Leicester's Gatehouse, Kenilworth Castle, Kenilworth, Warwickshire

Radiocarbon wiggle-matching of oak stair timbers

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

Scientific Dating

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Summary

Radiocarbon wiggle-matching of undated site chronology KNWCSQ08 suggests its final ring formed in *cal AD 1553–1573* (*95% probability*) probably in *cal AD 1557–1565* (*68% probability*), with the timber having an estimated felling date in the range cal *AD 1567–1605* (*95% probability*) probably *cal AD 1573–1591* (*68% probability*). Other timbers used in the Gatehouse appear to have felling dates clustering in the third quarter of the sixteenth century, the primary building of the Gatehouse by the site's namesake, Robert Dudley, Earl of Leicester, possibly during the AD 1560s and 70s. It is therefore likely that the stair timbers in the south-west turret represent primary material associated with the building's construction.

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Front cover image: Kenilworth Castle Kenilworth Warwickshire CV8 1ME spiral staircase in Leicester's Gatehouse, photograph by Nigel Corrie [PLB/N070885]. © Historic England Archive.

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Date of survey/research/investigation

The dendrochronological sampling was undertaken in AD 2004–5, the radiocarbon dating in AD 2021 and the report was written in AD 2022–23.

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Introduction

The extensive and impressive remains of Kenilworth Castle, its associated buildings and earthworks, stands to the north-west of the town on the main A456 Kenilworth to Coventry road (Fig 1). The first castle on the site, almost certainly of motte and bailey type, is believed to have been built by Geoffrey de Clinton in the early-twelfth century.

In AD 1253 Henry III granted the castle to Simon de Montfort, Earl of Leicester, it passing subsequently to his younger son, the Earl of Lancaster, in AD 1265. The Castle then transferred by marriage to John of Gaunt in AD 1361, and he was responsible for upgrading the site and transforming it into a Royal Palace in the later-fourteenth century. From John it went to his son, Henry IV, and then remained in Royal control until AD 1563 when it was given to Robert Dudley, favourite of Queen Elizabeth I, and who was created Earl of Leicester in AD 1564. Robert Dudley undertook further extensive structural development and modernisation at Kenilworth Castle, bringing it in line with late-sixteenth century fashion, with work continuing until his death in AD 1588, including altering the approach to the castle by erecting a new building at the northern end of the outer court. This new building, which is now known as Leicester's Gatehouse (grade I listed (List Entry Number 1035327)), is of two major components. Firstly, there is the Gatehouse proper, an imposing two-storied rectangular sandstone structure with octagonal corner turrets and mullioned and transomed windows above a large entrance archway.

During the English Civil War, Kenilworth Castle was initially occupied by forces for Charles I. When the King withdrew his garrison from Kenilworth the castle was occupied by the Parliamentarians who undertook a certain amount of demolition work to render the site defenceless. In the AD 1650s Leicester's Gatehouse was converted by Colonel Hawksworth into a private residence. Leicester’s Gatehouse remained in private hands into the twentieth century when it, and the other remains of the castle, came into the care of the Ministry of Works. The site is now managed by English Heritage and it, and the surrounding parkland, is a popular visitor attraction.

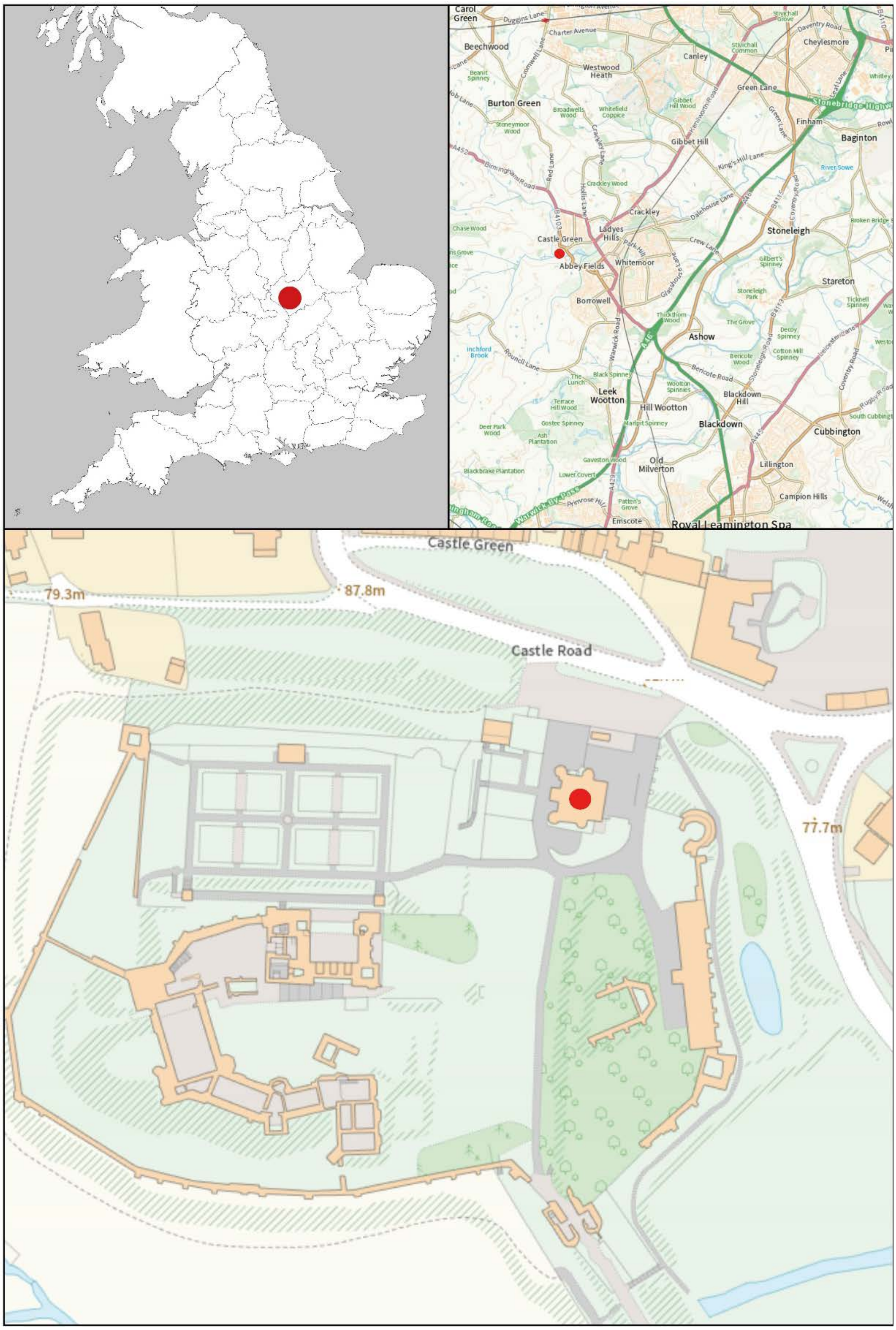

Figure 1: The location of the Leicester's Gatehouse, Kenilworth Castle marked in red. Scale: top right 1:52913; bottom 1:1654. © Crown Copyright and database right 2023. All rights reserved. Ordnance Survey Licence number 100024900.

Tree-ring analysis

A major programme of ring-width dendrochronology was undertaken during renovations and repairs to the building in AD 2004–5, when walls were opened up, leaving beams more clearly exposed, and scaffolding was available to allow access to otherwise inaccessible timbers (Howard et al. 2007). It was hoped that sampling and analysis would bolster the interpretation of the building by establishing with greater certainty the date, or dates, of various timber elements within both components of Leicester's Gatehouse.

Samples were obtained from 115 different timbers in the Gatehouse proper and Colonel Hawksworth's House. Of these 115, 91 were measured, 24 having too few rings. Of the 91, 62 can be combined into one of 12 site chronologies, seven of which, representing 49 samples, were dated. A further single sample was dated individually. Five site chronologies, representing 13 samples, and 28 measured ungrouped samples were undated.

The Gatehouse proper contains a number of timbers which were probably felled in the third quarter of the sixteenth century, a period coinciding with its construction by Robert Dudley, Earl of Leicester. The Gatehouse was later re-roofed with timber felled in AD 1740–60. Whilst Colonel Hawksworth's House contains a small amount of sixteenth-century material, the majority of dated timbers appear to have been felled in the later-fourteenth century. This includes timbers from partition walls, the newel posts of the staircase, some of timbers in the roof space, and possibly some oak panels, these last being of Continental origin. Most of these timbers are re-used. A number of other timbers remained undated. Most notably perhaps are those of the stairs in the south-west turret of the Gatehouse.

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Radiocarbon Dating

Although three samples from the timbers forming the stairs in the south-west turret of the Gatehouse had been dated by dendrochronology (KNW-C17, KNW-C19, and KNW-C24; Howard et al. 2007, table 1), with two of them estimated to have been felled in the late-sixteenth century (Fig 2), the existence of a 136-year undated chronology (KNWCSQ08; Howard et al. 2007, fig 23) comprising five samples all from stair treads was felt to warrant radiocarbon wiggle-matching to determine whether these represented primary stair treads or later replacements.

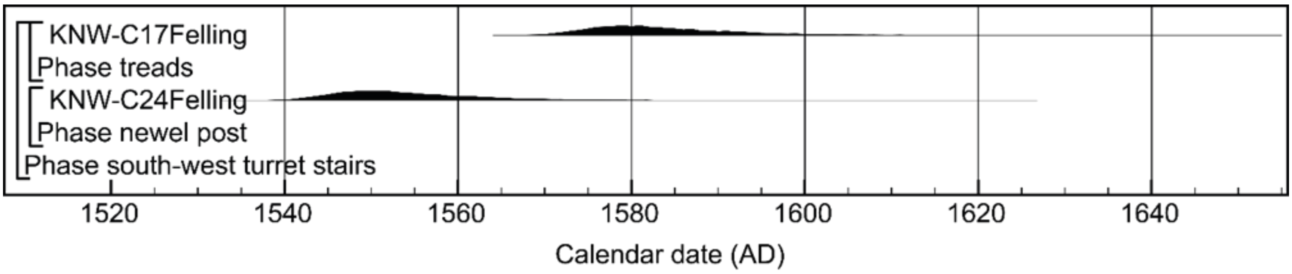

Figure 2: Probability distribution of the felling dates for timbers KNW-C17 and KNW-C24. Derived from applying the probability distribution of the expected number of sapwood rings in ancient oak timbers from England (Arnold et al. 2019, fig 9) to the date of the of the last measured ring (in both cases the heartwood/sapwood boundary)

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).

The undated site chronology KNWCSQ08 consists of five samples, 136 rings, all from stair treads in the south-west turret of the Gatehouse. Samples for radiocarbon dating were obtained from core KNW-C18 (stair tread 9) that has 110 rings ending at the heartwood/sapwood boundary and spanning relative years 26–136 of the undated chronology KNWCSQ08.

Five radiocarbon measurements have been obtained from single annual tree-rings from timber KNW-C18 (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

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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).

Table 1: Radiocarbon measurements and associated $\delta^{13}C$ values from oak sample KNW-C18, part of site chronology KNWCSQ08

Laboratory Number	**Sample**	**Radiocarbon Age (BP)**	**$\delta^{13}C_{AMS}$ (‰)**
ETH-112777	KNW-C18, ring 5, *Quercus* sp., heartwood, KNWCSQ08 relative year 31	432±18	−25.4
ETH-112778	KNW-C18, ring 25, *Quercus* sp., heartwood, KNWCSQ08 relative year 51	364±18	−25.3
ETH-112779	KNW-C18, ring 45, *Quercus* sp., heartwood, KNWCSQ08 relative year 71	334±11	−25.5
ETH-112780	KNW-C18, ring 65, *Quercus* sp., heartwood, KNWCSQ08 relative year 91	353±18	−24.6
ETH-112781	KNW-C18, ring 84, *Quercus* sp., heartwood, KNWCSQ08 relative year 110	269±18	−26.2

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 Leicester's Gatehouse derived from the probability method (Stuiver and Reimer 1993), are shown in outline in Figure 3.

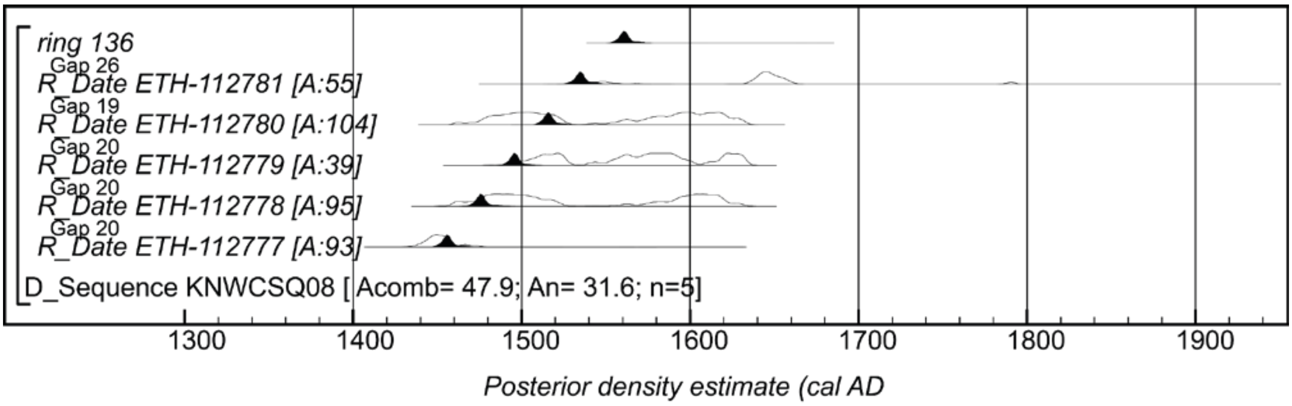

Figure 3: Probability distributions of dates from timber KNW-C18 part of site sequence KNWCSQ08. Each distribution represents the relative probability that an event occurs at a particular time. For each of the dates two distributions have been plotted: one in outline, which is the simple radiocarbon 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 '*ring 136*' is the estimated date when the last ring of sample KNW-C18 formed. 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

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 3 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).

KNWCSQ08

Figure 3 illustrates the chronological model for KNWCSQ08. This model incorporates the gaps between each dated annual ring known from tree-ring counting (eg that the carbon in ring 5 of the measured tree-ring series (ETH-112777) was laid down 20 years before the carbon in ring 25 of the series (ETH-112778; Fig 3), 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: 47.9, An: 31.6, n: 5; Fig 3), with two radiocarbon date having poor individual agreement (A > 60): ETH-112779 (A:39) and ETH-112781 (A:55). It suggests that the final ring of KNWCSQ08 formed in *cal AD 1553–1573* (*95% probability*; *ring 136*; Fig 3), probably in *cal AD 1557–1565* (*68% probability*).

Interpretation

The estimated last heartwood ring date of the single sample with the heartwood/sapwood boundary surviving from KNWCSQ08, KNW-C18, is *cal AD 1553–1573* (*95% probability*), probably *cal AD 1557–1565* (*68% probability*). Applying the probability distribution of the expected number of sapwood rings in ancient oak timbers from England (Arnold et al. 2019, fig 9) would give this timber an estimated felling date in the range *cal AD 1567–1603* (*95% probability;* Fig 4) probably *cal AD 1573–1591* (*68% probability*).

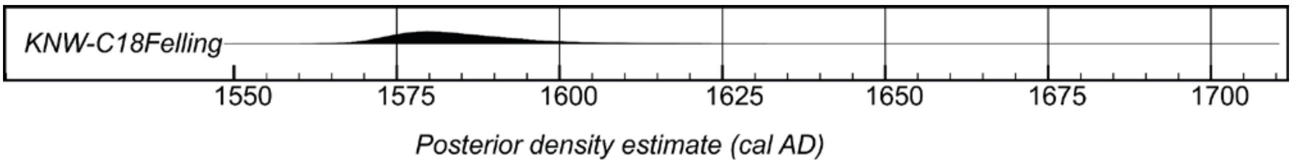

Figure 4: Probability distribution of the estimated felling date of timber KNW-C18 part of site sequence KNWCSQ08

All the timbers in KNWCSQ08 cross-match very well with each other, with, for example values in excess of *t*=13.0, 11.0, and 10.0, being seen between samples KNW-C18, C20, C21, C22, and C23. Such values would suggest that the timbers represented are derived from the same tree.

Discussion

Tree-ring dating and radiocarbon wiggle-matching has demonstrated that stair timbers in the south-west turret of the Gatehouse were felled in the second half of the sixteenth century (Fig 5). Other timbers used in the Gatehouse appear to have felling dates clustering in the third quarter of the sixteenth century, the primary building of the Gatehouse by the site's namesake, Robert Dudley, Earl of Leicester, possibly during the AD 1560s and 70s (Howard et al. 2007, fig 29). It is therefore likely that the stair timbers in the south-west turret represent primary material associated with the building's construction.

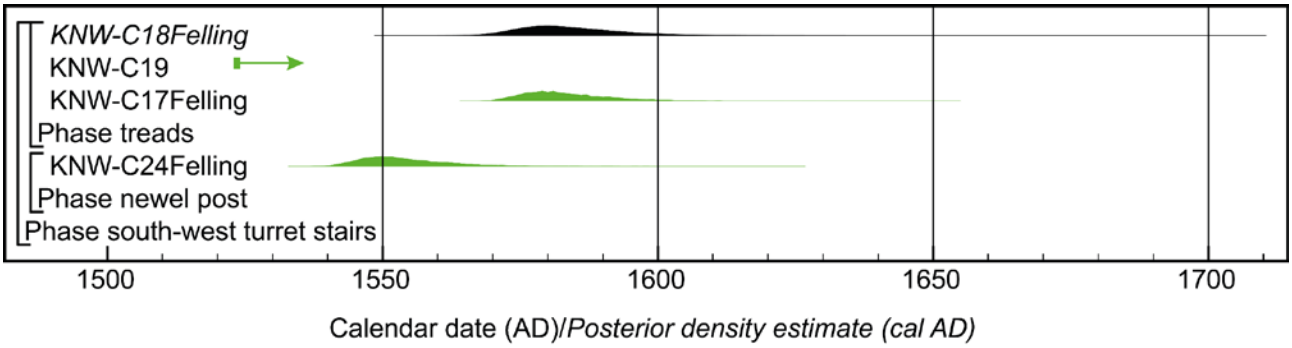

Figure 5: Summary of the scientific dating evidence from Leicester's Building south-west turret stairs. Green = dendrochronology, black = radiocarbon

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