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St Nicholas' Church, Newcastle upon Tyne, Tyne and Wear

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Discovery, Innovation and Science in the Historic Environment

Research Report Series no. 77/2018

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RADIOCARBON WIGGLE-MATCHING OF TIMBERS FROM THE ROOF OF ST MARGARET'S CHAPEL

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NGR: NZ 249 641

ISSN 2059-4453 (Online)

SUMMARY
Radiocarbon dating and wiggle-matching of the 302 year undated site sequence NWCCSQ01 derived from tree-ring analysis has conclusively shown that the timbers of the St Margaret's Chapel roof are not medieval in date but were probably felled in the early part of the nineteenth century

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ARCHIVE LOCATION
Tyne and Wear Historic Environment Record
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DATE OF RESEARCH
2015–2018

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CONTENTS

INTRODUCTION

St Nicholas' in Newcastle upon Tyne (NZ 249 641) was formerly a parish church, having been elevated to cathedral status in AD 1882. Although it does have some pre-Conquest and Norman remains in the crossing and north arcade the bulk of the cathedral is of fourteenth- and fifteenth-century date. Further alterations were made in the eighteenth century and again in the nineteenth.

A programme of grant aided repairs to the roof of St Margaret's Chapel, undertaken in the autumn of AD 2003, involved the stripping of the existing lead covering and its replacement with new material. As part of this process a scaffold platform was placed in the chapel providing a unique opportunity to safely access the roof timbers from below.

TREE-RING SAMPLING

Sampling and analysis by tree-ring dating of the roof timbers of St Margaret's Chapel were commissioned by English Heritage. This was requested as part of a research programme to better understand the structure of this part of the cathedral, and to inform a programme of grant-aided repairs, an earlier programme of tree-ring analysis having been undertaken on the roof timbers of the north transept (Howard *et al* 2002). It was hoped that analysis of the chapel roof timbers would provide a precise date for them and either confirm or refute the supposed late fourteenth- or early fifteenth-century date assigned to them.

TREE-RING ANALYSIS AND INTERPRETATION

Analysis by dendrochronology produced a single site chronology, NWCCSQ01, consisting of 11 samples with a combined overall length of 302 rings (Arnold *et al* 2004, table 1), together a single ungrouped sample (NWC-C23). Site chronology NWCCSQ01, and the single sample, was then compared to an extensive range of reference chronologies from the British Isles, and elsewhere in Europe, from Russia in the east to Ireland in the west, and from Norway to southern France, the reference material spanning the period AD 400 to the present date. However, despite this exhaustive attempt at cross-matching neither the site chronology or the single sample could be dated.

RADIOCARBON SAMPLING AND ANALYSIS

The lack of dating evidence for the roof of St Margaret's Chapel hampered decisions as to its conservation. Thus further dating was required. To this end, nine single-year growth rings were taken from three core samples, NWC-C14, NWC-C17, and NWC-C20 (Table 1) that formed part of the undated site sequence NWCCSQ01 were submitted for radiocarbon dating. Four samples were dated at the Oxford Radiocarbon Accelerator Unit (ORAU), and five at the ^{14}CHRONO, Queen's University Belfast. The samples dated by the Oxford Radiocarbon Accelerator Unit underwent an acid-base-acid pretreatment followed by bleaching (Brock *et al* 2010, table 1 (UW)). They were then combusted and graphitised as described by Brock *et al* (2010, 110) and Dee and Bronk Ramsey (2000), and dated by Accelerator Mass

Spectrometry (AMS) as described by Bronk Ramsey *et al* (2004). The samples dated at The Queen's University Belfast were processed and measured as described in Reimer *et al* (2015). Both laboratories maintain a continual programme of quality assurance procedures, in addition to participation in international inter-comparisons (Scott 2003; Scott *et al* 2007; 2010). These tests indicate no laboratory offsets and demonstrate the reproducibility and accuracy of these measurements.

The results are conventional radiocarbon ages (Stuiver and Polach 1977; Table 1), and are quoted in accordance with the international standard known as the Trondheim convention (Stuiver and Kra 1986).

Three pairs of replicate measurements are available on single year rings, representing relative years 113 (UBA-28963 and OxA-31831), 168 (UBA-28964 and OxA-31832), and 280 (UBA-28966 and OxA-31833) of site chronology NWCCSQ01, submitted for dating to both laboratories. In all cases the results are statistically consistent at 95% confidence (Table 1; Ward and Wilson 1978) and a weighted mean has been taken as providing the best estimate for the age of each ring.

Radiocarbon dating

Radiocarbon dating is based on the radioactive decay of carbon-14 and can be used to date organic materials, including wood. A small proportion of the carbon atoms in the atmosphere are of a radioactive form, carbon-14. Living plants and animals take up carbon from the environment, and therefore contain a constant proportion of carbon-14. Once a plant or animal dies, however, its carbon-14 decays at a known rate. This makes it possible to calculate the date of formerly living material from the concentration of carbon-14 atoms remaining. Radiocarbon measurements, like those in Table 1 are expressed in radiocarbon years BP (before present, 'present' being a constant, conventional date of AD 1950).

Calibration

Radiocarbon ages are not the same as calendar ages because the concentration of carbon-14 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 IntCal13 calibration curve (Reimer *et al* 2013). This is constructed from radiocarbon measurements on samples dated absolutely by other, independent means: tree rings, plant macrofossils, speleothems, corals, and foraminifera. In this report the calibrations which relate the radiocarbon measurements directly to the calendrical time scale have been calculated using IntCal13 and the computer program OxCal v4.3 (https://c14.arch.ox. ac.uk/oxcal/; Bronk Ramsey 1995; 2001; 2009). The calibrated date ranges quoted for each sample in Table 1, expressed 'cal AD', were calculated by the maximum intercept method (Stuiver and Reimer 1986) and are rounded outwards to the nearest five years as recommended by Mook (1986). The graphical distributions of the calibrated dates, shown in outline in Figures 1–2 are derived from the probability method (Stuiver and Reimer 1993).

Bayesian wiggle-matching

Wiggle-matching uses information derived from tree-ring analysis in combination with radiocarbon dates to provide a revised understanding of the age of a timber; a review is presented by Galimberti *et al* (2004). In this technique, the shapes of multiple radiocarbon distributions can be 'matched' to the shape of the radiocarbon calibration curve. The exact interval between radiocarbon dates can be derived from tree-ring analysis, since one ring is laid down each year.

Although the technique can be done visually, Bayesian statistical analyses (including functions in the OxCal computer program) are now routinely employed. A general introduction to the Bayesian approach to interpreting archaeological data is provided by Buck *et al* (1996). The approach to wiggle-matching adopted here is described by Christen and Litton (1995).

Details of the algorithms employed in this analysis — a form of numerical integration undertaken using OxCal — are available from the on-line manual or from various publications by Christopher Bronk Ramsey (1998; 2001; 2009). Because it is possible to constrain a sequence of radiocarbon dates using this highly informative prior information (Bayliss *et al* 2007), model output will provide more precise posterior density estimates. These posterior density estimates are shown in black in the Figures and quoted in italic in the text.

The Acomb statistic shows how closely the dates as a whole agree with other information 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 date agrees with the other information in the model; an acceptable threshold is reached when it is equal to or greater than 60.

NWCCSQ01

The chronological model for the undated site sequence NWCCSQ01 includes the radiocarbon dates for the six single-year dated tree-ring samples along with the information derived from the tree-ring analysis about the calendar age gap between them (Fig 1). The model has good overall agreement (Acomb=46.5 (An=28.9); n=6) and provides an estimate for the formation of the final ring of site sequence NWCCSQ01, ring 302, of *cal AD 1805–1825* (*95% probability*; *ring_302_end_ring*; Fig 1), probably *cal AD 1810–1825* (*68% probability*).

A model including the tentative tree-ring date of AD 1809 (Cathy Tyers pers comm) for the final ring of site sequence NWCCSQ01 has good overall agreement (Acomb=29.3 (An=26.7); n=7; Fig 2) indicating the radiocarbon dates support this potential date.

None of the dated timbers in site sequence NWCCSQ01 retains complete sapwood, the last growth ring produced by the tree before it was felled, this either having been removed by the original carpenter or as part of subsequent ‘conservation’ work. As a result, it is not possible to indicate a precise felling date for any timber. Two samples, NWC-C12 and NWC-C13 retain nine and 12 sapwood rings respectively and sample NWC-C14 ends at the heartwood/sapwood boundary (Arnold *et al* 2004, table 1), meaning that only the outer sapwood rings have been lost from the timbers. The average date of the heartwood/sapwood boundary on these three samples is relative year 291 of site sequence NWCCSQ01 and therefore tentatively AD 1798. Using the 95% confidence limit of 15–40 sapwood rings standardly applied by the Nottingham Tree-ring Dating Laboratory to native oak for timbers that do not contain complete sapwood provides an estimated felling date for the timbers in the range AD 1813–38.

INTERPRETATION

Radiocarbon dating and wiggle-matching of the 302 year undated site sequence NWCCSQ01 derived from tree-ring analysis has conclusively shown that the timbers of the St Margaret’s Chapel roof are not medieval in date but were probably felled in the early part of the nineteenth century.

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Table 1: Radiocarbon results from Newcastle Cathedral. All samples derive from the undated 302 year chronology NWCCSQ01. 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 reference, material & context	δ13C (‰)	Radiocarbon Age (BP)	Calibrated date – cal AD (2σ)	*Highest Posterior Interval - cal AD (95% probability)*
OxA-31830	NWC-C17, ring 1 *Quercus* sp. heartwood, relative year 1, from joist 6 of the roof.	−25.8±0.2	362±24	1450–1635	*1505–1525*
UBA-28962	NWC-C17, ring 57 *Quercus* sp. heartwood, relative year 57, from joist 6 of the roof.	−26.0±0.22	284±24	1520–1660	*1560–1580*
UBA-28963	NWC-C17, ring 113 *Quercus* sp. heartwood, relative year 113, from joist 6 of the roof.	−26.0±0.22	299±27		
OxA-31831	NWC-C14, ring 8 *Quercus* sp. heartwood, relative year 113, from joist 3 of the roof.	−23.8±0.2	321±23		
¹⁴C: 1312±18 BP; T'=0.4				1490–1650	*1620–1635*
UBA-28964	NWC-C20, ring 101 *Quercus* sp. heartwood, relative year 168, from joist 9 of the roof.	−25.3±0.22	150±23		
OxA-31832	NWC-C14, ring 63 *Quercus* sp. heartwood, relative year 168, from joist 3 of the roof.	−24.2±0.2	191±24		
¹⁴C: 170±17BP: T'=1.5				1665–1955*	*1675–1690*
UBA-28965	NWC-C20, ring 157 *Quercus* sp. heartwood, relative year 224, from joist 9 of the roof.	−25.6±0.22	191±22	1665–1955*	*1730–1750*
UBA-28966	NWC-C20, ring 213 *Quercus* sp.	−26.5±0.22	182±25		

Laboratory number	Sample reference, material & context	δ13C (‰)	Radiocarbon Age (BP)	Calibrated date – cal AD (2σ)	*Highest Posterior Interval - cal AD (95% probability)*
	heartwood, relative year 280, from joist 9 of the roof.				
OxA-31833	NWC-C14, ring 175 *Quercus* sp. heartwood, relative year 280, from joist 3 of the roof.	−24.9±0.2	190±24		
14C: 186±18 BP; T'=0.1				1660–1955*	*1785–1805*

* beyond calibration

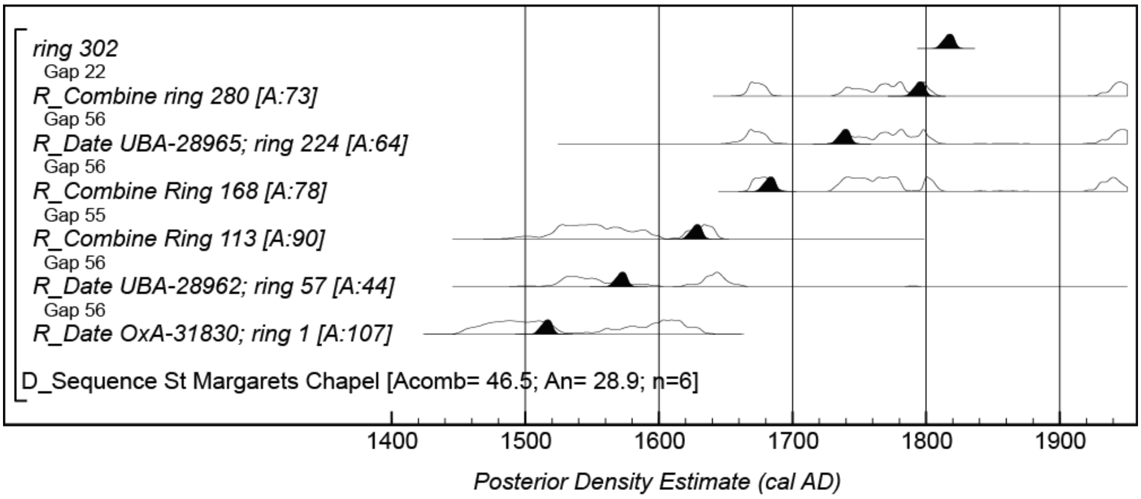

Figure 1: Probability distributions of dates from the undated site sequence NWCCSQ01. Each distribution represents the relative probability that an event occurs at a particular time. For each of the dates two distributions have been plotted: one in outline, which is the simple radiocarbon calibration, 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

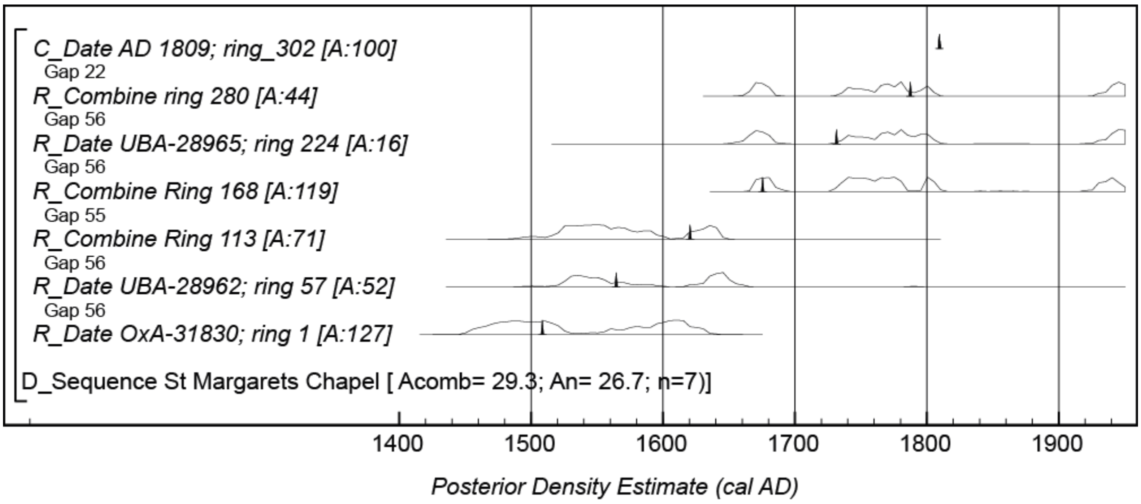

Figure 2: Probability distributions of dates from the undated site sequence NWCCSQ0, including the tentative tree-ring date of AD 1809 for ring 302. The format is identical to Figure 1

     

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