DENDROCHRONOLOGICAL ANALYSIS OF OAK TIMBERS FROM KETLEAS, CAPEL, SURREY, ENGLAND.

Tree-Ring Services Report: CAKE/04/04

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SUMMARY
Ketleas (originally Kettles) is a very attractive, ancient cottage of apparently only two bays, one of which was open to the roof. The roof structure is ‘sans-purlin’ (collar-rafter), now gabled it was probably hipped originally. There are jowl posts and passing braces in the wall framing which rise almost from ground level right up to the eaves. Four primary timbers dated dendrochronologically are consistent with a single phase of construction, one timber provides a probable felling date of AD 1389. This date is significantly earlier than the early 15th century date estimate made on stylistic grounds and important in view of the scarcity of tiny hall houses. The timbers were generally converted from comparatively young trees with an average age of 75 years at the time of felling. The chronology established matches well with another chronology in Capel, suggesting the timbers are from a common local origin. Data for an interim master chronology for Capel called (CAPEL-10) is presented.

FELLING DATE RANGES PRESENTED
- Ketleas: Primary construction
- AD 1389?

KEYWORDS
Dendrochronology, 14th Century, Standing building, Surrey, Capel.

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INTRODUCTION

There is an increasing interest in Britain's past as evinced by such television programmes as "Time Team" and "The House Detectives" which both promote and respond to this interest. Increasingly people wish to know precisely when ancient buildings were constructed in order to better understand the history of the land in which we live. However, although there is some ability to date a building on stylistic grounds, a precise date is rarely known except when there is a date-stone or documentary evidence, which is unusual in Surrey.

The advent of dendrochronology (tree-ring dating) is changing this scenario, at least for buildings with timbers containing sufficient rings for analysis. The science is simple in concept. The width of a tree's growth rings varies from year to year, so that each sequence of years has a unique pattern of narrow and wide rings. We now know in detail the pattern of rings shown by oak trees in England for at least the last 2000 years, and there is some work in progress on other species. Small cores of wood taken from the structural timbers of a building show the pattern of rings laid down during the lifetime of the trees from which the timbers were cut. If this pattern is then compared with 'master chronologies' it is often possible to identify the felling date of the trees with astonishing accuracy. Where bark is present, it is possible to give a precise year, sometimes even the season of the year. We know that oak for building was almost always used 'green', (unseasoned, not having been felled and prepared until required), so construction dates can be determined in which we can place considerable confidence.

National trends in building activity inevitably conceal regional differences that can only be explained by detailed local studies. The Royal Commission on the Historical Monuments of England (RCHME) has analysed 53 medieval buildings in Kent (Pearson 1994). Hampshire County Council has analysed well over 100 buildings in the county (Roberts et al., 2003). These projects utilise the specific dates provided by tree-ring analysis to refine the typological and stylistic dating of buildings.

An early reference chronology for Surrey was most usefully established by Dr. Martin Bridge (University College London) commissioned by English Heritage (Bridge 1998b). The Oxford Dendrochronology Laboratory has also carried out several relevant multi-building dendrochronology surveys. These include the dendrochronological analysis of eight buildings in the area of Surrey Heath and Hambledon (Miles and Worthington 2000) and five buildings around Charlwood (Miles and Worthington 2001). In the neighbouring county of West Sussex, six buildings in East Grinstead (Miles and Worthington 2001) and six buildings around Horsham (Miles 2002 unpubl) have been studied. Earlier this year, as part of the Charlwood Dendrochronology Project, Tree-Ring Services dated twelve more buildings in the parish of Charlwood, significantly contributing to the number of timber-framed buildings dated in Surrey (Moir, forthcoming). Following on the success of this earlier work, the Surrey Dendrochronology Project has been formed.
Surrey Dendrochronology Project
The Surrey Dendrochronology Project is a joint venture between the Surrey Archaeological Society and the Domestic Buildings Research Group (DBRG), with support from Surrey County Council. Through the dendrochronological dating of some 200 buildings the Project aims to:

- establish dating criteria for old buildings generally
- contribute to the work taking place nationally on trends in vernacular architecture
- support a wide range of historical and social research programmes
- involve local communities in their history (Cox et al 2002 unpubl).

The Project is divided into fifteen ‘clusters’, each of approximately fifteen buildings. The first two clusters are ‘South Mole Valley’ and ‘East Guildford Borough’. Both these clusters are being funded by a generous grant from the Heritage Lottery Fund. The Surrey Archaeological Society is also contributing.

The assessment of a large number of buildings will enable not just their dating, but also the examination of environmental and socio-economic issues which can rarely be addressed in the analysis of single buildings. The information derived from the large number of individual timbers (dated, undated and rejected) has great potential to further our understanding of the changing landscape, woodland management techniques and underlying environmental factors. The main objective from an architectural viewpoint is to develop a much more precise framework for the dating of timber buildings on technical and stylistic criteria than has hitherto been possible. Roberts (2001) identifies the value of constructing regional chronologies for carpentry joints, wall framing and other constructional features. Based on a firm methodological foundation, tree-ring dating can provide a precise framework of dates for both buildings and carpentry techniques.

Overall, this research should provide refined criteria by which to date more securely whole groups of buildings and locate them more accurately in their historical context. The additional contributions of owners and privately funded analyses, both in Surrey and neighbouring counties, will greatly enhance this research and its potential results.

Recording Timber Framed Buildings
Harris (1978) provides a useful introduction to the study of timber-framed buildings, while Brunskill (Brunskill 2000) details the study of vernacular architecture. His work includes information on how to carry out surveys, as well as providing a comprehensive references list for different regions. Alcock's (1996) glossary provides illustrative drawings, particularly useful in facilitating the naming of timbers in a building.
Ketleas (NGR: TQ 1829 4254)
The following descriptive paragraphs about the building have been drawn from those kindly provided by Rod Wild of the DBRG (Surrey):

Ketleas (originally Kettles) is a very attractive, ancient cottage of apparently only two bays, one of which was open to the roof. It is gabled but was probably hipped originally. The roof is of Horsham stone and there is evidence that it was so clad from the beginning. The roof structure is ‘sans-purlin’ (collar-rafter). This rare, early form has no longitudinal bracing; there is nothing to prevent the rafters falling over other than the cladding. There are jowl posts and passing braces in the wall framing. These long braces rise almost from ground level right up to the eaves. They are of the ‘sagging’ rather than arching variety and, as such, are thought to be particularly early.
Example Dendrochronological Report: Ketleas, Capel, Surrey

The braces to the centre tiebeam also rise in this way, from a point only 80 cm. from the floor. These tiny hall houses are rare in Surrey and perhaps even more so in other regions. The previous date estimate was early 15th century.

A floor was inserted into the open hall and an end chimney added, judging from the brickwork not until the 17th century.

Photo 1: South west aspect of Ketleas

Photo 2: North east aspect of Ketleas

Objective of the Analysis
The objective of this analysis has been to provide dendrochronological evidence to date the primary phase(s) of construction.

Dendrochronological Assessment
A brief dendrochronological assessment of the first phase timbers was undertaken on the 29th September 2003. All the timbers observed were considered to be oak (Quercus spp.). Later modifications which had left empty timber joints and some timbers ends observable in section suggested that few timbers contained sufficient number of rings to attempt dendrochronological analysis: most timbers apparently being from fast grown trees which had been felled young. However, survival of full sapwood was good and ten primary timbers with indications of more than 50 annual rings and sapwood/bark were located for sampling. The assessment was made in conjunction with Rod Wild of the DBRG (Surrey), who helped highlight areas of alteration and occurrences of re-used timbers.
METHODOLOGY

Methods employed by Tree-Ring Services are in general those described in English Heritage guidelines (English Heritage 1998). Details of the methods employed for the analysis of this building are described below.

Sampling and Preparation

Whenever possible, timbers with more than 50 annual growth rings are selected for sampling. This is necessary to provide a pattern of rings of sufficient length to be unique to the period of time when the parent tree was growing. Timbers were sampled using purpose-made 12mm and 15mm diameter corers attached to an electric drill. Sampling was located as discreetly as possible in what appeared to be original timbers and orientated in the most suitable direction to maximize the numbers of rings for subsequent analysis. Extracted core samples were immediately taped and glued onto wooden laths on site and then labelled and left to dry, ready for subsequent analysis.

Tree-ring sequences were revealed through sanding with progressively finer grits to a 600 abrasive grit finish to produce results suitable for measuring, see Photo 4. When required, for example where bands of narrow rings occurred, further preparation was performed manually. Where requested, extraction holes were "made good", employing pine dowelling, wood-glue, sawdust and wood stains to restore the timbers to their original appearance.

Measuring and Cross-matching

Tree-ring sequences are measured under a x20 microscope to an accuracy of 0.01 mm using a microcomputer-based travelling stage. All samples are measured from the centremost ring to the outermost. Samples considered unsuitable for dating purposes are then rejected. These include samples with disturbed ring sequences which cannot be measured due to knots or bands of extremely narrow rings, and those samples with less than 35 rings.

Samples of less than 50 rings are sometimes rejected from dendrochronological analysis because their ring patterns may not be unique (Hillam et al 1987). Although this is certainly true of all ring sequences of less than 30 rings, which should not be used in dating (Mills 1988), samples with 30 to 50 rings may be dated in some circumstances (English Heritage 1998). Because samples taken by Tree-Ring Services are often from listed...
structures, it has been felt wise to maximise the recorded amount of data, and sequences of 35-50 rings are included in analysis and cautiously considered for dating, usually when they match well with a number of other sequences. Samples are measured twice and the two sets of measurements cross-matched and plotted visually as a check. Where sequences match satisfactorily they are averaged and the resulting sequence used in subsequent analysis.

Cross-correlation algorithms are then employed to search for the positions where tree-ring sequences correlate and therefore possibly match. All statistical correlations are reported as \( t \)-values derived from the original CROS73 algorithm (Baillie and Pilcher 1973). A value of 3.5 or over is usually indicative of a good match as it represents the value of \( t \) which should occur by chance only once in every 1000 miss-matches (Baillie 1982). Due to the risk of high \( t \)-values being produced by chance, all indicated correlations are further checked to ensure that corroborative high results are obtained at the same relative position against a range of independent tree-ring sequences. Visual comparisons of sequences are also employed to support or reject possible cross-matches and serve as a means of identifying measuring errors.

Timber Groups

A further element of the tree-ring analysis of buildings and archaeological assemblages is the grouping of timbers within the sampled material. Inspection of in situ timbers may indicate that samples derive from a common timber, while common arrangements of anatomical features (knots & branching) may also indicate that samples are derived from a single tree.

Tree-ring analysis is used to support suggestions of same-tree groups between samples based on a combination of information. Timbers derived from the same tree are generally expected to have \( t \)-values over 10, although lower \( t \)-values may be produced when different radii measured from the same tree are compared. Tree-ring sequences producing \( t \)-values of 10 or above are examined to identify same-tree groups. Good comparisons of visual matching, growth rates, short and longer term growth patterns, are combined with pith information, sapwood boundaries, bark and anatomical anomalies, to help decide whether timbers are likely to come from the same tree. Where timbers are assessed to derive from the same tree, to avoid bias the sequences are averaged to produce a single tree-ring sequence before inclusion in the final site chronology, but inevitably some same-tree samples go undetected by dendrochronology.

Chronology building and Cross-dating

The process of cross-matching compares all tree-ring sequences against one another, and those found to cross-match satisfactorily together are combined to create an average sequence. The site mean(s) and individual ring sequences which remain unmatched with the site mean are then tested against a range of established reference sequences (reference chronologies). Significant \( t \)-values replicated against a range of sequences at the same position with satisfactory visual matching are similarly used to establish cross-matches with reference chronologies. Where cross-matching is established against dated reference chronologies, calendar dates can be assigned to the site sequences. The dates of the first and last ring of dated sequences are produced as date spans and these dates should not be confused with felling dates.
Felling Dates

Sequences dated by the cross-dating process provide calendar year dates for the final tree-ring present in the measured timber sample. The interpretation of these dates then relies upon the nature of the final rings in the sequence. Where bark survives intact on a sample a felling date is given as the date of the last ring measured on the tree-ring sequence. Based on the completeness of the final ring it is sometimes even possible to distinguish between spring, summer or winter fellings, corresponding to approximately March to May, June to September and October to February respectively. Where timbers were felled in either spring or summer and the final ring is incomplete and therefore not measured, allowance has to be made for the one-year discrepancy between the end of a measured sequence and the actual year of felling.

Sapwood Estimates

Where bark is missing from oak samples, as long as either sapwood or the heartwood/sapwood boundary have been identified, an estimated felling date range can be calculated using the maximum and minimum number of sapwood rings that were likely to have been present. Sapwood estimates have varied over time with different data sets, geographical location and researchers. A general trend identified is that the number of sapwood rings in oak decreases from north to south and from west to east across Europe. However, simply not enough is yet understood about sapwood variations and the mechanisms responsible for them. A generally accepted sapwood estimate of between 10 and 55 rings for British and Irish oaks (at 95% confidence) was given in 1987 (Hillam et al 1987). Analysis of the increased data set available ten years later indicated a range of 10-46 rings to be more appropriate for England (Tyers 1998). Currently as research in areas improves sapwood estimates are refined and new estimates applied. Therefore, when dendrochronological dates are produced, the reference to the sapwood estimate used in its calculation should always follow.

This report applies a minimum of 9 and maximum of 41 annual rings sapwood estimate, which means that 19 out of every 20 trees examined is expected have between 9 and 41 sapwood rings. This sapwood estimate is currently applied to most of the south east region and has been arrived at by Oxford Dendrochronology Laboratory (Haddon-Reece et al 1990; Miles 1997). Felling date ranges have been calculated by adding the sapwood estimate of minimum and maximum missing rings to the date of the heartwood/sapwood boundary. Felling date ranges have been refined by the presence of surviving sapwood where appropriate, see Table 3. Where samples ending in heartwood were dated, “felled after dates” have been calculated by adding the minimum expected number of missing sapwood rings to the samples' final ring dates. These dates represent the earliest probable felling dates. However, the actual felling date of a tree may be decades later due to an unknown number of missing heartwood rings.

Felling Groups

It is common to find that timbers used in the construction or repair of smaller buildings, or identifiable parts of larger buildings, date into groups whose felling dates occur within a narrow range of years. These groups are called associated fellings. Where they are identified the average heartwood/sapwood boundary of the component timbers is used
to calculate an overall estimated period of felling.

Close location association and a short (21 years at most) range of heartwood-sapwood boundary dates are normally used to define these groups. The estimates do not assume that trees within a group were felled at the same time, though evidence published by the Nottingham University Tree-Ring Dating Laboratory indicates that the range estimate encompasses the possible different individual felling dates (English Heritage 2001). Where bark is present within a group of timbers and other evidence does not dispute the precise date obtained, it is assumed that all the trees within a felling group were felled in this same year.

**Date of Construction**

It is vitally important to understand that dendrochronological analysis provides dates for when trees were felled and not necessarily when their timbers were used. Green or freshly felled wood is however far easier to work and it is standard practice to assume that medieval timbers were felled as required and used green (Rackham 1990; Miles 1997). However, the use of previously felled timbers in vernacular construction was not uncommon, with short-term stockpiling usually of not more than 1 to 2 years (Miles 1997), and the use of leftovers or re-used timbers may certainly give rise to differences between felling dates and the date of construction where samples are analysed in isolation.

A number of samples having a close range of felling dates are required from varying elements of a building to either strongly indicate a single date of construction or to identify separate phases of construction. Where fewer than 4 samples with sapwood evidence or bark are dated the term "Spot date(s)" is applied to help identify that the dates are derived in isolation and therefore should not be used to indicate a period of construction. It is also usual to incorporate other specialist evidence before dendrochronological dates can be reliably interpreted as reflecting the date of construction.

**Tree-Ring Services - Methods and Criteria**

Tree-ring analysis and graphics are achieved via a dendrochronological programme suite developed by Ian Tyers of Sheffield University (Tyers 1999). Location maps are produced via - Auto Street Navigator, software produced by ISYS Systems Ltd. which uses Ordnance Survey digital map data © Crown Copyright 1999-2000. Alcock's (1996) timber-framed building nomenclature has been adopted throughout to facilitate regional comparisons.

For the analysis of a building an initial assessment is conducted with the owner and recommendations in line with English Heritage guidelines on sampling strategies made, (i.e., that a minimum of 8 to 10 samples are obtained per building or per phase). However, the final decision for the number of samples taken for analysis rests with the individuals who commission the analysis. Tree-Ring Services aims to follow English Heritage guidelines on methodology in producing and interpreting dendrochronological dates throughout its reports (English Heritage 1998). Part 2 of the Guidelines are designed for large projects in conjunction with other specialist disciplines and are not applicable to the type of privately commissioned dendrochronological analysis generally conducted by Tree-Ring Services and are therefore not used.

It is generally beyond the scope of an analysis to describe a building in detail or to undertake the production of detailed drawings. Without the benefit of other specialist
disciplines there is always the danger that reused timbers can be inadvertently selected, and the conclusions presented in a report may be modified in the light of subsequent work. The photographic record presented in the results section of reports aims to provide a record of the precise location from which each core has been taken: particularly useful in the event of further analysis.

RESULTS

Ten samples were recovered on 29th September 2003. Trusses were labelled alphabetically from north-west to south-east on a sketch diagram of the building, and the coring locations recorded (see Appendix I).

![Photo 5: Core CAKE01](image)
![Photo 6: Cores CAKE02 (right), CAKE03 (middle) & CAKE04 (left)](image)
![Photo 7: Cores CAKE05 (top) & CAKE06 (bottom)](image)

![Photo 8: Cores CAKE07 (bottom) & CAKE08 (top)](image)
![Photo 9: Core CAKE09](image)
![Photo 10: Core CAKE10](image)

Seven of the cores were sampled from where there appeared to be full sapwood, but the sapwood/bark boundary was friable and a number of rings of sapwood were lost in most
instances. Cores CAKE03, CAKE08, CAKE09 and CAKE06a lost 1mm, 2mm, 3mm and 26mm from full sapwood recovery respectively. The end 6mm and 10mm of sapwood from samples CAKE05 and CAKE09 respectively broke and it is possible a ring or so of sapwood was lost at the break; also 9mm of sapwood broke from the end of sample CAKE07 and 3mm of sapwood was lost at the break.

All samples analysed were confirmed during preparation as Oak (Quercus spp). Three samples, CAKE05a, CAKE06a and CAKE10a, contained insufficient number of rings to be considered for further analysis and were therefore rejected at this stage. Statistical matching between remaining sequences suggested that four sequences cross-matched (see Table 1); visual comparison helped confirmed these matches and all four sequences were combined to form a 70-year mean sequence CAPEL-KE. No further reliable intra-site matches were established and therefore the mean sequence CAPEL-KE along with the remaining individual sequences were compared against our database of reference chronologies.

Table 1: Cross-matching between the four sequences.

<table>
<thead>
<tr>
<th>Filenames</th>
<th>Start Date</th>
<th>End Date</th>
<th>cake03</th>
<th>cake04</th>
<th>cake09</th>
</tr>
</thead>
<tbody>
<tr>
<td>cake01</td>
<td>AD1321</td>
<td>AD1383</td>
<td>5.07</td>
<td>3.62</td>
<td>-</td>
</tr>
<tr>
<td>cake03</td>
<td>AD1322</td>
<td>AD1388</td>
<td>3.74</td>
<td>4.22</td>
<td></td>
</tr>
<tr>
<td>cake04</td>
<td>AD1328</td>
<td>AD1377</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cake09</td>
<td>AD1319</td>
<td>AD1378</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

KEY: - = t-values less than 3.50. Note: n = 6, min t = 1.48, max t = 5.07, mean t = 3.33, s.d. = 1.27.

The sequence CAPEL-KE was found to produce consistently high t-values and good visual matches with the first ring of the sequence at AD 1319 and the final ring at AD 1388 (see Table 2).
### Table 2: Dating evidence for site chronology CAPEL-KE against reference chronologies.

<table>
<thead>
<tr>
<th>File</th>
<th>Start Date</th>
<th>End Date</th>
<th>t-value</th>
<th>Overlap (yr.)</th>
<th>Reference chronology</th>
</tr>
</thead>
<tbody>
<tr>
<td>capel-oh</td>
<td>AD1283</td>
<td>AD1373</td>
<td>9.04</td>
<td>55</td>
<td>THE OLD HOUSE - CAPEL - SURREY (Moir 2003d)</td>
</tr>
<tr>
<td>nwdgate1</td>
<td>AD1261</td>
<td>AD1483</td>
<td>7.56</td>
<td>70</td>
<td>HOME FARM - NEWDIGATE - SURREY (Bridge 1998b)</td>
</tr>
<tr>
<td>gentmn</td>
<td>AD1291</td>
<td>AD1464</td>
<td>6.62</td>
<td>70</td>
<td>17 GENTLEMAN’S ROW - ENFIELD - LONDON (Bridge 1997)</td>
</tr>
<tr>
<td>capel-cx</td>
<td>AD1296</td>
<td>AD1402</td>
<td>6.47</td>
<td>70</td>
<td>ST JOHN - CAPEL - SURREY (Moir 2003d)</td>
</tr>
<tr>
<td>wymond1</td>
<td>AD1283</td>
<td>AD1364</td>
<td>6.41</td>
<td>70</td>
<td>PRIORY - LITTLE WYMONDLEY - HERTS (Bridge 2001)</td>
</tr>
<tr>
<td>charl-8</td>
<td>AD1336</td>
<td>AD1554</td>
<td>5.63</td>
<td>70</td>
<td>CHARLWOOD MASTER - SURREY (Moir 2003g)</td>
</tr>
<tr>
<td>mbishgat3</td>
<td>AD1249</td>
<td>AD1403</td>
<td>5.35</td>
<td>70</td>
<td>GT. HOSPITAL - BISHOPGATE - NORWICH-NORFOLK (Bridge 2003)</td>
</tr>
<tr>
<td>ford</td>
<td>AD1286</td>
<td>AD1511</td>
<td>4.98</td>
<td>70</td>
<td>ST ANDREWS CHURCH - FORD - W SUSSEX (Bridge 2000)</td>
</tr>
<tr>
<td>charl-sc*</td>
<td>AD1233</td>
<td>AD1536</td>
<td>4.96</td>
<td>70</td>
<td>SWAN COTTAGE - CHARLWOOD - SURREY (Moir 2003h)</td>
</tr>
<tr>
<td>ockly-w2</td>
<td>AD1273</td>
<td>AD1378</td>
<td>4.79</td>
<td>60</td>
<td>RE-USED - WAYLEYS - OCKLEY - SURREY (Moir 2003e)</td>
</tr>
<tr>
<td>croydon</td>
<td>AD1266</td>
<td>AD1377</td>
<td>4.48</td>
<td>59</td>
<td>CHURCH STREET - CROYDON - G LONDON (Bridge 1998a)</td>
</tr>
<tr>
<td>fieldpb</td>
<td>AD1309</td>
<td>AD1465</td>
<td>4.18</td>
<td>70</td>
<td>FIELDPLACE - NR. BROADBRIDGE HEATH - W. SUSSEX (Bridge 1993)</td>
</tr>
</tbody>
</table>

**KEY:** **Bold** = indicates a composite reference chronology consisting of multiple site chronologies, * = component of the charl-8 chronology.

No further cross matching was established and therefore sequences CAKE02, CAKE07 and CAKE08 remain undated. Calendar dates were assigned to the four component sequences of CAPEL-KE ([Table 1 and Table 3](#)).
Table 3: Summary of Dendrochronological Analysis

<table>
<thead>
<tr>
<th>Sample</th>
<th>Timber and Position</th>
<th>Conversion</th>
<th>Timber Dimensions (mm)</th>
<th>Rings</th>
<th>Sapwood</th>
<th>Average Growth Rate (mm/yr)</th>
<th>Sequence Date Range</th>
<th>Felling Date</th>
<th>End Range</th>
<th>H/S Boundary</th>
<th>Core Sapwood</th>
<th>Pith</th>
<th>Age Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>cake01</td>
<td>Tiebeam - B to B1</td>
<td>A2</td>
<td>250 x 190</td>
<td>63</td>
<td>11</td>
<td>1.88</td>
<td>AD1321-AD1383</td>
<td>AD1383-1413</td>
<td>1383</td>
<td>1372</td>
<td>11</td>
<td>10</td>
<td>80</td>
</tr>
<tr>
<td>cake02</td>
<td>Post C</td>
<td>?</td>
<td>0 x 0</td>
<td>50</td>
<td>16+Bw</td>
<td>2.29</td>
<td>AD1322-AD1385</td>
<td>AD1385-AD1388</td>
<td>1388</td>
<td>1373</td>
<td>15</td>
<td>10</td>
<td>78</td>
</tr>
<tr>
<td>cake03</td>
<td>Tiebeam - C to C1</td>
<td>A2</td>
<td>230 x 240</td>
<td>67</td>
<td>15+1+?B</td>
<td>2.31</td>
<td>AD1322-AD1386</td>
<td>AD1386-AD1388</td>
<td>1389</td>
<td>1373</td>
<td>15</td>
<td>10</td>
<td>78</td>
</tr>
<tr>
<td>cake04</td>
<td>Centre post - C to C1</td>
<td>A2</td>
<td>210 x 210</td>
<td>50</td>
<td>+HS</td>
<td>2.2</td>
<td>AD1328-AD1377</td>
<td>AD1366-AD1418</td>
<td>1377</td>
<td>1377</td>
<td>0</td>
<td>10</td>
<td>78</td>
</tr>
<tr>
<td>cake05</td>
<td>Tiebeam - A to A1</td>
<td>?</td>
<td>220 x 0</td>
<td>28</td>
<td>5+2</td>
<td>4.51</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cake06</td>
<td>Centre post - A to A1</td>
<td>A2</td>
<td>220 x 0</td>
<td>33</td>
<td>1+1</td>
<td>2.61</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cake07</td>
<td>Post A1</td>
<td>A2</td>
<td>0 x 0</td>
<td>43</td>
<td>6+9</td>
<td>2.95</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cake08</td>
<td>Wall plate - A1 to B1</td>
<td>A2</td>
<td>190 x 0</td>
<td>38</td>
<td>8+1</td>
<td>2.83</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cake09</td>
<td>Spine beam [Gnd floor] - A to B</td>
<td>A2</td>
<td>150 x 150</td>
<td>60</td>
<td>10+8</td>
<td>1.67</td>
<td>AD1319-AD1378</td>
<td>AD1366-1409</td>
<td>1378</td>
<td>1366</td>
<td>10</td>
<td>0</td>
<td>68</td>
</tr>
<tr>
<td>cake10</td>
<td>Post A</td>
<td>A2</td>
<td>0 x 0</td>
<td>23</td>
<td>+?HS</td>
<td>4.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**KEY**

- + = additional sapwood information not measured on the core
- ?HS = probably heartwood/sapwood boundary
- HS = heartwood/sapwood boundary
- B = probably bark
- Bw = winter bark
- A2 = boxed heartwood & trimmed
- = sequences used in felling date range

Note: Timber dimensions were generally taken at the core sample location and are not necessarily the maximum dimensions of the timber.
INTERPRETATION AND DISCUSSION

Felling Dates
The sapwood evidence used to calculate the felling dates now discussed is presented in Table 3, and the bar diagram (Figure 3) helps visually demonstrate the findings.

Span of ring sequences

AD1350            AD1400

CAKE01

F CAKE04

C CAKE09

CAKE03

AD1383-1413

AD1386-1418

AD1386-1409

AD1389?

KEY

heartwood

sapwood

unmeasured sapwood

C pith present

F fairly near pith

Figure 3: Bar diagram showing the date interpretations for the sequences dated.

Abrasion of the final ring from full sapwood recovery on sample CAKE03 produces a probable felling date of AD 1389. Felling on this date is closely supported by sample CAKE09 which produces a felling date range of AD1386 to AD1409 and, having lost only 3mm from full sapwood recovery, is therefore likely to have been felled in the earliest part of this range. The two other primary timbers dated produce felling date ranges which are also consistent with an AD1389 felling.

Timber Analysis
All the primary phase timbers are of boxed heartwood conversion. The primary build timbers dated with pith evidence have an average growth rate of 1.92mm per year and an average age of 75 years at the time of felling. The intra-group cross-matching is low (mean $t=3.33$) and variable, but this might be explained by the limited number and sequence length of samples rather than suggesting different source(s) of timber. There are a limited number of reference chronologies in the immediate area which extend to the fourteenth century with which to compare. Nevertheless, high matching ($t=9.04$ and $t=7.56$) with the
Old House in Capel and the Home Farm in Newdigate reference chronologies respectively (see Table 2) provides reasonable evidence that the timbers are of local origin. The age of the trees and the comparatively high growth rate suggests the source was young or open woodland.

**CONCLUSIONS**

The four primary timbers dated are consistent with a single phase of construction. One timber provides a probably felling date of AD 1389, a date reasonably corroborated by a sample that lost only 3mm from full sapwood recovery, and which is additionally entirely consistent with the felling date ranges produced by the two other samples dated. This date is significantly earlier than the early 15th century date estimate made on stylistic grounds and particularly important in view of the scarcity of tiny hall houses.

The problem of sequences containing insufficient numbers of rings due to fast grown source trees felled young is emphasised by the six samples which failed to date. The timbers dated were converted from formative trees with an average age of 75 at the time of felling. The site chronology established matches well ($t=9.04$ and $t=7.56$) with two local reference chronologies, providing reasonable evidence that the timbers are probably of local origin.

The Surrey Dendrochronology Project is producing rare clusters of site chronologies from discrete parish areas. Further dendrochronological analysis of this corpus of data at completion of the project has the potential to help further our understanding of the changing landscape, woodland management techniques and perhaps also to reveal something of the underlying environmental and socio-economic issues which can rarely be addressed when analysing buildings in isolation. Already a clear benefit of the dendrochronological analysis of small clusters of buildings is an overall increase in the success rate of dating sequences. Obtaining replication (repeated good statistical matches over the same period) with several independent reference chronologies is a strict requirement of tree-ring dating. As the number of site chronologies in a particular area increases, generally, the potential to date tree-ring sequences of the same period improves.

A reference chronology called CAPEL-10 is presented in this report (Appendix III) as what may be termed a "master chronology", i.e., constructed by averaging a number of individual site means. The master chronology takes individual reference chronologies a step further by averaging and refining the response of trees to their environment over a particular area, and in effect filtering out individual background noise and focusing the common climatic signal. The CAPEL-10 chronology is produced here as an interim tool to assist further dendrochronological analysis in the area.
ACKNOWLEDGEMENTS

I would like to thank the owners for their permission to conduct the analysis. I am particularly grateful to Rod Wild for his considerable organizational efforts on behalf of the project and for the help of all DBRG (Surrey) members who attended the site. Thanks are also due to the Surrey Dendrochronology Project for commissioning this analysis, and to the funding bodies - the Heritage Lottery Fund and Surrey Archaeological Society - for their generous support. Lastly but by no means least, grateful thanks go to my fellow dendrochronologists who allow their chronologies to be used in dating.

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APPENDIX I: Floor plan for Ketleas

Adapted from the original by J. Shelley (1981)
APPENDIX II: Raw ring-width data

Ring widths (0.01mm), starting with innermost measured ring

Raw data removed from PDF file report

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