headstone Manor, marked in red. Scale: top right 1:52913; bottom 1:2500. © Crown Copyright and database right 2022. All rights reserved. Ordnance Survey Licence number 100024900

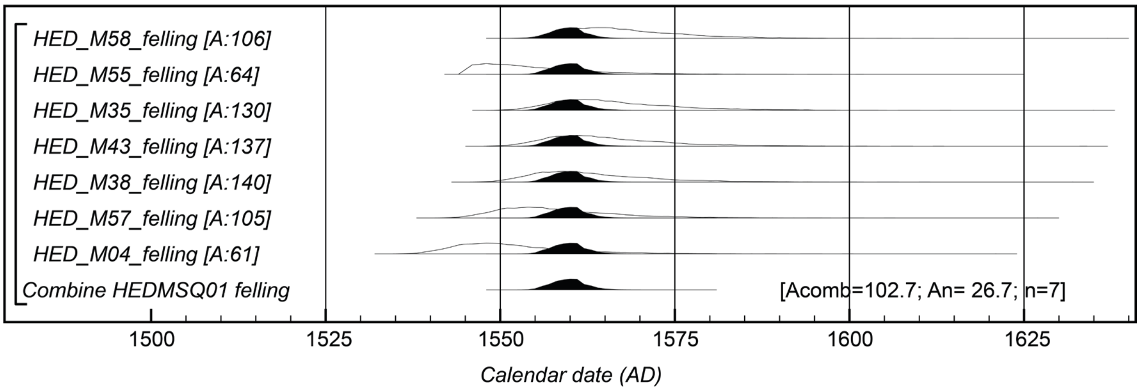


Figure 2: Combined probability distribution estimating the felling date of timbers in site sequence HEDMSQ01, if it is interpreted as representing a single felling event

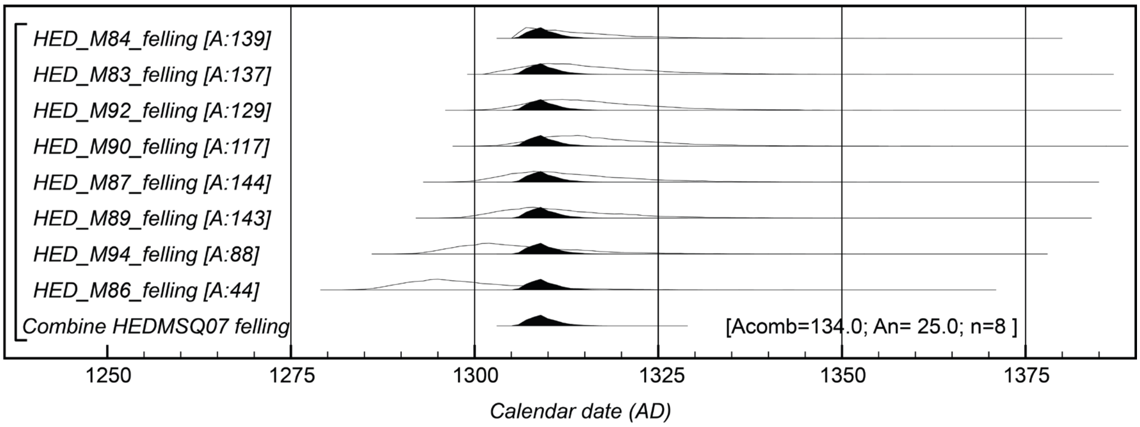


Figure 3: Combined probability distribution estimating the felling date of timbers in site sequence HEDMSQ07, if it is interpreted as representing a single felling event

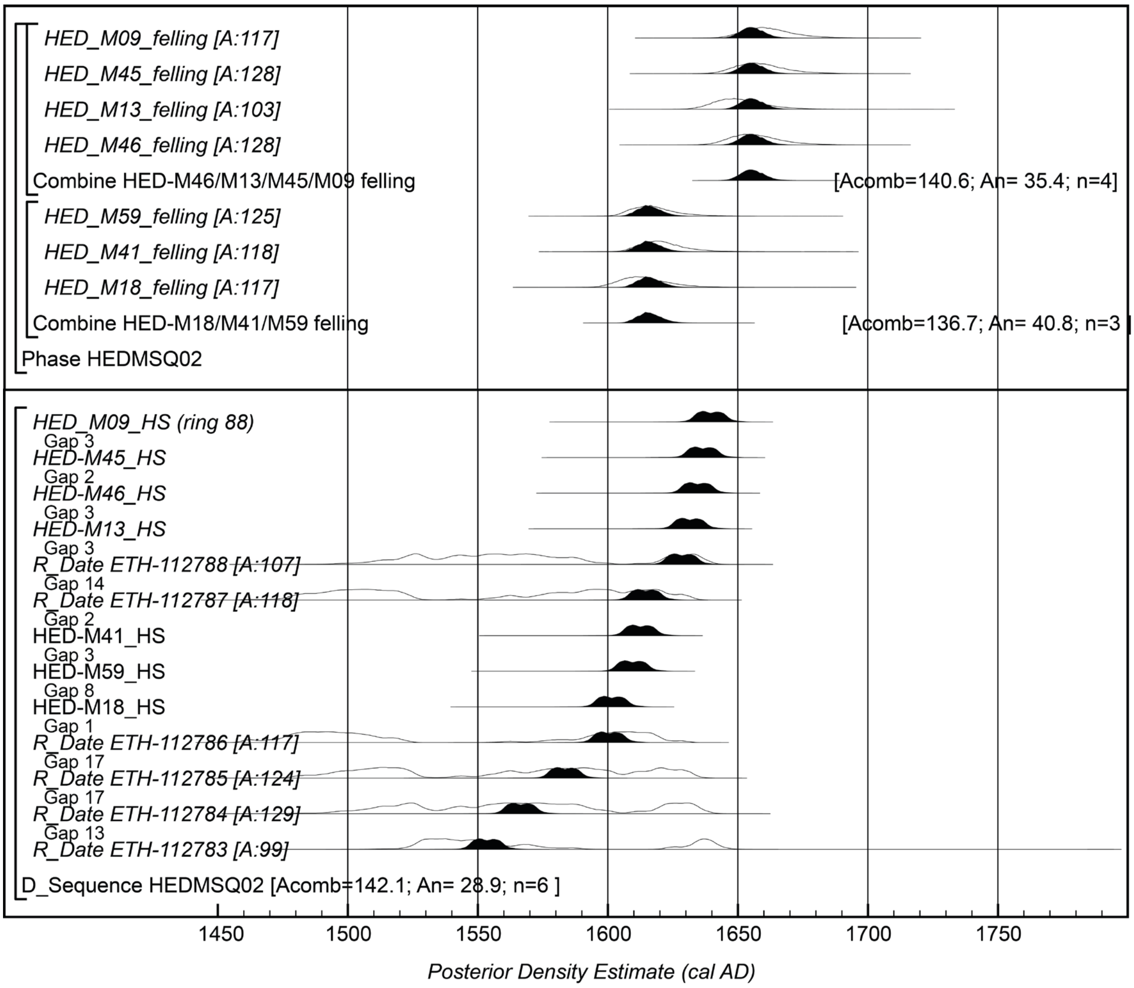


Figure 4: Probability distributions of dates from timber HED-M59 part of site sequence HEDMSQ02. Each distribution represents the relative probability that an event occurs at a particular time. For each of the dates two distributions have been plotted: one in outline, which is the simple radiocarbon calibration, and a solid one, based on the wiggle-match sequence. Distributions other than those relating to particular samples correspond to aspects of the model. For example, the distribution 'HED-M18/41/59 felling' *is the estimated date when the three timbers* HED-M18, M41, and M59 were felled. *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*

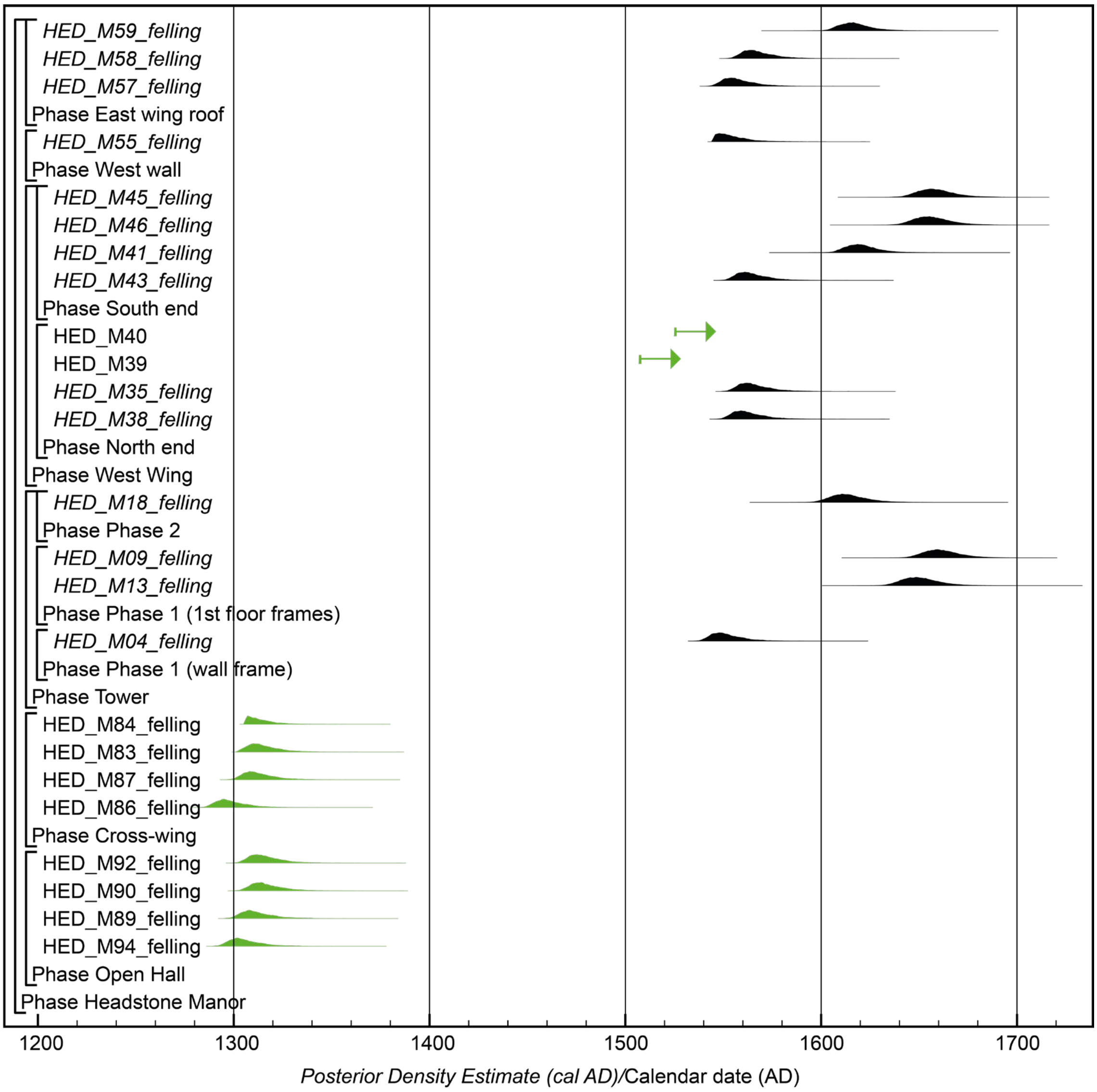
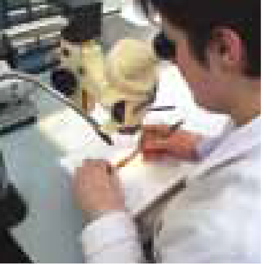
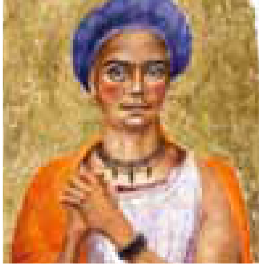
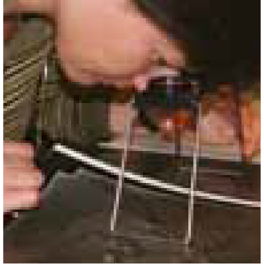


Figure 5: Summary of the scientific dating evidence from Headstone Manor: green = ring-width dendrochronology, black = radiocarbon dating. The arrows represent dates after (ie termini post quos*)*



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