A MEDIEVAL OAK TREE-RING CHRONOLOGY FROM SOUTHWEST ENGLAND

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ABSTRACT

Extensive rescue excavations in Exeter during 1972 produced large quantities of waterlogged oak timbers. These were used to construct a tree-ring chronology for the period A.D. 799-1216. The chronology crossmatches well with tree-ring sequences from other areas of the British Isles. It will thus form an important building block in the construction of a long English tree-ring curve which can be used to date archaeological timbers from most regions of Britain.

Des fouilles de sauvetage étendues réalisées en 1972 à EXETER, ont fourni de grandes quantités de poutres de chêne. Celles-ci ont été utilisées pour construire une chronologie s'étendant de 799 à 1216 A.D. Cette chronologie se synchronise bien avec les séquences obtenues dans d'autres régions des Iles Britanniques. Elle forme donc un ensemble important pour la construction d'une longue courbe dendrochronologique anglaise qui peut être utilisée pour dater les bois archéologiques de la plupart des régions de Grande-Bretagne.

Umfangreiche Rettungsgrabungen in Exeter im Jahre 1972 haben große Mengen an Eichenhölzern zu Tage gefördert. Sie dienten dem Aufbau einer Jahrringchronologie für die Zeit von 799 bis 1216 n.Chr. Die Chronologie zeigt eine hohe Ähnlichkeit mit Chronologien von anderen Regionen der britischen Inseln. Sie stellt somit einen wichtigen Baustein für den Aufbau einer langen englischen Jahrringkurve dar, die zur Datierung archäologischer Hözer aus den meisten Gegenden Großbritaniens eingesetzt werden kann.

INTRODUCTION

Dendrochronological research in the British Isles began in earnest in the late 1960s, when the use of tree-ring dating in this country was still in question because of Britain's very temperate climate. The doubts fortunately proved to be without foundation and the 1970s saw the production of many tree-ring chronologies of varying length from different regions of Britain. Some were constructed from modern samples with dendroclimatological research in mind (Leggett et al. 1978), others were used for the dating of archaeological timbers (Hillam 1979b) or art-historical objects (Fletcher 1977) and, in Ireland, long prehistoric sequences, produced from the examination of sub-fossil 'bog' oaks, were used primarily for the calibration of the radiocarbon timescale (Pilcher et al. 1977).

The production of these British chronologies have presented many problems. Progress was slow because, unlike many parts of the world, Britain has no trees which attain very great ages. Oak (*Quercus* sp.), the species used almost exclusively in British dendrochronology, rarely lives longer than 300 years and, in the past, it was normally felled at a much younger age. Thus, the construction of long tree-ring sequences is painstaking work involving the piecing together of short ring patterns, often with only 50-100 rings. Attempts at producing regional chronologies for the last 2000 years have been made more difficult by the scarcity of available timber whose rings cover certain periods, such as the 14th and 17th centuries (Baillie 1977a). Nor is it yet known how many regional reference curves will be needed to provide a dating framework for timbers from the whole of the British Isles, although it now seems possible that, despite regional variations in climate, fewer tree-ring sequences will be required than originally thought (Baillie 1978). This has been confirmed by the work outlined below.

Recent research tended to suggest that there was some difference between tree-ring curves from sites in the 'highland' zone and those in the 'lowland' zone, no doubt due to the distinct climatic and topographical features of the two areas. Sequences from northwest of the line in Figure 1 crossmatch well with each other, whilst southeast of

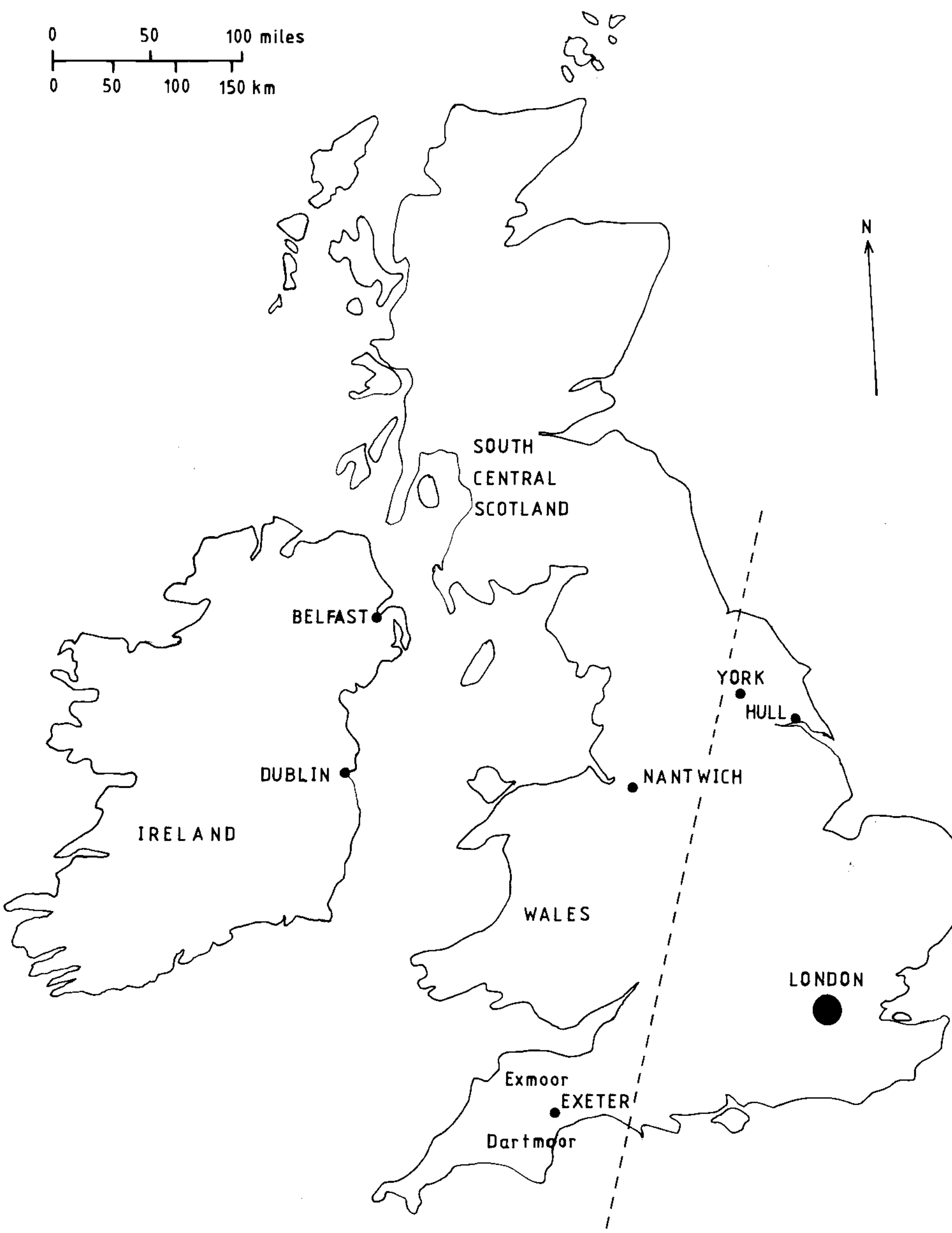

Figure 1. Map of the British Isles showing the location of Exeter and other sites mentioned in the text. The dotted line represents an arbitrary division between the 'highland' and 'lowland' areas, the latter being to the southeast of the line.

the line, considerable difficulty is often experienced in crossmatching timbers from a single site (Hillam and Ryder 1980). No evidence has been found, however, for the existence of distinct growth types for oak, dependent on differences in average ring widths (Fletcher 1977). Nor does it seem likely that chronologies from the 'highland' and 'lowland' areas will be so different in character as to make crossdating between them impossible, as suggested by Fletcher (1978). It has merely been noted that timbers from some 'lowland' regions show little or no similarity in ring pattern. Thus, out of the 95 samples so far examined from the Coppergate excavations at York, only 12 have been crossmatched to form a mean curve. This difficulty in dating 'lowland' samples may be partly due to the fact that less research has been carried out in this area; hence there are few suitable reference chronologies.

The Sheffield dendrochronology laboratory was established by the Department of the Environment in 1975; the tree-ring work is closely linked with rescue archaeology in England and concentrates on dating timbers from archaeological sites threatened by redevelopment. Thus, the construction of long tree-ring chronologies from a single area, such as that produced for the north of Ireland (Baillie 1977a), is out of the question. The principal aim, therefore, is to provide a dating service for archaeologists and, at the same time, produce reference curves for areas of England where no tree-ring work has previously been undertaken. By crossdating these sequences, it will eventually be possible to provide an absolute chronology extending from modern times back to the beginning of the Roman period.

Until 1977, southwest England was a region where there had been no dendrochronological work. However, extensive rescue excavations during 1972, on a site threatened by the proposed construction of a new shopping precinct in Exeter's city centre, offered an opportunity to explore the tree-ring potential of this part of Britain (Figure 1). Its climate overall is the mildest and most equable in the country but it can vary widely throughout the region: for example, parts of Dartmoor have up to 82 inches of rain each year compared with 31 inches in Exeter. Thus, it was not known whether a chronology from the Exeter area would be similar to curves from other upland regions or be more akin to those from southeast England or, indeed, whether it would be unique to that part of the British Isles.

THE TIMBER

Most of the wood samples came from the excavation in Trichay Street, a medieval street which ceased to be used in 1350 when the construction of a parish rectory blocked its entry at one end. The waterlogged timbers were found in pits scattered throughout the site. Although oak timbers of Roman, medieval and post-medieval date were examined at Sheffield during 1977, only the medieval samples proved useful in the construction of a tree-ring chronology; those of Roman and post-medieval age had few rings, being taken for the most part from fast-grown trees. The medieval timbers were mainly radially-split planks, containing between 100 and 300 rings, which had originally been used for the construction of buildings. This paper is primarily concerned with the importance of these timbers in the production of a reference curve for southwest England; further details of the tree-ring work with respect to the archaeology of the site can be found elsewhere (Hillam, in press).

The other site relevant to this chronology was that at and around the medieval Exe Bridge. The date of its construction is documented as late 12th-early 13th century

(Hoskins 1960), but part of the bridge can still be seen in Exeter today. Of the several timbers from the bridge's foundations, only one was suitable for dendrochronology. As it dated to the late 10th century, it must have been re-used, either from an earlier wooden bridge or from another building.

THE CHRONOLOGY

Slices of the waterlogged oak timbers were deep-frozen to give a firmer cross-section on which to work. They were planed so that the individual annual rings could be readily identified. The apparatus used for measuring the ring widths consists of a low-power binocular microscope over a travelling stage; the latter is connected by a linear transducer to a display panel which shows the ring width measurements in 0.1mm. The raw data were plotted on transparent semi-logarithmic recorder paper and the resulting tree-ring graphs compared together visually and by computer. Whilst it was the quality of the visual match that decided whether or not the cross-matching was acceptable, the Belfast CROS computer program (Baillie and Pilcher 1973) was used extensively to save time and to give some statistical meaning to the quality of the matches.

Similarities between the individual curves from Trichay Street were relatively easy to find in comparison to some English sites, such as the timbers from the Viking and late medieval levels at Coppergate, York, mentioned above. Originally two sub-masters were formed; these were linked together by tentative matches (Figure 2). Computer comparisons with dated reference chronologies showed up an exceptionally high correlation between Exeter and Dublin (Baillie 1977b), which confirmed this link and dated the Exeter curve to A.D. 811-1216. A working master was produced by averaging the ring widths of the matching ring patterns. The Student's t values, calculated by the Belfast computer program, between it and various sequences throughout the British Isles are set out in Table 1; values greater than 3.5 are statistically significant at the $P<0.001$ level (Baillie 1978). The agreement of $t = 13.12$ between Exeter and

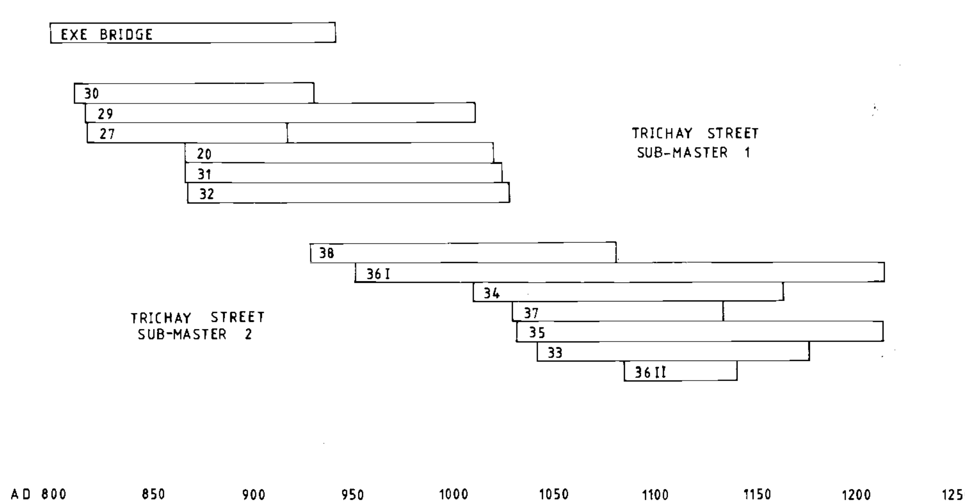

Figure 2. Block diagram showing the years spanned by each sample in the Exeter chronology.

Table 1. Comparison of the Exeter chronology with other sequences from the British Isles and Germany.

CHRONOLOGY	*t*-value
Dublin (Baillie 1977b)	13.12
Germany, Munich (Huber and Giertz-Siebenlist 1969)	2.01
Germany, Trier (Hollstein 1965)	2.08
Hull, Chapel Lane (Hillam 1979)	0.76
London, REF 6 (Fletcher 1977)	4.88
Nantwich (Leggett, pers. comm.)	2.94
Northern Ireland (Baillie 1977a)	6.49
South central Scotland (Baillie 1977c)	5.24
York, Coppergate (Hillam, unpublished data)	0.50
York, Lloyd's Bank (Morgan, pers. comm.)	3.50

Dublin is unusually high; it is reflected in the visual comparison, which shows very close similarity (Figure 3) for sites separated by a distance of ca. 350 km. The t-values for Exeter individual samples compared to the Dublin master range from 2.61 to 9.98 and are as high as between the Exeter individuals themselves. This at first suggested that the Exeter timber was of Irish origin but there is no archaeological evidence to support this theory, nor is it likely that timber was imported continuously over several hundred years as the results would necessitate. Instead, it seems more logical that the trees were growing, separated by the Irish Sea, under almost identical conditions and responding to the same climatic signals.

Apart from this spectacular agreement, the Exeter curve also correlates well with chronologies from Northern Ireland (Baillie 1977a), southern Scotland (Figure 3; Baillie 1977c) and the London area (REF 6 in Fletcher 1977). Comparison of Exeter with the Nantwich sequence (Leggett, pers. comm.) gives a t-value of only 2.94, but examination of the visual crossmatching indicated that the level of agreement between the two curves varied throughout the period of overlap. For the period A.D. 930-1060, there was a value of $t = 0.85$, but for the period A.D. 1061-1216, the t-value was as high as 4.55. Thus, trees growing in different regions responded to the same limiting factors in some centuries but not in others.

Although it shows poor agreement with some places, particularly those sites in the 'lowland' zone (eg. Chapel Lane, Hull, and Coppergate, York), the similarities between Exeter and other sites illustrate the potential of the Exeter curve as a tool for dating archaeological samples over large areas of the British Isles. The fact that there are significant t-values between Exeter and London and between Exeter and the sequence obtained from the Lloyd's Bank excavation in York (Morgan, pers. comm.) indicates that the difference between tree growth in 'highland' and 'lowland' areas might not be as great as first thought, although there will always be sites, such as Coppergate, York, that prove difficult.

The Exeter working master was further extended when the Exe Bridge timber was dated to A.D. 799-941 (Figure 2). After it was ascertained that no more samples could be included, this curve, plus the 13 dated Trichay sequences, was standardized using the INDXA computer package with a polynomial curve-fit option (Fritts et al. 1969).

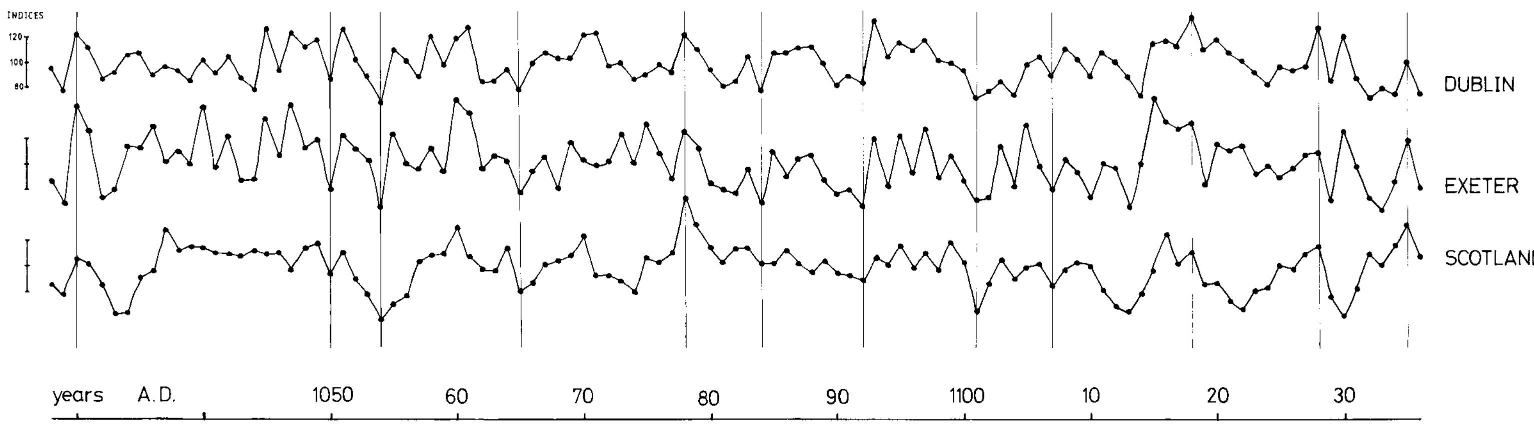

Figure 3. Comparison of the Exeter index chronology with the Dublin and Scotland index chronologies for the period A.D. 1028-1136.

A chronology of index values, covering the period A.D. 799-1216, was then produced (Table 2).

CONCLUSION

The 418-year Exeter chronology given here has already provided accurate archaeological dating for two sites in the city. It is now proving invaluable as a reference curve by which to date other Exeter timbers, such as those from Goldsmith Street (Morgan, pers. comm.). Furthermore, it is another building block, the most substantial yet in English dendrochronology, in the construction of an absolute tree-ring chronology for England going back to Roman times. As such, it has recently been used to date a group of tree-ring sequences from London; these span the period A.D. 682-968 and, in turn, will form the basis for crossdating timbers from earlier Saxon times.

Of wider significance is the successful correlation of Exeter with other regional reference curves, which confirms earlier suggestions that master chronologies, at least, can be synchronised over long distances (Baillie 1977c), particularly throughout Ireland and the 'highland' area of Britain (Hillam and Ryder 1980). Thus, the construction of independent 2000 year chronologies from each area of the British Isles seems to be unnecessary. Instead, shorter sequences from different parts of the country can be linked together to form a general British chronology. The problems encountered with some sites in the 'lowland' region, such as York, indicate that here tree growth may be more complex. However, in this respect, the links between Exeter and timbers from Lloyd's Bank, York, and from London are encouraging. This is especially so as, a little over a decade earlier, it was considered that the climate of the British Isles was such as to make the use of dendrochronology impossible.

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Table 2. Exeter oak chronology, A.D. 799 to 1216.

	Tree Ring Indices										Number of Samples									
Year	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
799										145										1
800	135	102	155	133	88	112	78	72	67	105	1	1	1	1	1	1	1	1	1	1
810	87	108	113	115	96	104	99	87	128	92	1	2	2	2	2	2	3	4	4	4
820	82	119	134	117	121	81	114	84	84	73	4	4	4	4	4	4	4	4	4	4
830	55	63	76	89	85	86	72	137	79	123	4	4	4	4	4	4	4	4	4	4
840	104	86	93	87	86	108	70	91	81	77	4	4	4	4	4	4	4	4	4	4
850	80	76	141	127	117	119	110	99	117	141	4	4	4	4	4	4	4	4	4	4
860	130	89	117	117	97	112	133	116	94	140	4	4	4	4	4	4	6	7	7	7
870	117	90	94	74	75	86	124	108	78	108	7	7	7	7	7	7	7	7	7	7
880	139	142	111	150	132	107	122	102	97	101	7	7	7	7	7	7	7	7	7	7
890	102	113	110	113	96	120	106	74	62	87	7	7	7	7	7	7	7	7	7	7
900	124	71	91	101	90	89	110	105	84	83	7	7	7	7	7	7	7	7	7	7
910	84	88	103	93	75	55	56	111	90	88	7	6	6	6	6	6	6	6	5	5
920	73	73	78	95	93	115	84	114	87	110	5	5	5	5	5	5	5	5	5	6
930	107	85	81	74	105	72	107	114	108	90	6	6	6	6	6	6	6	6	6	6
940	96	116	89	96	128	111	134	104	123	86	6	6	5	5	5	5	5	5	5	5
950	118	86	95	111	117	110	75	100	95	77	5	5	6	6	6	6	6	6	6	6
960	101	95	79	102	75	67	81	78	100	95	6	6	6	6	6	6	6	6	6	6
970	124	114	107	62	63	101	102	128	91	125	6	6	6	6	6	6	6	6	6	6
980	117	79	117	112	68	91	96	97	90	105	6	6	6	6	6	6	6	6	6	6
990	85	118	95	107	115	100	98	122	126	141	6	6	6	6	6	6	6	6	6	6
1000	118	108	128	112	97	118	110	100	90	77	6	6	6	6	6	6	6	6	6	6
1010	88	81	55	60	73	85	97	100	102	87	6	6	5	5	5	5	5	5	5	5
1020	95	106	95	91	98	104	104	92	88	70	5	4	4	4	4	3	3	3	3	2
1030	146	128	74	80	114	113	130	103	110	101	3	3	4	4	4	4	4	4	4	4

Table 2, continued.

	Tree Ring Indices										Number of Samples									
Year	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1040	145	98	122	88	89	136	108	148	114	120	4	4	5	5	5	5	5	5	5	5
1050	81	123	112	104	67	125	101	98	113	95	5	5	5	5	5	5	5	5	5	5
1060	151	141	97	107	104	78	95	106	82	117	6	6	6	6	6	6	6	6	6	6
1070	104	101	103	124	103	133	109	89	126	113	6	6	6	6	6	6	6	6	6	6
1080	86	81	78	96	71	110	91	105	108	89	6	6	6	5	5	5	5	6	6	6
1090	77	80	68	120	84	123	94	128	91	106	6	6	6	6	6	6	6	6	6	6
1100	88	72	74	114	84	131	100	81	104	94	6	6	6	6	6	6	6	6	6	6
1110	75	101	98	67	101	152	134	129	134	85	6	6	6	6	6	6	6	6	6	6
1120	116	112	115	94	99	91	97	108	110	73	6	6	6	6	6	6	6	6	6	6
1130	127	99	73	64	86	119	82	65	90	99	6	6	5	5	5	5	4	4	4	4
1140	114	104	101	109	79	89	104	93	77	107	4	4	4	3	3	3	3	3	3	3
1150	76	96	108	134	89	78	119	109	86	117	3	3	3	3	3	3	3	3	3	3
1160	96	80	84	92	87	97	106	92	82	83	3	3	3	3	3	3	2	2	2	2
1170	76	77	79	82	81	69	69	65	110	119	2	2	2	2	2	2	2	2	2	1
1180	90	75	75	90	90	120	90	120	60	105	1	1	1	1	1	1	1	1	1	1
1190	90	75	90	90	105	105	105	60	90	105	1	1	1	1	1	1	1	1	1	1
1200	90	90	105	150	75	90	120	90	90	105	1	1	1	1	1	1	1	1	1	1
1210	150	135	135	120	90	120	120				1	1	1	1	1	1	1			