An English Tree-Ring Chronology, A.D. 404–1216

By JENNIFER HILLAM

AN 813-YEAR OAK CHRONOLOGY, A.D. 404–1216, is presented. Its construction has taken three years because of the difficulty of finding suitable Saxon timbers and the need to test the reliability of the dating. Although based on only a few timbers for the period c. A.D. 700, it can be used to date Saxon and medieval timbers whilst more material is found to consolidate that section of the chronology.

Tree-ring analysis relies upon the availability of reference curves by which to date wood samples of unknown age. Without these dated chronologies, absolute dating is not possible. Until recently, no British tree-ring chronology extended back earlier than c. A.D. 800.¹ This paper describes the work at the University of Sheffield Dendrochronology Laboratory where analysis of timbers from various archaeological sites has allowed an English tree-ring chronology to be constructed for the period A.D. 404–1216. Such a chronology will form the basic framework for dating wood samples from Saxon and medieval sites and may in future provide a link with Roman tree-ring curves² which are presently dated only by radiocarbon or by associated material.

**DENDROCHRONOLOGY IN THE BRITISH ISLES**

Oak (*Quercus*) is the wood species used almost exclusively for dating purposes in the British Isles. It is long-lived by comparison with other British trees, but was often felled before reaching maturity. Samples examined for tree-ring analysis normally have less than 300 annual growth rings and more usually contain between 50 and 150 rings. The construction of tree-ring chronologies is therefore laborious work. In addition, there are some decades, and even some centuries, for which few samples have yet become available, making the production of continuous curves more difficult. In Ireland, Dr M. G. L. Baillie found that timbers with rings spanning the 14th and 17th centuries were in short supply.³ A similar situation existed for Scotland until recently⁴ and is still causing problems for English tree-ring dating (Fig. 1). In Ireland and Scotland, the problems were partly overcome by examining many timbers, beginning with samples from modern trees and searching for progressively older ones. Nevertheless, no curves extend back before c. A.D. 850. In England, numerous reference curves of 200–400 years in length have been published,⁵ again with none older than c. A.D. 800 (Fig. 1). As in Ireland and Scotland, there was a
shortage of timber for the earlier Saxon period. Apart from the wood from the Old Windsor and Portchester excavations (Fig. 2), which was used by Dr. J. M. Fletcher to construct a floating chronology of 322 years, very little material was available. Absolute dating, therefore, was only possible for the period from c. A.D. 800 to the present day.

The Department of the Environment Dendrochronology Laboratory in Sheffield was established in 1975 primarily to process timbers found on archaeological sites. Samples of different periods and from all areas of England pass through the laboratory for tree-ring analysis. Saxon timbers from excavations in London and Essex have now made it possible to date the Old Windsor-Portchester sequence and so to produce the curve presented in this article. The chronology is not final; for certain periods, particularly around A.D. 700, it is represented by only a few timbers. (This situation was somewhat improved by the inclusion of data from the Tamworth horizontal mill, A.D. 404–825, which was kindly supplied by Dr. Baillie.) These portions of the curve need strengthening by the addition of more timbers, but a chronology of English origin now exists which can be used to date Saxon as well as medieval timbers. It will thus be possible to offer accurate tree-ring dates for this period of the kind available to archaeologists on the Continent for such sites as Hedeby in Germany or Dorestad in Holland.
TREE-RING DATING

The only criterion used to establish the contemporaneity of the timbers was the similarity of the ring patterns present within those timbers. This was done by the visual crossmatching of the ring-width patterns, although a computer program was also used to save time and to provide a quantitative value for the quality of the crossmatching. The final decision as to the acceptance of a match between two curves was always taken by examining the visual agreement. Radiocarbon dating was used to give a rough guide to the date of timbers where no archaeological evidence was available. Radiocarbon has not been used to ascertain that two timbers were contemporary, the approach applied without success to the dating of the Old Windsor and Portchester timbers. Each site was considered separately. The ring widths of the timbers were measured and where several ring patterns were found to be similar, a site master curve was produced. Crossmatching of the individual curves was done using the unaltered ring-width data in mm. When as many curves as possible had been synchronized, the widths were converted to index values as suggested by Baillie. A chronology of index values was then constructed by taking a mean through the matching curves. A computer program is available for these processes.

Although dendrochronology is a very simple technique in theory, in practice it is not so easy. The construction of a chronology such as that presented here involves a great deal of work. It is beyond the scope of this paper to describe the step by step progress which resulted in the published chronology. Instead, a summary of the major steps in the chronology building is given. The chronology was originally constructed as two sequences: Period I, A.D. 682–1216, and Period II, A.D. 416–737. Whilst there was reliable crossmatching between the two sequences, it was considered more valid to present them as two separate chronologies until the section around A.D. 700 could be consolidated by the inclusion of more curves (Figs. 3, 4). However, with the Tamworth data provided by Baillie, which covers the period A.D. 404–825, the chronology can now be presented as a continuous sequence. The work is still described in two sections: Period I, A.D. 682–1216, and Period II, which, with the inclusion of Tamworth, now becomes A.D. 404–825. The table giving the multi-site master data and the individual site master curves are not given here but they can be found published elsewhere or obtained from the author.

PERIOD I, A.D. 682–1216

Exeter

In 1972, a rescue excavation by Mr C. Henderson at Trichay Street in Exeter’s city centre (Fig. 2) provided many waterlogged timbers of Roman, medieval and post-medieval age. They were examined at Sheffield in 1976, the medieval timbers proving most suitable for dendrochronological work. They were mostly radially-split planks containing 100–250 rings, more than is usually found in English archaeological timbers. Thirteen tree-ring curves were crossmatched to produce the 406-year master. This was further extended to 418 years by the addition of a timber excavated from the site of the medieval Exe Bridge.
Archaeological evidence from associated finds had suggested that the timbers dated to the 10th/12th centuries. The Exeter master curve was therefore tested against other European reference chronologies of this period. It showed a high degree of similarity with the Dublin sequence for the period A.D. 799–1216. The Student’s t-value for the correlation between the two chronologies is 13.12. This is of high statistical significance and suggests that the trees, of which the ring patterns were so similar, had grown under almost identical conditions in the Dublin and Exeter areas.

York

Three timbers from the Anglo-Danish excavations at Lloyd’s Bank in York were examined by Mrs R. A. Morgan at the Sheffield laboratory. The ring patterns of the three timbers were so similar that it was postulated that they came from the same tree. The mean curve was dated in 1977 by the author in the Oxford laboratory. It showed good agreement with a chronology from Schleswig-Holstein in Germany.
Later it was also found to match well with sequences from Exeter and London. These agreements dated the curve to A.D. 778–946. It was published by Fletcher as part of his REF 6 chronology. It is in the present chronology in order to make it more representative for the whole of England.

London

Rescue excavations carried out by the staff of the Museum of London's Department of Urban Archaeology have produced waterlogged timbers from many sites in the City, particularly along the Thames waterfront where much redevelopment is taking place. Several tree-ring chronologies have been constructed for the Roman and medieval periods. However, relatively few timbers of Saxon age have been found. The site which proved to be of prime importance to English and Irish dendrochronology was to the W. of the City, at Tudor Street, excavated in 1978. Several timbers were uncovered which could only be dated approximately by associated finds. One of these, TUD 574, was a radially-split plank with 237 rings. It was dated to A.D. 682–918 by comparison with the Exeter and Dublin chronologies \( t = 4.00 \) and 3.91 respectively. This timber's importance must again be stressed since it is the only English tree-ring curve to extend back before c. A.D. 770 and so at present provides the only link with the earlier Saxon material (see below).

Other timbers from the 1975 and 1978 excavations at New Fresh Wharf, another waterfront site, crossmatched with the Tudor Street curve (Fig. 3). SM 183, measured by Morgan, from the 1975 excavation, dated to A.D. 767–932, whilst FRE 592 and FRE 3005 from the 1978 excavation dated to A.D. 835–961 and A.D. 869–968 respectively.

The cross-agreement values between the three site master curves are: Exeter/York \( t = 3.50 \), Exeter/London \( t = 4.85 \) and York/London \( t = 4.73 \). The tree-ring sequences from the three cities give a total chronology of 535 years, which spans the period A.D. 682–1216 (Table 1).

**Table 1**

**Summary of the site master curves which make up the 813-year chronology**

<table>
<thead>
<tr>
<th>Chronology</th>
<th>Site</th>
<th>No. of timbers</th>
<th>Date (A.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Period I</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exeter</td>
<td>Exe Bridge</td>
<td>1</td>
<td>799–941</td>
</tr>
<tr>
<td></td>
<td>Trichay Street</td>
<td>13</td>
<td>811–1216</td>
</tr>
<tr>
<td>London</td>
<td>New Fresh Wharf</td>
<td>3</td>
<td>767–968</td>
</tr>
<tr>
<td></td>
<td>Tudor Street</td>
<td>1</td>
<td>682–918</td>
</tr>
<tr>
<td>York</td>
<td>Lloyd's Bank</td>
<td>3</td>
<td>778–956</td>
</tr>
<tr>
<td><strong>Period II</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mersea</td>
<td>Mersea Strood</td>
<td>3</td>
<td>445–661</td>
</tr>
<tr>
<td>Odell</td>
<td>Odell wells</td>
<td>6</td>
<td>473–623</td>
</tr>
<tr>
<td>REF 8</td>
<td>Old Windsor mill</td>
<td>5</td>
<td>416–737</td>
</tr>
<tr>
<td></td>
<td>Portchester well</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Tamworth</td>
<td>Tamworth mill</td>
<td>9</td>
<td>404–825</td>
</tr>
</tbody>
</table>
OLD WINDSOR/PORTCHESTER

The tree-rings from the timbers of these two sites (Fig. 2) were published by Fletcher in the form of a floating curve, REF 8. The sequence is made up of five timbers from Old Windsor and nine from Portchester, the Old Windsor timbers being older than those from Portchester. Fletcher suggested that it dated to c. A.D. 500–800 on the basis of some tentative cross-dating and the radiocarbon dates from Old Windsor. Dr D. J. Schove has given several dates for the first year of the Old Windsor sequence, and hence of the REF 8 sequence, A.D. 490 being the result stated in his latest publication.

The importance of REF 8 is that it provides valuable data for a period in which timber remains are scarce in England. It was to form an important link with the Period I chronology described above.
Mersea Island

Mersea Island (Fig. 2) is connected to the Essex mainland by an artificial causeway, known as the Strood. A section of the causeway was excavated by the Colchester Archaeological Trust in 1978. Many oak timbers, which had served as foundation piles for the causeway, were uncovered. Because of the extensive Roman remains found on the island, a Roman date was originally postulated for the Strood.\textsuperscript{28} Five samples were taken from the piles for tree-ring analysis. Three of these, two from the same tree, crossmatched to give a site master curve of 217 years (Fig. 4). Because this master did not crossdate with other Roman chronologies, a sample of wood was submitted for radiocarbon dating. The result was surprising in that it indicated that the piles were of Saxon origin (HAR–3369: a.d. 530 ± 70). Thus, an unexpected source of early Saxon timber was found.

Odell

Excavations at Odell in Bedfordshire (Fig. 2) during 1974–78, revealed several pits of Saxon age, some of which contained oak timbers.\textsuperscript{24} These were dated by radiocarbon to the 5th/7th centuries (for example, HAR–1428: a.d. 560 ± 70; HAR–3629: a.d. 450 ± 80). The wood samples were small in cross-section and contained only 30–100 rings. However, in spite of their short ring patterns, it was possible to crossmatch some of the tree-ring curves and produce a master curve of 151 years (Fig. 4).

Tamworth

The Tamworth chronology was constructed by Baillie in 1980 and is made up from timbers excavated from the horizontal mill at Tamworth (Fig. 2).\textsuperscript{25} The mill
was provisionally dated by radiocarbon to the late 8th century, but dendrochronology provided a more accurate date when the 422-year tree-ring sequence was dated to A.D. 404–825. The data are included here to consolidate the English chronology over the period c. A.D. 700.

**Dating the Period II material**

Radiocarbon dating and archaeological evidence indicated that the Period II chronologies should crossdate with each other. This proved to be true, with good visual matching between the master curves (Fig. 5). The Mersea and REF 8 sequences matched particularly well, the agreement producing a t-value of 8.36 (Table 2). It was therefore possible to construct a single chronology of 322 years, Tamworth not being included until later.

There were two methods available to achieve absolute dating: firstly, to crossdate the younger end of REF 8 with the older end of the Period I chronology and secondly, to crossdate the Period II sequences with dated reference chronologies from Ireland and Germany. Both were attempted so as to obtain reliable results.

The computer comparison between REF 8 and the Tudor Street curve gave a t-value of 3.80 when the rings of REF 8 were equal to A.D. 416–737. The visual match was good but the overlap between the two curves was only 57 years (Fig. 6). Although the t-value was acceptable at the P<0.001 significance level, it was felt that, because of the shortness of the overlap, further proof was necessary before the crossdating could be accepted.

In Ireland, there were several unpublished tree-ring sequences covering parts of the first millennium A.D. Research of a similar nature to that at Sheffield was being carried out in the Belfast laboratory in order to date these chronologies. In 1980, data were exchanged between the two laboratories and a combined effort was made to provide absolute dating for both England and Ireland. Links, which tentatively dated the Irish chronology, were found between the Tudor Street, London curve and a sequence from Ballydowane in Co. Waterford (t = 4.87). A similar link was then found between Ballydowane and REF 8 (t = 3.46). This tentative crossmatching, Tudor Street-Ballydowane-REF 8, again indicated that REF 8 covered the period A.D. 416–737.

As a third check, two unpublished German chronologies were available with which to compare the English material. The first, constructed by Professor D. Eckstein at Hamburg, was made up from timbers found in the Schleswig-Holstein region of N. Germany, including many timbers from the Hedeby excavations. The second chronology was produced by Dr B. Becker of Stuttgart and consists of data from sub-fossil oak timbers found in the Danube valley in S. Germany. When the REF 8, Mersea and Odell sequences were compared with these, the Mersea curve gave t-values of 4.78 and 4.88 with the Schleswig and Danube chronologies respectively (Table 2). REF 8 also agreed with the Danube curve, t = 3.67. These results confirmed the dating of REF 8 as A.D. 416–737; the dates for Mersea and Odell are set out in Table 1.

Later in 1980, Baillie’s Tamworth chronology was crossdated with the existing English and Irish sequences, thus providing additional evidence for the dating
FIG. 5
Matching tree-ring curves: comparison of the four Period II chronologies for the period A.D. 490-580.

MERSEA  TAMEWORTH  REF 8  ODELL

2.0  1.0  0.6

1.5  1.0  0.6

3.0  2.0  1.0

580 years A.D.

490  500  510  520  530  540  550  560  570  580

years

All
<table>
<thead>
<tr>
<th></th>
<th>A. ENGLAND</th>
<th>B. GERMANY</th>
<th>C. IRELAND</th>
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<tr>
<td></td>
<td>Mersea</td>
<td>Odell</td>
<td>REF 8</td>
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<tr>
<td>Mersea</td>
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<td>4.2</td>
<td>8.4</td>
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<td>Odell</td>
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<td>5.9</td>
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<tr>
<td>REF 8</td>
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<tr>
<td>Tamworth</td>
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<td>Tudor St</td>
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</table>

TABLE 2
CROSSDATING OF THE PERIOD II CHRONOLOGIES:
SUMMARY OF T-VALUES
The 57-year overlap between REF 8 (a) and Tudor Street (b). The agreement between them gives a t-value of 3.80.

APPLICATIONS OF THE CHRONOLOGY

The tree-ring dates given here are absolutely reliable, although their accuracy in relation to the date of construction varies, depending on how close the date of the timber's outer ring is to the felling date of the tree and hence to the construction date. This relates to the amount of wood removed during the conversion of the timber into a beam or plank, and to the quantity of sapwood present. In spite of this problem of interpretation, reasonably accurate construction dates can still be quoted, although the possibility that a timber has been re-used must also be considered. For Period I, the dating of the London samples indicated that the Tudor Street timber had formed part of a late Saxon structure which was built some time after A.D. 941. Sample 3005 from New Fresh Wharf, a revetment timber, has a felling date after A.D. 981, whilst 592, from the same site, was felled after A.D. 984. The archaeological context of the latter had indicated an 11th- or 12th-century date, which suggests that, although it was felled in the late 10th century, it was later re-used in the medieval period. In York, the Anglo-Danish timber from the Lloyd's Bank site was felled in A.D. 982 ± 9. The fourteen timbers from Exeter had felling dates...
in the 10th–13th centuries. All these felling dates, with the exception of the re-used timber from New Fresh Wharf, are likely to be close to the construction dates since timber was not seasoned until very recently, unless it was to be used for furniture or panelling.

Absolute dates can at last be given for Old Windsor and Portchester, about which there has been so much debate. The timber-framed well at Portchester was constructed c. A.D. 740. This accuracy is possible because one of the planks retained almost its full complement of sapwood rings. Other timbers were known to be replacement planks; the trees for these were probably felled 10–20 years after those used for the original structure and so must have been added to the well in c. A.D. 750–60.

An accurate date for the construction of the Old Windsor mill cannot be given here since it is not known whether sapwood was present on any of the timbers. However, it must have been built during the mid or late 7th century. Also of late 7th-century date is the causeway across to Mersea Island; the Strood’s foundations were laid down in A.D. 693 ± 9. Here, the use of scientific dating methods—radiocarbon analysis, to give a rough idea of the date, and dendrochronology, for the accurate absolute date—produced results entirely unexpected, which were unobtainable from the evidence otherwise available to the archaeologists.

The interpretation of the tree-ring results for Odell was difficult because none of the matching timbers contained sapwood. A terminus post quem for the construction of four of the wells was estimated. The results supplemented the radiocarbon dates and assigned the wells to the 6th and 7th centuries.

The Saxon chronology increases the chances of obtaining absolute dates for the Roman period. Several floating Roman tree-ring sequences have been constructed, particularly for the London area. These are dated by radiocarbon and associated finds to c. 140 B.C.–A.D. 230. Thus only about 150 years separate the Roman curves from the dated Saxon chronology. If the latter could be extended back in time by 250 years, crossdating with the Roman material should be possible. Alternatively, since suitable timbers of 5th-century date may prove difficult to find, the Roman chronologies may in time crossdate with Irish sequences. As a consequence of the absolute dating described above, there is now a dated Irish chronology covering the period 12 B.C.–A.D. 894. It may be useful for dating English curves from the Roman period.

It is hoped that the A.D. 404–1216 chronology can be used to date timbers from all over England. It is made up of tree-ring data from various regions of the country (Fig. 2), some highland areas and others lowland areas. There were no difficulties in crossdating their ring patterns, such as those experienced by Fletcher when trying to crossmatch ‘highland’ and ‘lowland’ timbers. Individual sites may still present problems: wood samples from the Coppergate excavations in York have produced few positive results, yet the Lloyd’s Bank timber was easily dated. Carlisle must be regarded as a ‘highland’ site, as opposed to the lowland York, but the Roman timbers are proving impossible to crossmatch. These sites are probably the exceptions rather than the general rule. As more and more timbers are analysed, the less the difference seems to be between highland and lowland regions of the British Isles, in relation to
tree growth. In addition, good crossdating was found between the English sequences which make up the 813-year chronology, and also between them and curves from Ireland and the Continent. This indicates that the chronology can be applied over a wide geographical area.

CONCLUSION

The establishment of a firm chronology gives absolute dates for a major period of English archaeology. Even with relatively few timbers, the curve is made up of data from different parts of the country. This, plus the high agreements between the English sequence and curves from Ireland and Germany, indicates that the chronology will be of use for dating wood samples from all over England. Apart from providing absolute dates for the 5th/13th centuries, it may also form the basis for the production of a continuous English tree-ring chronology covering the last 2000 years.

ACKNOWLEDGEMENTS

I am grateful to Dr Becker and Prof Eckstein for making available their Danube and Schleswig-Holstein curves prior to publication, and to Mrs Morgan for allowing some of her data to be included in the chronology. The Tamworth data were supplied by Dr Baillie, whose co-operation was most helpful during the chronology’s construction. Finally, I would like to thank the Department of the Environment for financing the work.

NOTES

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20 Fletcher, op. cit. in note 1.


25 Ibid.

26 Baillie, op. cit. in note 3; Baillie, op. cit. in note 25.

27 A third chronology has recently been published for the Rhine area of Germany: E. Hollstein, *Mittel­europäische Eichenchronologie* (Mainz am Rhein, 1980). This also cross-matches with Mersea, $t = 4.06$, and Tamworth, $t = 3.77$.


29 Details are given in Hillam, op. cit. in note 13.


31 Ibid., 274–75.

32 Hillam and Morgan, op. cit. in note 18.


34 For example: Fletcher, op. cit. in note 1; Schove, op. cit. in note 22.

35 For example: J. M. Fletcher, 'Oak chronologies for eastern and southern England: principles for their construction and application: their comparison with others in north-west Europe', in Fletcher (ed.), op. cit. note 2, 139–56.


The Society acknowledges with gratitude a publication grant for this paper received from the Department of the Environment.