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Dendrochronology, timber analysis, and historic building consultants

TOTON MILL,
TOTON MANOR FARM RECREATION GROUND,
NOTTINGHAMSHIRE;

TREE-RING ANALYSIS OF EXCAVATED TIMBERS

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SUMMARY

Analysis by dendrochronology was undertaken on samples from two timbers found during archaeological excavation at the site of a former watermill at Toton in Nottinghamshire. This analysis produced dates for both samples. It is estimated that the earlier timber, represented by sample TOT-M02 (DBO), was felled at some point between 1210 at the earliest and 1235 at the latest, while the later timber, represented by sample TOT-M01 (DBP), was felled at some point between 1231 at the earliest and 1256 at the latest. It is possible that these timbers relate to the water mill referred to in the early-fourteenth century documentary evidence.

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Introduction

Trent & Peak Archaeology was commissioned by the Friends of Toton Fields to complete an archaeological evaluation at the site of Toton Manor Farm Recreation Ground in Nottinghamshire, the area centred on SK 501 343 (Fig 1a/b), as part of the Heritage Lottery-funded community archaeology project '*Toton Unearthed'.* Toton Manor was a medieval township located along the River Erewash and administered by the parish church of Attenborough. The settlement may have had Anglo-Saxon origins, but certainly by the time Domesday was written in 1086 a Manor House and two associated water mills were in existence. Following the death of Lord John de Grey *(do we know when this was?)* a survey of the Toton Manor recorded two mills at the site worth £4, and by 1308 it is recorded that "there is a water mill, worth yearly 30/-". The second mill appears to have gone out of use by at this time.

In June 2013 the Friends of Toton Fields learned of a planned play area to be situated on a potential site of one of the ancient water mills. Through the Connected Communities scheme funded by the Arts and Humanities Research Council, they were able to commission a geophysical survey of the area, which was conducted by the University of Nottingham in partnership with Trent & Peak Archaeology. Both magnetometry and resistivity methods were employed to reveal reasonably clear anomalies, particularly in the resistance data. High-resistance anomalies in the north-east of the area were interpreted as sub-surface structural remains of a mill building, while low-resistance anomalies were interpreted as the northernmost extent of the in-filled millpond.

Following the evaluation process a full-scale archaeological excavation was undertaken of the site. Amongst the material excavated were two large upright oak stake piles along with a horizontal timber with a mortise. The alignment of this structure suggests a possible timber revetment for the 18th century mill related to stones however they may also relate to an earlier medieval mill (Trent & Peak Archaeology, 2015).

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Sampling

In an attempt to obtain accurate and reliable dates for these timbers Trent & Peak Archaeology commissioned analysis by dendrochronology of samples from two different beams. It was hoped that tree-ring analysis would provide some dating for the structure, there being no other certain evidence for its period of use or its potential sequential development.

Sliced samples were thus taken from the two submitted timbers. Having been buried for some time the timbers were waterlogged, and the sliced samples were initially frozen for a short period to harden them. Once sufficiently solid the slices were reduced in size to narrow-width, cross-sectional, radii. The radii were then allowed to air dry naturally for three weeks before being prepared for measuring by sanding and polishing to clearly reveal the annual tree-ring growth (Fig 2). The two samples were given the Nottingham Tee-ring Laboratory code TOT-M (for Toton Mill), and were numbered 01 and 02, as well as being denoted by their Trent and Peak excavation code (respectively DBP and DBO). Details of the samples are given in Table 1, including the site code of the timber sampled, the total number of rings each sample has, and how many of these, if any, are sapwood rings. The individual date span of each dated sample is also given.

Tree-ring dating

Tree-ring dating relies on a few simple, but quite fundamental, principles. Firstly, as is commonly known, trees (particularly oak trees, the timber most commonly used in building construction until the introduction of pine from the late eighteenth century onwards) grow by adding one, and only one, growth-ring to their circumference each, and every, year. Each new annual growth-ring is added to the outside of the previous year's growth just below the bark. The width of this annual growth-ring is largely, though not exclusively, determined by the weather conditions during the growth period (roughly March–September). In general, good conditions produce wider rings and poor conditions produce narrower rings. Thus, over the lifetime of a tree, the annual growth-rings display a climatically influenced pattern. Furthermore, and importantly, all trees growing in the same area at the same time will be influenced by the same growing conditions and the annual growth-rings of all of them will respond in a similar, though not identical, way.

Secondly, because the weather over a certain number of consecutive years is unique, so too is the growth-ring pattern of the tree. The pattern of a shorter period of growth, 20 or 30 consecutive years, might conceivably be repeated two or even three times in the last one thousand years, and is considered less reliable. A short pattern might also be repeated at different time periods in different parts of the country because of differences in regional micro-climates. It is less likely, however, that such problems would occur with the pattern of a longer period of growth, that is, anything in excess of 45 years or so. In essence, a short period of growth, anything less than 45 rings, is not reliable, and the longer the period of time under comparison the better.

Tree-ring dating relies on obtaining the growth pattern of trees from sample timbers of unknown date by measuring the width of the annual growth-rings. This is done to a tolerance of 1/100 of a millimeter. The growth patterns of these samples of unknown date are then compared with a series of reference patterns or chronologies, the date of each ring of which is known. When the growth-ring sequence of a sample 'cross-matches' repeatedly at the same date span against a series of different reference chronologies the sample can be said to be dated. The degree of cross-matching, that is the measure of similarity between sample and reference, is denoted by a '*t*-value'; the higher the value the greater the similarity. The greater the similarity the greater is the probability that the patterns of samples and references have been produced by growing under the same conditions *at the same time*. The statistically accepted fully reliable minimum *t*-value is 3.5.

However, rather than attempt to date each sample individually it is usual to first compare all the samples with one another, whether they be from a single archaeological structure, single archaeological site or phase, from a seemingly non-integral structure, or from a standing building. This comparative process is undertaken in an attempt to cross-match each sample with all the others from the same archaeological structure/phase, or building. It should be pointed out that this is not done by simply comparing the 'raw' ring-width data of the samples (the 'raw' growth pattern), but rather by calculating a moving five-year average for each individual consecutive ring (requiring the first two and the last two rings of each sample to be 'lost'), and then turning this average into a ratio relative to the next average. It is thus that a series of 'normalised' patterns are compared with each other.

When samples from the same phase do cross-match with each other they are combined at their matching positions to form what is known as a 'site chronology'. As with any set of data, this has the effect of reducing the anomalies of any one individual (brought about in the case of tree-rings by some non-climatic influence) and enhances the overall climatic signal of the group of samples. As stated above, it is the climate that gives the growth pattern its distinctive pattern. The greater the number of samples in a site chronology the greater is the climatic signal of the group and the weaker is the non-climatic input of any one individual.

Furthermore, combining samples in this way to make a site chronology usually has the effect of increasing the time-span that is under comparison. As also mentioned above, the longer the period of growth under consideration, the greater the certainty of the cross-match. Any site chronology with less than about 55 rings is generally too short for reliable dating.

However, this process of combining individual samples is not always possible, particularly with archaeological sites, where non-integral structures may contain timbers of different dates. In such instances, each sample may be compared individually with the full corpus of reference data in an attempt to date them as 'singletons'. Although this approach is usually less successful than dating combined groups where the data of the samples is replicated, it can be done.

Having obtained the date span of the individual samples the felling date of the tree or trees represented may be calculated. Where a sample retains complete sapwood, that is, it has the last or outermost ring produced by the tree before it was cut, the last measured ring date is the felling date of the tree.

Where the sapwood is not complete it is necessary to estimate the likely felling date of the tree. Such an estimate can be made with a high degree of reliability because oak trees generally have between 15 to 40 sapwood rings. For example, if a sample with, say, 12 sapwood rings has a last sapwood ring date of 1400 (and therefore a heartwood/sapwood boundary ring date of 1388), it is 95% certain that the tree represented was felled sometime between 1403 (1400+3 sapwood rings (12+3=15)) and 1428 (1400+28 sapwood rings (12+28=40)).

Analysis

Thus, once sufficiently prepared, the widths of the annual growth rings of the two samples were measured, the data of these measurements then being initially compared with each other as described in the notes above. This comparative process indicated that although there was some cross-matching between the two samples at one particular position (when the first ring of sample TOT-M01 (DBP) is at +56 years relative to the first ring of sample TOT-M02 (DBO)), this was not at a significantly high level.

Because of this, the two samples were then compared individually to the full corpus of reference data, this indicating cross-matches and dates for both of them; sample TOT-M01 (DBP) cross-matching significantly well and repeatedly with a large number of reference chronologies when its 101 rings span the years 1116–1216, while sample TOT-M02 (DBO) cross-matches significantly well and repeatedly with a large number of reference chronologies when its 136 rings span the years 1060–1195. It will be seen that the first ring date of each sample corresponds to the relative position of the low level cross-matching between the two samples seen in the initial analysis (ie, +56 rings).

Because of the satisfactory dating of the two individual samples, and because of their corresponding, though low-level, cross-matching, the samples were combined at their indicated offset positions to form a single site chronology, TOTMSQ01, this have a combined overall length of 157 rings (Fig 3). Site chronology TOTMSQ01 was then compared with the full corpus of reference data, this indicating a cross-match spanning the years 1060–1216. The evidence for this dating is given in the t-values of Table 2.

Interpretation

Neither of the dated samples retains complete sapwood (the last ring produced by a tree before felling), and it is thus not possible to reliably determine the precise felling date of either of the trees represented. The two samples do, though, retain the heartwood/sapwood boundary, this meaning that although each sample has lost its sapwood rings, it is *only* the sapwood rings that have been lost. This situation allows an estimated date range within which it is highly likely that the trees were felled.

Allowing for a likely minimum of 15 sapwood rings and a likely maximum of 40 sapwood rings (the usual 95% confidence interval), and given that the heartwood/sapwood boundary on sample TOT-M02 (DBO) is dated to 1195, it is likely that the tree represented was felled at some point between 1210 at the earliest and 1235 at the latest.
Likewise, allowing for the same sapwood estimates as above, 15–40 rings, and given that the heartwood/sapwood boundary on sample TOT-M01 (DBO) is dated to 1216, it is likely that the tree represented by this sample was felled at some point between 1231 at the earliest and 1256 at the latest.

Conclusion

Tree-ring dating has thus produced dates for both of the samples analysed in this programme, this indicating that both timbers date from the early- to mid-thirteenth century. It is most likely that the timbers were felled at slightly different times, though there is a slight possibility that they were felled together in the period 1231–35 (where their estimated felling date ranges overlap). As such, these timbers represent an unusually early survival, and may relate to the mill referred to in the survey of 1308.

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Table 1: Details of tree-ring samples from Toton Mill, Toton Manor Farm Recreation Ground, Nottinghamshire

Sample number	Sample location/identifier code	Total rings	Sapwood rings*	First measured ring date (AD)	Heart/sap boundary	Last ring date	Estimated felling date range**
TOT-M01	DPB	101	h/s	1116	1216	1216	1231–56
TOT-M02	DBO	136	h/s	1060	1195	1195	1210–35

*h/s = heartwood/sapwood boundary, i.e., only the sapwood rings are missing

**Felling date range based on a minimum of 15 sapwood rings and a maximum of 40 sapwood rings

Table 2: Results of the cross-matching of site chronology TOTMSQ01 and the reference chronologies when the first ring date is 1060 and the last ring date is 1216		
Reference chronology	*t*-value	
England, London master chronology	6.2	(Tyers and Groves 1999 unpubl)
Angel Choir, Lincoln Cathedral	6.0	(Laxton and Litton 1988)
Manor House, West Bromwich	5.9	(Arnold *et al* 2009)
Manor House, Medbourne, Leicestershire	5.7	(Howard *et al* 1999)
London Fleet Valley chronology	5.7	(Tyers and Hibbard 1993)
Bede House, Lyddington, Rutland	5.6	(Arnold and Howard forthcoming)
Holy Trinity Church, Wistanstow, Hampshire	5.6	(Miles 1998)
LON-S01M master chronology	5.5	(Morgan 1977)

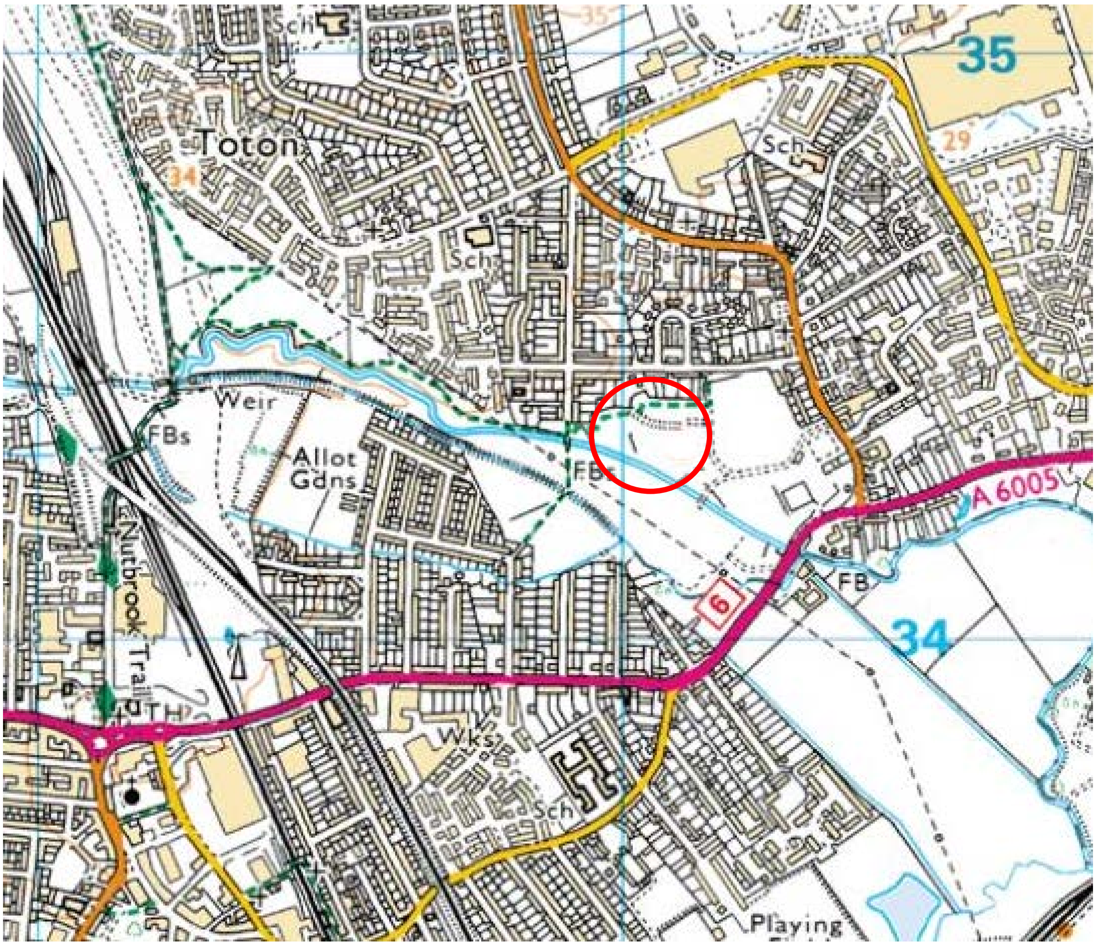
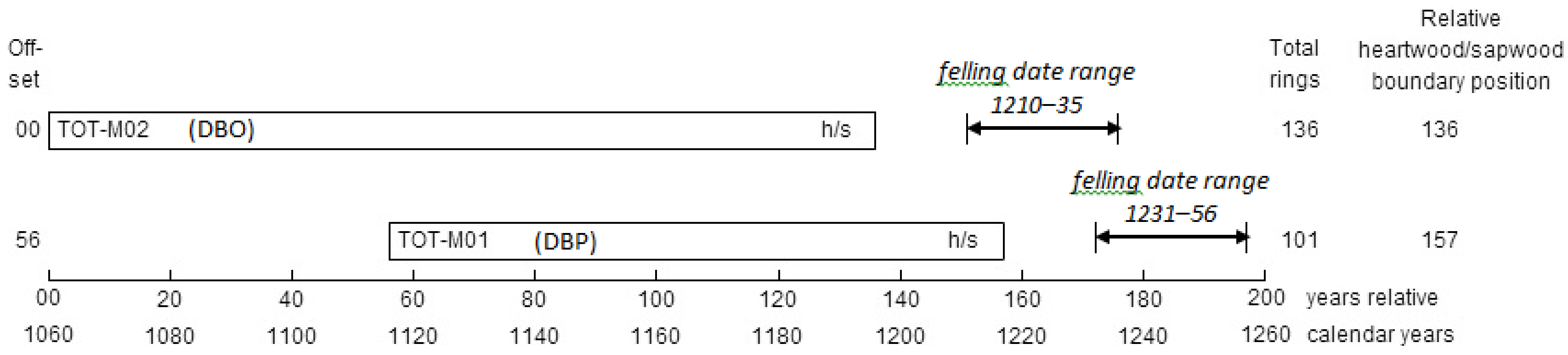


Figure 1: Map to show location of Toton (top) and site of excavation (bottom)

Figure 2: View of the sample radii



blank bars ☐ = heartwood rings
h/s = heartwood/sapwood boundary, i.e., only the sapwood rings are missing

Figure 3: Bar diagram showing of the samples in site chronology TOTMSQ01 and their estimated felling date ranges, these ranges based on a minimum of 15 and a maximum of 40 sapwood rings.

Given that their felling date ranges overlap between 1231–35, it is in theory possible that the two trees represented were felled at the same time during these few years. It is more likely, though, that the trees were felled at different times.