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TREE-RING ANALYSIS OF TIMBERS FROM THE BROOKS, WINCHESTER, HAMPSHIRE

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Summary

A total of 137 wood samples from 14 features of Roman, Saxon and medieval date were submitted for analysis. Of the 89 samples selected for dating purposes, 61 were dated. The results produced a series of felling date ranges for the Saxon and medieval features, which were mostly timber lined pits. Details of the tree-ring dating are described, and a 686-year Winchester tree-ring chronology for the period AD 443-1128 is also presented as well as some information about the timbers. The latter includes the identification of a relatively rare piece of walnut timber, possibly imported from the Continent.

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Contents

List of Figures

List of Tables

TREE-RING ANALYSIS OF TIMBERS FROM THE BROOKS, WINCHESTER, HAMPSHIRE

Introduction

The 1987-88 excavations at The Brooks by the Winchester Museums Service Archaeology Section revealed large quantities of waterlogged timbers (Scobie *et al* 1991). A total of 137 were sampled for dendrochronology, 72 from Trench I and 64 from Trench II. The Saxon and medieval features were timber lined pits whilst the Roman levels were represented by the primary lining of a drain and its replacement (Table 1). The dating of these features prior to tree-ring analysis, based on stratigraphy and associated pottery, was very approximate. Dendrochronological analysis was undertaken in an attempt to provide a more precise dating framework. The samples were examined at Sheffield during 1988-1991.

The Roman samples came from two successive "land drains", the earliest of which (F1706) was thought to be late 1st century AD in date. It was replaced by F1697 in the early 2nd century AD.

The timber-lined pit F5799 was associated with the earliest post-Roman occupation found on the site. It was the least sophisticated of the timber-lined pits excavated, being lined with unjointed vertical piled planks which showed no evidence of crossbracing or decking. It was associated with some form of glass working activity.

The majority of the remaining samples came from timber-lined pits and wells. Those with deep central pits (eg F5885) were probably wells, whilst those with shallow flat-bottomed pits, sometimes with a central scoop, were probably industrial in function. The pits were square and rectangular in plan with substantial baseplates. Less substantial uprights were inserted in to the corners to hold horizontal planking against the sides. The larger pits (eg F1087) may have been partitioned with timber decking covering at least one half of the pit.

The latest timbers on the site were recovered from the demolition deposits of the masonry-lined latrine F5300 (Scobie *et al* 1991, Fig 40). The latrine was found within a high status residence which fronted onto Upper Brook Street (Scobie *et al* 1991, Fig 34). Many of the timbers were structural, part of a collapsed floor and/or roof, but the remains of the toilet seat and its box-like surround were also found.

Methods

The samples were prepared by freezing them for at least 48 hours and then cleaning their cross-sections with a surform plane (Hillam 1985). When the samples had thawed a note was made of their cross-sectional dimensions and the orientation of the annual rings (Table 2). A note was also made of timbers which might have come from the same tree. Any non-oak species were identified by taking thin sections and identifying key characteristics as set out in, for example, Schweingruber (1978). Samples which were unsuitable for dating purposes were rejected at this stage. These include those samples with unclear annual rings or those with less than 50 rings. The former are likely to produce inaccurate data and the latter do not give reliable dates since short ring sequences may not be unique (Hillam *et al* 1987).

The ring widths were measured to an accuracy of 0.01mm on a travelling stage built in the Department of Geography, City of London Polytechnic. The stage is connected to an Atari microcomputer which uses a suite of dendrochronology programs written by Ian Tyers (pers comm 1990). The measured ring sequences were plotted as graphs either by hand or using a graphing program on the Prime mainframe (Okasha 1987). The graphs were then compared with each other on a light box to check for any similarities between the ring patterns which might indicate contemporaneity. The Atari is also used to aid the crossmatching process, although it is the quality of the visual matching which dictates whether or not a match is accepted. The crossmatching routines are based on the Belfast CROS program (Baillie & Pilcher 1973; Munro 1984), and all the t values quoted in this report are identical to those produced by the first CROS program (Baillie & Pilcher 1973). Generally t values of 3.5 or above indicate

a match provided that the visual match between the tree-ring graphs is acceptable (Baillie 1982, 82-5).

Dating is achieved by crossmatching ring sequences within a site or structure, combining the matching sequences into a site master, and then testing that master for similarity against dated reference chronologies. A site master is used for dating whenever possible because it enhances the general climatic signal at the expense of the background noise from the growth characteristics of the individual samples. Any unmatched sequences are tested individually against the reference chronologies.

If a sample has bark or bark edge, the date of the last measured ring is the date in which the tree was felled. A complete outer ring indicates that the tree was felled during its dormant period in winter or early spring. This is referred to as "winter felled". If the ring is incomplete, felling took place during the growing season in late spring or summer (referred to as "summer felled"). In the absence of bark edge, felling dates of oak timbers are calculated using the sapwood estimate of 10-55 rings. This is the range of the 95% confidence limits for the number of sapwood rings in British oak trees over 30 years old (Hillam *et al* 1987). Where sapwood is absent, felling dates are given as *termini post quem* by adding 10 years, the minimum number of missing sapwood rings, to the date of the last measured heartwood ring. The actual felling date could be much later depending on how many heartwood rings have been removed.

Non-oak species such as beech and ash do not have recognisable sapwood rings. Unless bark edge is present, the felling date must be quoted as a *terminus post quem.* In such cases the *terminus post quem* is the date of the last measured ring.

Once the felling date range or *terminus post quem* has been calculated, factors such as seasoning of timber, reuse, stockpiling, or repairs have also to be taken into account. Timbers for a timber lined pit, for example, will not have been seasoned but they may be reused. Thus whilst the tree-ring dates

for the measured rings are precise and independent, the interpretation of these dates often requires other archaeological evidence.

Results

It is not possible to provide a detailed step-by-step account of how each sample was dated since it involves many computer comparisons, checking of graphs, testing against numerous reference chronologies and so on. The samples from F5799 were examined first and these produced a chronology for the period AD443-842 by reference to other dated Saxon chronologies. (Hereafter all dates are AD unless stated otherwise.) The *t* values between the individual samples and those between the F5799 master and dated reference chronologies are set out below (Tables 3-5, 8-10). F1532/1014 next produced a chronology which matched the F5799 sequence and other dated chronologies over the period 770-1031. This gave a working Winchester chronology for the period 443-1031, and samples from the other Saxon and medieval features were dated against this. The exception was F5300 which was of a later date and had to be crossdated against other reference chronologies (Table 7). Similarly the Roman sequences were tested against dated chronologies of Roman date, and any undated sequences were also checked against chronologies dating to 252BC to the present day. The tree-ring dates are described below, feature by feature. The raw data and feature master data are stored in the Sheffield Dendrochronology Laboratory where they can be consulted on request.

Trench I

F1000

Two oak samples (*Quercus* spp) were submitted from the bottom of this circular structure. Sample 2 with only 15 rings was rejected. Sample 1, a tangentially split plank, had 76 rings and probably bark edge, but it has not been possible to date its ring sequence.

F1061

The two planks (1, 3) from the lining of F1061 were radially split timbers whilst the upright 2 was a smaller, squarer timber. The inner rings of 1 were too narrow for accurate measurement so only the outer 104 rings were measured.

The other two samples had 107 and 227 rings; none of the three, all oak, had sapwood. The ring sequences from the planks matched each other with a t value of 4.5. They were combined to construct a feature master of 227 years which dates to 754-980 (Table 3).

F1087

Twelve of the 15 samples from this rectangular timber lined pit were identified as oak and three (22, 27, 52) as beech (*Fagus sylvatica* L). The timbers were either planks used as decking or supports for the decking. The planks were generally radial timbers although some (eg 12, 13) were not true radially split planks. The decking supports came from trunk quarters. Three of the supports were thought to be reused.

Two of the beech samples were rejected, one (52) because its rings were unclear and the other (27) because it had insufficient rings. The oak sample 18 was also rejected because it had less than 50 rings.

Two pairs of timbers had almost identical ring sequences suggesting that they came from the same tree. There are no statistically sound criteria for establishing which timbers are from the same tree. The convention used at Sheffield is for samples whose ring patterns look very similar, both as samples and graphs, and which crossmatch to give t values greater than 10 to be classed as the same tree. Whilst this ensures that timbers from different trees are not classed as the same tree, there may may be some from the same tree that are not detected because their ring patterns are less similar. The two samples from F1256, for example, fall into this category (see below). In the case of F1087, 11 and 16 matched to give a t value of 13.7, whilst 25 and 51 gave 17.4 (Table 5). The ring widths were averaged to produce a single ring sequence in each case before being included in the feature master so as to avoid bias.

The four samples from two trees crossmatched five other sequences to provide a F1087 feature master of 264 years which dated to 767-1030 (Table 3). An additional sample (7) was also dated against other feature masters (eg t =

5.1 with F1532) but because it was a relatively weak match, it was not included in the final Winchester master.

The final timber to be dated from this feature was the beech sample 22. It is not possible to construct long, continuous chronologies for species other than oak since they are not long-lived enough nor found in sufficient quantities in archaeological contexts. However research on samples from living trees has shown that ring sequences from species such as ash and elm can sometimes be crossmatched against oak chronologies (Groves & Hillam 1988). This has proved to be true for beech. Not only do modern oak and beech chronologies crossmatch well, but a medieval beech chronology made up from 111 timbers from London excavations has recently been dated by reference to oak chronologies (Tyers pers comm 1990). This London beech chronology spans the period 817-1272 and was made available for use with the Winchester beech samples. F1087 22 was found to crossmatch over the period 906-1038 with a *t* value of 7.4. It does not match any of the oak chronologies.

F1178

Of the seven oak samples from F1178, only 3 and 7 were suitable for dating purposes; the remainder were small pieces of timber with less than 50 rings. The two measured samples were from base beams of radially split timber which had 136 and 147 rings. Their ring sequences were almost identical (t = 15.2) indicating an origin in the same tree. The combined ring sequence of 170 years dated to 817-989 (Table 3).

F1226

All the samples from F1226 were oak except for plank 1 which was beech. The timbers were mostly radially split timbers which had 62-233 rings. The ring sequences from 4 and 5 crossmatched (t = 5.3) to give a 103-year sequence which dated to 865-967 (Table 3). None of the other sequences matched this but 2 and 6 showed similarities to other feature masters. 2, for example, matched F1532 over the period 696-928 (t = 5.8), whilst 6 gave a t value of 8.1 with F1087 over the period 880-990. The beech sample showed no similarity

with the London beech chronology or with any of the other Winchester beech sequences.

F1256

The two oak samples from F1256 were shaped from quartered trunks and contained 102 and 105 rings (Table 2). The outer corner of each was probably the heartwood-sapwood transition. Although the t value for the match between them is 10.8, visual comparison of the graphs suggested that they were not necessarily from the same tree. They were therefore combined to produce a two tree master of 105 years which dated to 847-951 (Table 3).

F1532/1014

Ten samples from planks, uprights and base beams composing the lower lining of a pit were analysed. F1014 is represented by samples 7-10 and F1532 by 1-5; 3A and 3B were originally thought to be from the same timber. The planks, with the exception of 3A, were radially split timbers whilst the base beams and uprights were shaped from quartered trunks. The samples were oak, except 5, which was identified as beech. All were suitable for dating purposes and they produced ring sequences with 60-208 rings.

The ring patterns of the two base beams, 7 and 8 were very similar (t = 12.6) and probably came from the same tree. They matched five other sequences (Table 4) and were all combined into a 262-year master which dated to 770-1031 (Table 3). The sequences from the planks 3A and 3B matched with t value of only 4.9 and are not from the same timber. It is possible that 3A was wrongly labelled on site since it is not a radially split timbers like the other planks.

F1697

Although 22 oak samples from the replacement lining of this Roman drain were sampled, all but six were rejected because they had less than 50 rings or their rings were unmeasurable. The timbers were generally shaped from whole tree trunks (eg 11, 31), although halved (eg 9) or quartered trunks (eg 6) and occasionally tangential planks (eg 2, 3) were also used.

The measured ring sequences of 51-73 rings were relatively short compared to those from some of the Saxon or medieval features. None of them appeared to match each other and when they were tested against dated reference chronologies, only one sequence gave reliable results. Sample 3 gave consistently high t values with many chronologies, particularly those from London, over the period 32BC-AD41 (Table 6). The t values are so high for a single ring sequence of 73 years that it is a puzzle why none of the other sequences date.

Although their ring sequences were not measured because of a band of very narrow rings in the middle, the patterns of samples 34 and 39 looked identical and were probably cut from the same tree; both were summer felled.

F1706

The primary oak timbers from the lining of the Roman drain were mostly tangential planks, the exception being 40 which was a squared half trunk. Two of the samples (1, 8) were rejected since they had under 50 rings. The remaining four samples had 73 to just over 114 rings. The ring sequences of 3 and 9 matched each other ($t = 7.5$) to give a 94-year tree-ring curve, but none of the sequences matched the F1697 sequences or the reference chronologies.

Trench II

F5300

The youngest feature on the site to produce timbers for analysis was F5300, a medieval latrine pit. Some of the timbers were thought to be structural, others were from the remains of a wooden toilet seat and its surround. The timbers were all oak except for the toilet seat 55, which was identified as walnut (*Juglans regia* L). The walnut sample was from a fine tangentially cut plank measuring 405mm by 25mm in cross-section. Many of the oak planks were also tangential timbers, some of a similar size to the walnut plank, others smaller (Table 2). A few other timbers had been roughly shaped into squares or rectangles from whole or quartered trunks. The timbers were generally from young trees and consequently many of the samples had less than 50 rings and

were rejected. The walnut sample was rejected because its ring boundaries were not very clear.

Comparison between the ring sequences showed that 54 and 59, two tangential planks, had been cut from the same tree (t = 14.5). Originally 54 was thought to be part of a toilet seat and 59 part of a floorboard, but the tree-ring results suggest that they are from the same structure, probably both pieces of the toilet seat. The small beam 9 also matched the 54/59 sequence (t = 4.6) but no other sequence could be crossmatched. The 85-year sequence from F5300 did not appear to match the other Winchester sequences. When it was tested against dated reference chronologies for the period AD400 to the present day, it correlated well with numerous chronologies over the period 1157-1241 (Table 7) and therefore does not overlap the main Winchester chronology.

F5726

Twenty two oak timbers made up of planks, uprights and base beams from a rectangular timber lined pit were sent for analysis. Thirteen of these were selected for measurement so as to include all the samples with sapwood whilst giving an even representation of timber function. Two samples had been submitted from timber 11; the sample which included a few sapwood rings was selected for measurement.

The timbers were either radial (eg 22) or tangential (eg 18) planks, or rectangular-shaped timbers hewn from halved (eg 11), quartered (eg 2) or whole (eg 25) trunks. Those selected for measurement had 61-265 rings. The ring patterns of 6, 19 and 27 were very similar suggesting that the timbers came from the same tree (Table 8). Their ring widths were averaged to produce a 169-year ring sequence. This in turn matched seven other samples. The ten matched sequences were therefore incorporated into a 271-year master which dated to 718-988 (Table 3).

F5799

The oak timbers from the pit lining of F5799 were undoubtedly the finest quality timber on the site, even though the construction of the lining was

less sophisticated than in other pits. All were planks which were radially split although some may have been reworked so that they were not true radials.

All but 1 and 13 were measured. The excluded samples were delivered after the others and since they had no sapwood, it was felt that their analysis would add nothing further to the results. The ten measured samples all had more than 100 rings, including two with more than 300 rings and a further six with more than 200 rings. This is well above the average number of rings for timbers from urban archaeological sites, and indicates that trees over 400 years old were being exploited to produce the planks.

Three of the timbers (6, 7, 10) came from the same tree (Table 9), and their ring sequences also matched those from the remaining seven samples. The resulting 400-year master was tested against chronologies from AD404 to the present day. A strong agreement was found with Saxon chronologies over the period 443-842 (Table 10).

F5885

The twelve oak samples from this timber lined well were all suitable for dating purposes except for 16, a timber not *in situ* when excavated, which had only 32 rings. The timbers were side planks, base beams and uprights although the two base beams (9, 10) appeared to be reused. The uprights were small rectangular shaped sections which had been taken from much larger trees. The timbers not *in situ* when excavated also fell into this category. The side planks and base beams were radial or almost radial planks except for the base beam 10 which was almost a complete half trunk (Table 2). The planks and base beams were of similar size, being almost twice the width of the uprights.

The measured samples contained 56-212 rings and seven matched each other to produce a 153-year ring sequence (Table 11). This dated to 815-967 (Table 3). The base beam 9 with 212 rings also dated but to an earlier period. It gave a t value of 10.0 against the F5799 master over the period 470-681 confirming that it was reused from an earlier structure.

The remaining three timbers, including the other reused base beam could not be dated. It should be noted that whilst 9 looked very similar in quality to the planks from F5799, 10 did not, possibly indicating that it is more recent in date.

F5889

The two oak planks from the base of pit F5889 had 225 and 180 rings. Their ring sequences did not appear to match each other. When they were tested against the Winchester masters and other dated chronologies, 2 was found to match over the period 949-1128 (Table 3) but surprisingly the 225-year sequence from 1 did not match.

Interpretation of the tree-ring dates

The above results provided dates for 61 timbers, 60 oak and one beech. None of these timbers had bark edge, although many had sapwood, and therefore it is necessary to look at the dates of the heartwood-sapwood boundaries or the last measured ring in order to estimate felling dates. The relative positions of the ring sequences and their sapwood boundaries are illustrated as a bar diagram (Fig 1). Using the bar diagram and the dates set out in Table 2, it is possible to arrive at the felling date ranges and *termini post quem* summarised in Fig 2 by applying the sapwood estimate of 10-55 rings (see above).

Trench I

F1061

The two dated timbers end in 955 and 980, giving a *terminus post quem* for felling of 965 and 990 respectively. This indicates that the pit lining was not inserted until after 990.

F1087

Examination of the F1087 bar diagram shows that there are at least two phases of felling. The two oak timbers, 12 and 15, both of which have sapwood, provide a felling date range of 1030-1051. This can be refined even further by the beech timber 22 which was still growing in 1038. The felling date

range for the primary timbers therefore becomes 1038-1051. Timbers 7, 15, 25 and 30 are likely to be contemporary.

Three of the timbers thought to be reused have been dated. 11 and 16 end in 930 and 951 respectively and, because they are from the same tree, must have been felled after 961. The third timber 32 has some sapwood preserved and its heartwood-sapwood boundary dates to 922. This produces a felling date range of 932-977. If the reused timbers are contemporary, a combined felling date range of 961-977 would be applicable.

Sample 13 from the decking ends in 887 and was felled some time after 897. It could therefore have lost many heartwood rings and be primary, or it could be reused.

F1178

The two dated timbers from F1178 are from the same tree. Sample 7 which ends in 986 provides a *terminus post quem* of 996 for the felling of the timbers.

F1226

The only dated timber with sapwood is 6, a plank not *in situ* when excavated. This timber gives a felling date range of 991-1029. Another plank 5 ends in 967 and was felled after 977. It is likely to be contemporary with 6.

The other two dated planks were felled after 936 and 938 and could therefore be earlier than 5 and 6.

F1256

The two dated timbers have possible heartwood-sapwood transitions dating to 949 and 951. This gives a *terminus post quem* for felling of 961 with the possibility that they were felled before 1004.

F1532/1014

A felling date range of 1036-1081 is obtained from plank 1 which has a heartwood-sapwood transition of 1026. None of the other dated timbers have sapwood. The dates of their last measured heartwood ring range from 939 to 989. Some could be earlier than 1 but it is more likely that heartwood rings

were lost when the timbers were converted into beams or planks.

F1697, F1706

The only dated timber from the Roman levels is 3 from F1697. It ends in AD41 giving a *terminus post quem* of AD51 for the replacement lining of the drain.

Trench II

F5300

None of the three dated timbers have sapwood. Their end dates are 1228, 1240 and 1241 giving a *terminus post quem* of 1251 for the felling of the timber for the toilet seat/possible floorboard (same tree - 54/59) and one of the beams (9).

F5726

Due to selective sampling in the laboratory, all but one of the dated timbers had sapwood. The earliest heartwood-sapwood transition dates to 939 (25) and the latest to 975 (3). However timber 19 was part of a living tree in 988. The timbers were therefore felled after 988 and probably (95% confidence limits) before 994.

F5799

The sapwood boundary was present on five samples. Timber 2 cannot have been felled before 843, the date of its outer ring, whilst 10 is likely to have been felled before 863. These give the felling date range of 843-863 since all the other dated timbers are likely to be contemporary.

F5885

Two phases of felling were identified from this feature. The reused timber 9 was felled after 691. The similarity in timber quality between 9 and the planks from F5799 suggests that it was originally used at about the same time, particularly as it may have lost heartwood rings during secondary reworking.

The seven dated timbers from the primary phase of the feature appear to be contemporary with each other. Three samples have sapwood or sapwood boundary: 17 has a sapwood boundary dating to 944, 4 ends in 947 and has a sapwood

boundary of 929, and 11 ends in 967 with a sapwood boundary of 952. The timbers were therefore felled after 967 and probably before 984.

F5889

The only dated timber from F5889 does not have sapwood. It ends in 1128 and was therefore felled some time after 1138.

Chronology of the timber features

The earliest timber to be dated from the site is from the F1697 replacement lining of the Roman drain. This was felled after AD51. There is then a hiatus of several hundred years until further activity is identified in the Saxon period when timbers were felled for the F5799 timber lined pit during the period 843-863 (Fig 2). A timber of broadly similar date was also found reused in pit F5885.

The late 10th-11th century provides the next group of dated timbers. The timbers for F5885 give a tight felling date range of 967-984 whilst those for F5726 were felled slightly later in 988-994. The timbers from F1256, felled after 961 and possibly before 1004, could be contemporary with either group. The timbers for F1061 and F1178 were felled some time after 990 and 996 respectively, whilst those from F1087 and F1532/1014 were felled during the periods 1038-1051 and 1036-1081 respectively.

Later medieval activity is indicated by a timber from F5889, which was felled after 1138, and those from F5300 which were felled after 1251. F5300 was excavated in Phase B of Building 365/6.3 (Scobie *et al* 1991, Fig 34). This Phase is linked by documentary evidence to the period of ownership by John de Tytyng, a wealthy wool merchant. He occupied the tenement between 1299 until his death in about 1312 and is thought to have added the internal latrine.

A Winchester Tree-ring Chronology

As well as providing felling date ranges, the 61 dated rings sequences have provided new tree-ring chronologies. The Roman sequence spans the years 32BC-AD41 (Table 12), whilst three others from F5300 provide a short chronology of

85 years which dates to AD1157-1241 (Table 13).

The remaining 57 sequences form a well-replicated chronology covering the period AD443-1128. Data from 55 samples, representing a maximum of 48 trees, have been used to construct the Winchester chronology (Table 14). The two excluded samples are the oak 7 and the beech 22 from F1087 (The ring width data of the latter are set out in Table 15.) The level of agreement between 7 and the remaining Winchester sequences was not considered high enough to warrant its inclusion, whilst it would also be inappropriate to include beech data in an oak chronology.

The chronology presented here (Table 14) spans 686 years and matches well with over 60 independent oak chronologies from all over the British Isles (Table 16). The Winchester chronology is most similar to the chronologies made up from timbers excavated in London, particularly those from Billingsgate Lorry Park in the City of London (eg Hillam 1991c), but it also gives t values greater than 6.0 with chronologies from, for example, Beverley in North Humberside and Dublin in Ireland. It does not match the tree-ring chronology obtained from the Winchester Round Table. This dates to AD1041-1211 (Barefoot & Haddon-Reece pers comm 1988) and therefore should overlap the Brooks long chronology by 87 years. This may indicate that the timber for the Table came from somewhere different to the timbers found at the Brooks; the boards may have been bought specially to construct the Table.

Discussion

The Brooks tree-ring study has produced 61 dates from the 89 samples selected for dating. This gives a 68.5% success rate which is relatively high for a large urban site. The figure would be higher if the Roman samples were ignored since only one out of ten of these could be dated. The difference in dating success rate between the Saxon/medieval timbers on the one hand and the Roman timbers on the other also applies to the quality of timber. The Roman timbers tended to be from young trees; the wood was relatively poor in quality producing short, knotty ring sequences. The Saxon and medieval timbers, although there was some variation in quality, were generally far superior.

The Winchester timbers also stand out in quality when compared to timbers from other urban sites, such as those from Billingsgate Lorry Park in London which match so well with Winchester. Many of the timbers came from long-lived, straight-grained trees. Seven of the features, for example, produced samples with sequences greater than 200 rings.

The best quality timbers come from F5799. These Saxon timbers must have come from oak trees well over 400 years old when felled. The wood is straight-grained and free from knots, and compares in quality to the Baltic oak boards imported into England during the Middle Ages. This superior quality native timber must have been common in England during Saxon times since similar timbers have been found lining wells and pits at other sites such as Hamwic in Southampton (Hillam 1984), Slough House Farm in Essex (Hillam 1990a) or West Heslerton in North Yorkshire (Hillam 1990b). Thirteen sites have produced such timbers and all of them have ring patterns starting in the period AD400-450. That is, all the timbers, regardless of location or felling date, came from trees which probably started life about AD400. The reason for this is not yet known but clearly must have some connection with forest regeneration after the withdrawal of Roman influence (Tyers *et al* 1991).

As well as the oak timbers, the study also showed that beech and walnut were used on the site. The presence of the walnut timber is very unusual. It is the first time that a waterlogged timber has been identified as walnut at Sheffield. Although walnut was introduced into this country by the Romans, the tree was not common and was grown for its nuts rather than its timber (Salzman 1979, 252). Its timber would therefore be relatively expensive, even compared to oak (Edlin 1973, 121). The wood is found more frequently on the Continent, particularly in Italy and southern France, where it was used for carving, turning and the production of panels. Many paintings in France and Italy, for example, were painted on walnut panels (Marette 1961). It is therefore probable that the F5300 walnut timber was imported from the Continent. The discovery and identification of a relatively rare and expensive timber, probably imported into Winchester for use as a toilet seat,

provides further evidence of the presence of a high-status residence.

Conclusion

A high success rate was achieved for the 89 samples selected for dating purposes, although the dating of only one sample from the Roman drain was disappointing. Absolute dates were obtained for timbers from twelve out of fourteen features thus providing a more precise dating framework than that given by the stratigraphical and pottery evidence, at least for the Saxon/medieval period. The tree-ring dates indicate that timber was being felled for use on the site from the mid-9th century to the 13th century, but that there was a concentration of felling phases during the late 10th-11th centuries.

The production of a 686-year tree-ring chronology for the period AD443-1128 plus a shorter sequence for the period AD1157-1241 was an added bonus. The chronologies will undoubtedly be useful for dating timbers from other archaeological sites in the future.

The tree-ring analysis has also provided information about the type and quality of the timbers with the most superior timber being used in the least sophisticated of pit lining constructions. The identification of a walnut toilet seat in the internal latrine of tenement 365/6.3, the timber of which was probably imported, provides more evidence about the status of the residence in which it was found.

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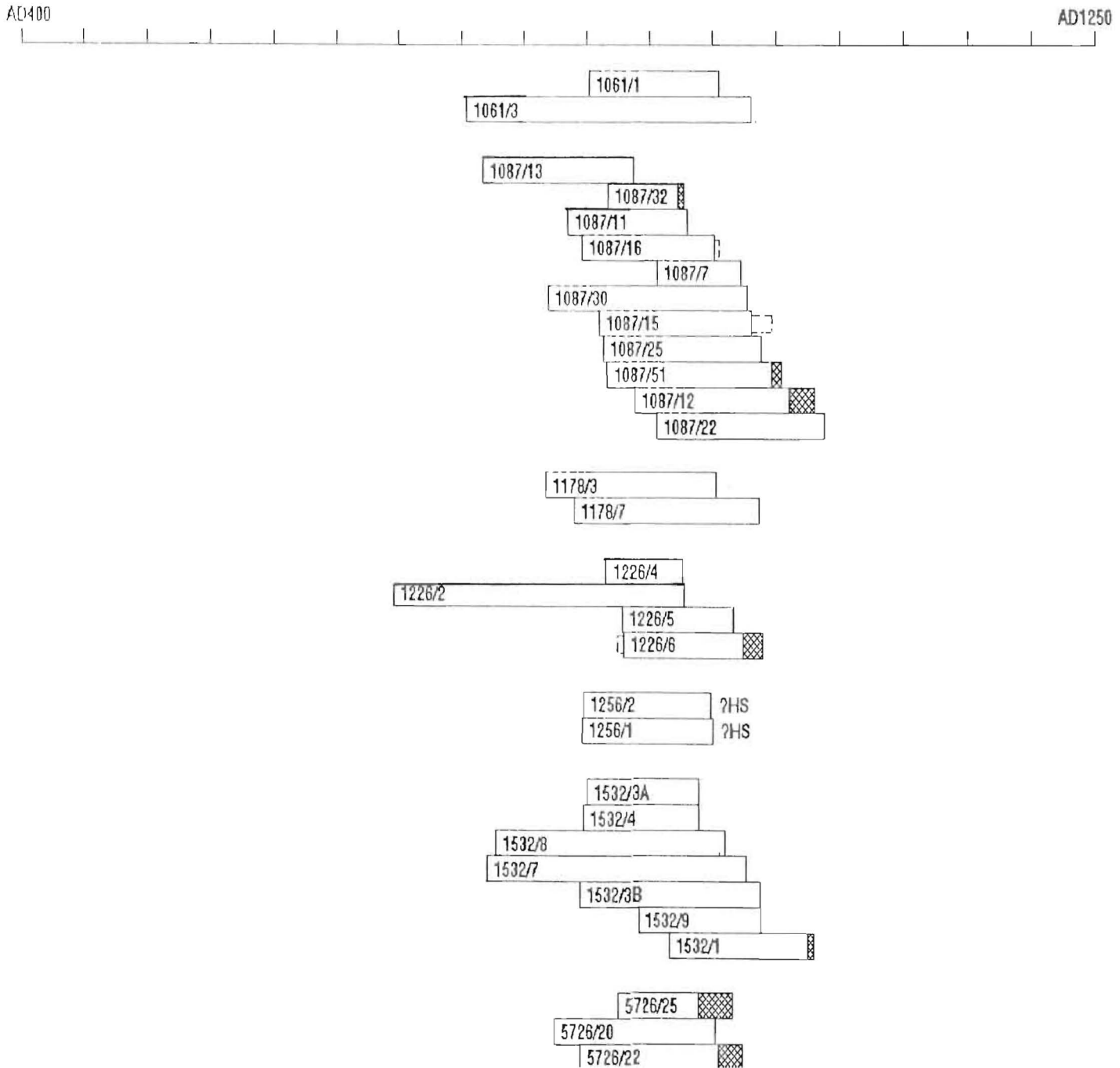

AD1400
AD1250
1061/1
1061/3
1087/13
1087/32
1087/11
1087/16
1087/7
1087/30
1087/15
1087/25
1087/51
1087/12
1087/22
1178/3
1178/7
1226/4
1226/2
1226/5
1226/6
1256/2
?HS
1256/1
?HS
1532/3A
1532/4
1532/8
1532/7
1532/3B
1532/9
1532/1
5726/25
5726/20
5726/22

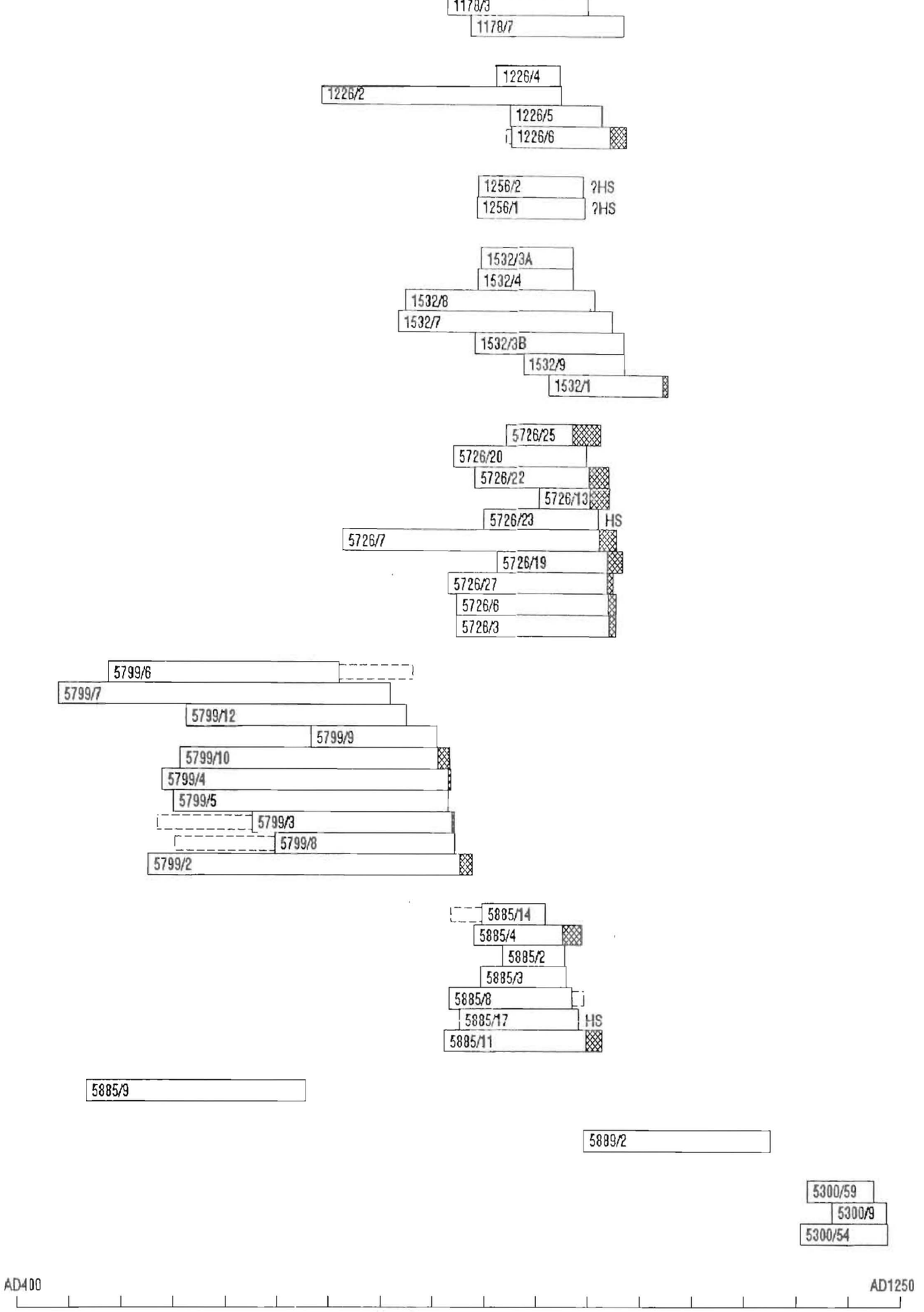


Figure 1: Bar diagram showing the relative positions of the dated ring sequences. White bars - heartwood rings; hatching - sapwood; broken lines - unmeasured rings; HS - heartwood-sapwood transition.

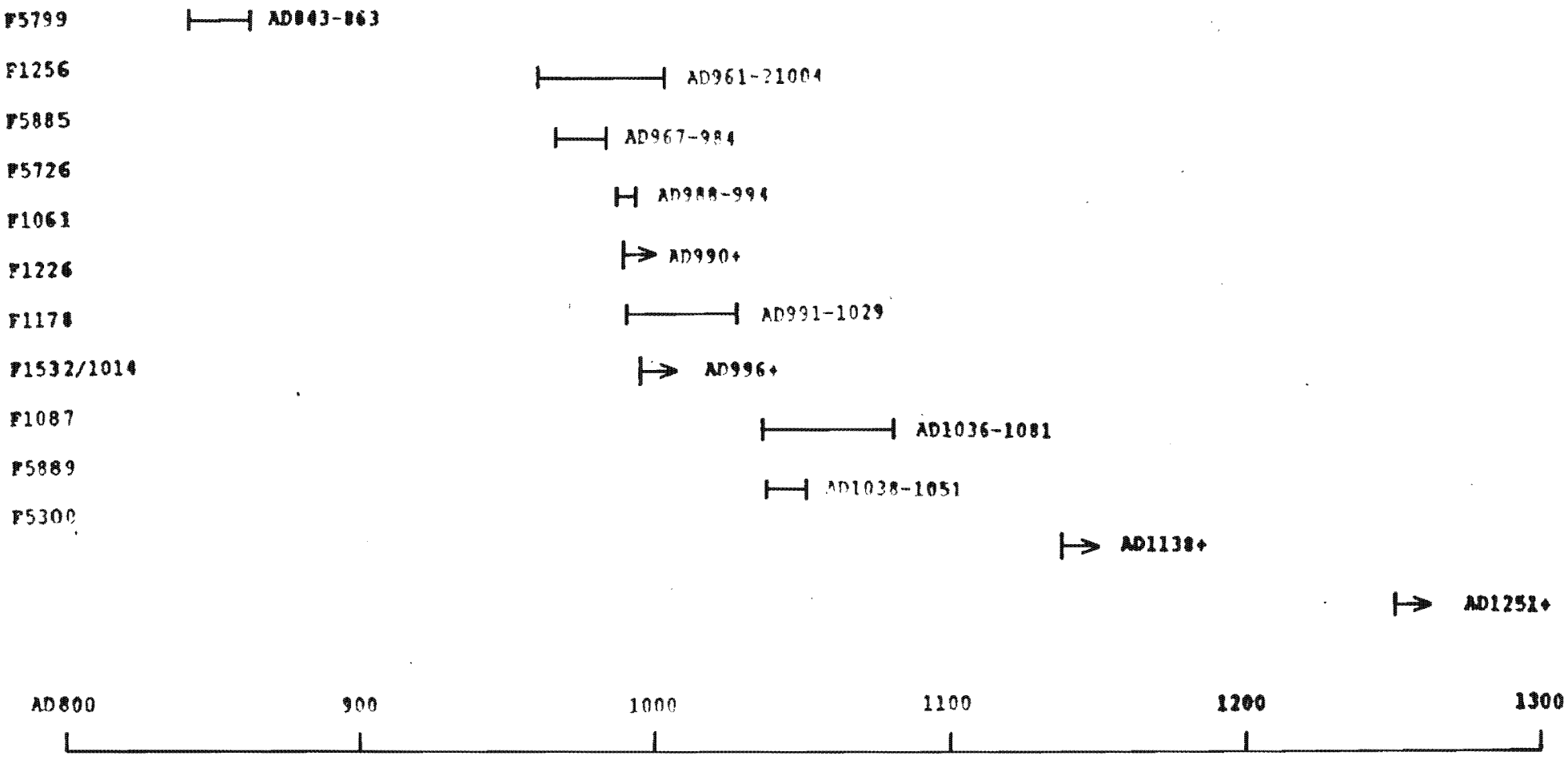
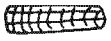
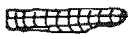
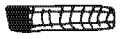
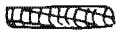
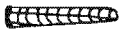


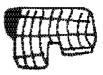
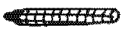
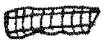
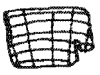
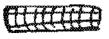
Figure 2: The chronology of the Saxon and medieval timber features as indicated by dendrochronology. Each bar represents the felling date range of a single feature; vertical bars with arrows indicate the *termini post quem* for felling. The dates for the reused timbers from F1087 (probably felled during 932-977) and F5885 (felled after 691) are not illustrated.

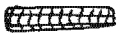
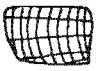
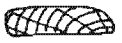
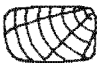
Table 1: List of features from which the tree-ring samples were taken; timber functions are given where known.

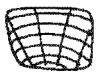
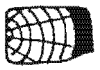
feature	description	timbers sampled
TRENCH I		
F1000	large flint lined circular structure	2 beams at base of lining
F1061	pit with remains of timber lining	planks: 1, 3 upright: 2
F1087	rectangular timber lined pit	planks - decking: 12, 13, 15, 25, 30, 51? supports for decking (reused?): 11, 16, 32
F1178	large rectangular pit	base beams: 3, 7
F1226	timber lined pit	planks: 1, 4, 5, 6 (6 - not in situ) uprights: 2, 3
F1256	timber lined pit	function of timbers unknown
F1532/ 1014	lower lining of large pit	planks: 1, 3A, 3B, 4 upright: 2 base beams: 7-9
F1697	replacement lining of F1706 drain, 2nd century?	plank: 2 stakes: 31, 33, 34, 36-39
F1706	primary lining of early Roman drain, replaced by F1697	
TRENCH II		
F5300	medieval latrine pit	floorboards?: 52, 59 toilet: 54 toilet?: 28, 50, 51, 53, 55 beams: 9, 29 small posts: 56, 57 structural: 6?, 11, 20, 27, 58?
F5726	rectangular timber lined ?well	uprights: 1, 2, 6, 8, 13, 18, 19, 25 planks: 3, 4, 7, 10, 12, 15-17, 22, 23, 30 base beams: 11, 20, 26, 27
F5799	timber lined pit; earliest post-Roman activity in Trench II	pit lining
F5885	timber lined well	uprights: 2 (reused?), 3, 4 side planks: 8, 11, 14, 17 base beams: 9, 10 (reused?) not in situ : 1, 6, 16
F5889	pit	planks in base of pit

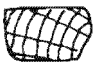
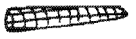
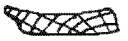
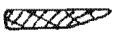
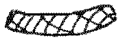
Table 2: Details of the tree-ring samples, context by context. Samples are oak unless stated otherwise. Sketches of cross-sections are not to scale; sapwood on sketches is indicated by shading. HS - heartwood-sapwood boundary; "+" - unmeasured rings present.

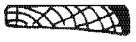
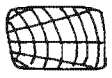
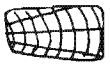
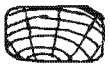
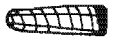
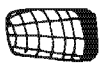
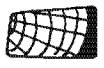
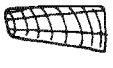
feature	timber no	total no of rings	sapwood rings	average ring width (mm)	sketch	maximum dimensions (mm)	date span of rings	felled	comments
1000	1	76	18	1.80		420x65			bark edge?
	2	15	-	-		145x50			unsuitable
1061	1	+104	-	1.28		215x35	852-955	965+	
	2	107	-	1.17		135x80			
	3	227	-	1.09		260x45	754-980	990+	
1087	7	67	-	1.73		115x35	906-972	982+	
	11	96	-	1.04		105x60	835-930	940+	
	12	143	20	1.13		165x25	888-1030	1030-1065	
	13	121	-	1.25		170x15	767-887	897+	
	15	121+	-	1.05		140x20	860-980	1016+	+16 rings
	16	106	-	0.94		100x65	846-951	961+	
	18	31	-	-		90x15			unsuitable
	22	133	-	1.07		145x40	906-1038	1038/1039	BEECH; bark edge
	25	+126	-	1.65		345x25	863-988	998+	
	27	44	-	-		105x35			BEECH; rejected oak
	30	159	-	1.47		235x20	819-977	987+	

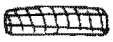
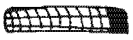
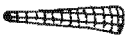
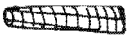
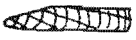
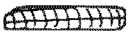
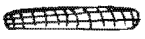
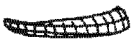
feature	timber no	total no of rings	sapwood rings	average ring width (mm)	sketch	maximum dimensions (mm)	date span of rings	felled	comments
1087/ cont	32	61	5	1.63		110x20	867-927	932-977	
	50	85	12	1.35		115x75			
	51	139	8	1.72		240x20	866-1004	1006-1051	
	52	-	-	-		115x30			BEECH; unmeasurable
1178	1	40	-	-		95x65			unsuitable
	2	28	-	-		70x45			unsuitable
	3	136	-	0.98		135x45	817-952	962+	
	4	42	-	-		100x65			unsuitable
	5	33	-	-		130x50			unsuitable
	6	73	-	1.70		130x70			
	7	147	-	1.14		170x65	840-986	996+	
1226	1	92	-	2.04		200x50			BEECH
	2	233	-	0.78		185x45	696-928	938+	
	4	62	-	1.48		165x85	865-926	936+	
	5	89	1	1.44		135x85	879-967	976-1021	
	6	+111	16	1.75		225x45	880-990	990-1029	
1256	1	105	HS?	1.15		130x100	847-951	961-?1006	
	2	102	HS?	1.23		125x105	848-949	959-?1004	

feature	timber no	total no of rings	sapwood rings	average ring width (mm)	sketch	maximum dimensions (mm)	date span of rings	felled	comments
1532/ 1014	1	116	5	1.80		205x25	916-1031	1036-1081	
	2	68	-	1.63		125x125			knotty
	3A	90	-	1.94		200x185	850-939	949+	
	3B	145	-	0.87		125x15	844-988	998+	
	4	93	-	1.62		155x10	847-939	949+	
	5	63	BE?	1.39		85x55			BEECH
	7	208	-	0.93		175x120	770-977	987+	
	8	184	-	0.94		180x135	777-960	970+	
	9	99	-	1.53		205x130	891-989	999+	
	10	60	-	1.71		110x55			
1697	1	67	-	1.75		230x70			
	2	72	HS?	1.53		200x45			knotty
	3	73	-	2.51		270x55	32BC-AD41	AD51+	
	4	23	12	-		75x60			unsuitable
	6	57	HS?	2.00		120x70			
	7	24	3	-		125x85			unsuitable
	8	-	-	-		110x70			unsuitable; narrow rings
	9	26	-	-		120x70			unsuitable

feature	timber no	total no of rings	sapwood rings	average ring width (mm)	sketch	maximum dimensions (mm)	date span of rings	felled	comments
1697/ cont	10	37	-	-		125x70			unsuitable
	11	34	1	-		110x75			unsuitable
	12	64	14	1.60		110x90			bark edge?
	13	26	-	-		120x75			unsuitable
	14	51	-	1.48		130x70			
	23	35	8	-		140x80			unsuitable
	24	36	1	-		125x75			unsuitable
	31	29	4	-		115x70			unsuitable
	33	46	-	-		120x70			unsuitable
	34	-	14	-		100x75			unsuitable; felled summer
	36	25	-	-		120x65			unsuitable
	37	46	-	-		115x75			unsuitable
	38	41	6	-		95x80			unsuitable
	39	-	15	-		95x80			unsuitable; felled summer
1706	1	46	7	-		190x60			unsuitable
	2	114+	11+	1.15		300x50			
	3	73	11	1.64		290x65			
	8	41	-	-		145x50			unsuitable

feature	timber no	total no of rings	sapwood rings	average ring width (mm)	sketch	maximum dimensions (mm)	date span of rings	felled	comments
1706/ cont	9	76	-	1.73		140x70			
	40	76	-	1.82		175x125			
5300	6	18	-	-		65x55			unsuitable
	9	53	-	2.54		160x90	1188-1240	1250+	
	11	66	-	1.87		130x125			
	20	15	-	-		150x120			unsuitable
	27	65	-	2.10		150x120			
	28	53	-	2.08		425x30			
	29	24	-	-		150x145			unsuitable
	50	54	-	4.56		270x20			
	51	28	-	-		275x25			unsuitable
	52	29	-	-		165x20			unsuitable
	53	33+	-	-		195x25+			unsuitable; broken
	54	85	-	2.64		295x25	1157-1241	1251+	
	55	-	-	-		405x40			WALNUT; unmeasurable
	56	22	-	-		95x40			unsuitable
	57	23	-	-		90x45			unsuitable
	58	19	-	-		205x160			unsuitable

feature	timber no	total no of rings	sapwood rings	average ring width (mm)	sketch	maximum dimensions (mm)	date span of rings	felled	comments
5300/ cont	59	65	-	2.41		210x25	1164-1228	1238+	
5726	1	-	-	-		160x75			not selected for measurement
	2	-	yes	-		170x60			unmeasurable
	3	155	7	1.77		455x35	828-982	985-1030	
	6	155	8	1.21		190x55	828-982	984-1029	
	7	265	17	1.00		305x55	718-982	982-1020	
	8	-	-	-		155x100			not selected
	10	-	-	-		215x75			not selected
	11	61	5	1.96		210x95			
	12	-	-	-		145x20			not selected
	13	69	19	1.61		125x115	907-975	975-1011	
	15	-	-	-		305x55			not selected
	16	68	5	2.28		165x55			
	17	62	9	2.33		155x60			
	18	-	-	-		265x80			not selected
	19	122	15	1.43		175x85	867-988	988-1028	
	20	129	-	1.98		265x90	824-952	962+	
	22	130	19	1.64		215x40	845-974	974-1010	

feature	timber no	total no of rings	sapwood rings	average ring width (mm)	sketch	maximum dimensions (mm)	date span of rings	felled	comments
5726/ cont	23	111	HS	0.96		395x50	854-964	974-1019	
	25	92	27	1.03		145x135	875-966	966-994	
	26	-	-	-		310x110			not selected
	27	160	6	1.34		220x75	820-979	954-1009	
	30	-	-	-		155x30			unsuitable; broken
5799	1	-	-	-		265x35			not selected
	2	314	13	0.84		270x30	529-842	842-884	
	3	+196	2	1.07		255x30	629-824	832-877	
	4	280	3	0.97		280x35	542-821	828-873	
	5	266	-	0.89		270x30	553-818	828+	
	6	223+	-	1.01		300x30	491-713	794+	71 rings broken off
	7	320	-	1.04		355x35	443-762	772+	
	8	+175	1	0.74		270x30	651-825	834-879	
	9	122	-	1.98		255x30	686-807	817+	
	10	262	12	1.16		315x35	559-820	820-863	
	12	214	-	0.77		165x30	565-778	788+	
	13	-	-	-		235x30			unmeasurable

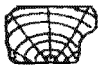
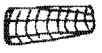
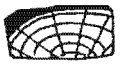
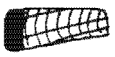
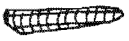
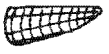
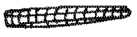
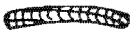
feature	timber no	total no of rings	sapwood rings	average ring width (mm)	sketch	maximum dimensions (mm)	date span of rings	felled	comments
5885	1	56	-	1.55		120x75			
	2	61	-	2.13		140x70	871-931	941+	
	3	84	-	1.35		115x70	850-933	943+	
	4	105	18	1.12		115x85	843-947	947-984	
	6	64	-	1.42		90x50			knotty
	8	120+	-	1.61		200x30	819-938	959+	+ about 11 rings
	9	212	-	1.16		245x85	470-681	691+	
	10	72	17	1.72		225x95			bark edge
	11	153	16	1.55		215x65	815-967	967-1006	
	14	+62	-	1.78		215x20	851-912	922+	outer rings only
	16	32	-	-		105x50			unsuitable
	17	116	HS	1.77		210x85	829-944	954-999	
5889	1	225	-	0.97		220x15			
	2	180	-	1.24		230x15	949-1128	1138+	

Table 3: t value matrix showing the degree of correlation between each of the feature masters, and between the masters and selected reference chronologies. Values less than 3.0 are not printed; "/" - no overlap. BIG45 - London, Billingsgate period 4/5 chronology (Hillam unpubl); S'WARK - London, Southwark (Tyers pers comm); EXETER (Hillam 1980).

	1061	1087	1178	1226	1256	1532	5726	5799	5885	5889	BIG45	S'WARK	EXETER
1061 1/3	*	4.7	7.3	4.0	5.3	4.4	4.4		6.7		6.0	5.0	4.7
1087T7(S9)		*	7.2	5.5	6.2	7.9	9.2	3.9	7.6	5.8	8.8	5.4	5.7
1178 3/7			*		3.2	8.0	7.9	4.0	5.3	3.6	7.0	5.0	3.8
1226 4/5				*	6.6	3.9	7.4	/	6.6		3.1	3.3	
1256 1/2					*	5.3	5.4	/	7.3	/	5.3	4.0	4.6
1532T6(S7)						*	9.1	4.6	7.7	6.0	9.0	5.4	5.0
5726T8(S10)							*	7.0	8.2	3.9	7.8	6.1	5.7
5799T8(S10)								*		/	4.7		
5885T7									*		7.8	8.3	4.4
5889/2										*	6.4	6.5	3.9

Table 4: t value matrix for F1014/1532. Values less than 3.0 are not printed.

	1	3A	3B	4	7	8	9
1	*			3.7			3.6
3A		*	4.9	3.7			3.2
3B			*	4.5	3.6	3.6	3.2
4				*	5.7	7.0	3.5
7					*	12.6	3.9
8						*	
9							*

Table 5: t value matrix for F1087. Values less than 3.0 are not printed; "\" - overlap less than 15 years.

	11	12	13	15	16	25	30	32	51
11	*	4.4	3.4		13.7	3.4	4.0		
12		*	\		3.1	5.1			4.0
13			*		3.0		3.2	3.7	
15				*		4.3	3.4	5.5	
16					*			4.0	
25						*		3.1	17.4
30							*	3.0	
32								*	
51									*

Table 6: Dating F1697/3 to 32BC to AD41. *t* values against some of the chronologies with which it matches.

chronology	*t* value
Caerleon (Hillam unpubl)	4.4
Droitwich, Upwich (Groves & Hillam 1991)	4.5
London, Dowgate Hill (Tyers pers comm)	9.2
Pudding Lane (Hillam unpubl)	6.8
Swan Lane (Groves & Hillam 1987)	5.0
Papcastle, Cumbria (Hillam 1988)	4.7
Snettisham, Norfolk (Hillam 1991a)	3.8
Vindolanda (Hillam 1991b)	4.1

Table 7: Dating the F5300 master, AD1145-1210. *t* values against some of the chronologies with which it matches.

chronology	*t* value
Dublin (Baillie 1977a)	4.1
East Midlands (Laxton & Litton 1988)	5.9
London, Billingsgate periods 8-11 (Hillam unpubl)	6.6
Little Britain (Tyers pers comm)	6.8
Oxford (Haddon-Reece & Miles pers comm)	6.2
Reading (Groves *et al* 1985)	7.5
Scotland (Baillie 1977b)	4.9
Southern England (Bridge 1988)	6.8

Table 8: *t* value matrix for F5726. Values less than 3.0 are not printed.

	3	6	7	13	19	20	22	23	25	27
3	*	5.4			3.8		5.2			6.3
6		*	3.9		10.9		3.2	5.4		9.7
7			*			4.1		6.5	3.7	4.2
13				*			6.1	3.8		
19					*		3.9	4.9		13.1
20						*		4.3		
22							*	3.1	3.9	5.5
23								*	3.3	4.8
25									*	
27										*

Table 9: t value matrix for F5799. Values less than 3.0 are not printed.

	2	3	4	5	6	7	8	9	10	12
2	*	4.4	6.6	8.3	5.7	5.5	5.1		3.7	4.5
	3	*			3.3	4.0		4.4		4.6
		4	*	8.6	10.3	9.3	5.1	4.2	8.1	6.1
			5	*	8.6	6.4	6.4	7.0	5.7	6.2
				6	*	18.1			17.3	7.1
					7	*			16.4	6.0
						8	*	3.3		4.1
							9	*		3.8
								10	*	6.4
									12	*

Table 10: Dating the F5799 master, AD443-842. t values against some of the chronologies with which it matches.

chronology	t value
Barking Abbey (Tyers 1988)	4.5
Hamwic (Hillam 1984)	8.3
Ipswich, Greyfriars 0630 (Hillam 1989)	6.1
London, York Buildings (Tyers 1989)	5.4
Odell, Bedfordshire (Hillam 1981)	4.1
REF8 (Fletcher 1977)	7.9
Tamworth (Baillie pers comm)	5.2

Table 11: t value matrix for F5885. Values less than 3.0 are not printed.

	2	3	4	8	11	14	17
2	*				3.3		5.1
	3	*	4.7		4.4		
		4	*		5.8		
			8	*		8.3	3.1
				11	*	4.3	4.3
					14	*	3.3
						17	*

Table 12: Tree-ring data from Roman timber, F1697/3.

date	ring widths (0.01mm)									
32BC									320	436
	476	310	382	482	552	514	326	266	464	372
	274	218	228	292	296	358	394	320	360	186
	296	334	234	270	278	220	198	240	192	148
AD1	216	308	204	182	152	200	218	170	186	186
	150	160	154	130	178	194	230	232	218	244
	234	220	166	250	234	192	232	270	196	128
	194	180	230	208	172	216	168	248	146	160
	184									

Table 13: F5300 master chronology, AD1157-1241.

date	ring widths (0.01mm)										no of samples									
AD1157							478	638	495	546							1	1	1	1
	448	513	506	526	433	338	410	512	638	456	1	1	1	1	1	1	1	1	1	1
	574	345	560	408	399	424	202	339	300	200	1	1	1	1	1	1	1	1	1	1
	250	374	299	201	197	242	299	277	402	406	1	1	1	1	1	1	1	2	2	2
	257	304	342	240	252	293	196	106	164	199	2	2	2	2	2	2	2	2	2	2
AD1201	261	197	232	124	188	128	129	155	140	217	2	2	2	2	2	2	2	2	2	2
	185	131	92	146	114	183	121	145	152	206	2	2	2	2	2	2	2	2	2	2
	277	225	284	205	241	263	140	334	403	289	2	2	2	2	2	2	2	2	2	2
	140	119	128	228	231	204	349	297	261	186	2	2	2	2	2	2	2	2	2	2
	129										1									

Table 14: A Winchester tree-ring chronology, AD443-1128.

date	ring widths (0.01mm)										no of samples									
AD443			193	237	197	229	275	277	273	295			1	1	1	1	1	1	1	1
AD451	247	175	193	147	147	183	229	165	195	131	1	1	1	1	1	1	1	1	1	1
	199	139	179	93	65	165	143	167	167	133	1	1	1	1	1	1	1	2	2	3
	92	86	140	129	119	149	154	111	120	151	3	3	3	3	3	3	3	3	3	3
	108	105	109	110	115	157	152	89	74	49	3	3	3	3	3	3	3	3	3	3
	76	66	130	104	119	129	101	123	104	132	3	3	3	3	3	3	3	3	3	3
AD501	121	100	84	96	140	105	92	109	149	143	3	3	3	3	3	3	3	3	3	3
	143	113	97	143	134	116	162	111	88	86	3	3	3	3	3	3	3	3	3	3
	75	70	70	122	112	98	109	126	82	81	3	3	3	3	3	3	3	3	4	4
	97	106	95	112	130	76	77	68	59	45	4	4	4	4	4	4	4	4	4	4
	70	73	74	100	93	96	60	81	97	112	4	5	5	5	5	5	5	5	5	5
AD551	86	93	106	103	63	36	61	88	109	99	5	5	6	6	6	5	5	5	5	5
	80	78	51	67	50	80	101	109	100	102	5	5	5	5	6	6	6	6	6	6
	71	52	42	78	74	58	73	102	118	103	6	6	6	6	6	6	6	6	6	6
	106	111	68	51	64	85	95	98	81	68	6	6	6	6	6	6	6	6	6	6
	64	57	89	73	57	62	88	64	84	75	6	6	6	6	6	6	6	6	6	6
AD601	85	90	77	62	75	96	94	93	84	87	6	6	6	6	6	6	6	6	6	6
	100	84	68	97	76	68	86	71	49	38	6	6	6	6	6	6	6	6	6	6
	59	81	109	91	95	98	67	106	72	80	6	6	6	6	6	6	6	6	7	7
	81	87	113	98	96	153	116	95	131	108	7	7	7	7	7	7	7	7	7	7
	103	95	115	98	114	110	121	118	124	94	7	7	7	7	7	7	7	7	7	7
AD651	73	91	107	115	114	125	114	125	101	113	8	8	8	8	8	8	8	8	8	8
	107	102	135	97	107	97	94	73	74	79	8	8	8	8	8	8	8	8	8	8
	84	112	98	114	94	70	75	87	95	70	8	8	8	8	8	8	8	8	8	8
	93	95	101	95	117	131	123	75	73	111	8	7	7	7	7	8	8	8	8	8
	137	115	117	105	119	110	91	81	114	117	8	8	8	8	8	9	9	9	9	9
AD701	112	97	101	112	94	100	71	65	84	76	9	9	9	9	9	9	9	9	9	9
	106	103	96	86	97	98	91	130	104	109	9	9	9	9	9	9	9	10	10	10
	104	101	107	95	86	99	135	138	127	108	10	10	10	10	10	10	10	10	10	10
	98	94	112	103	75	61	84	99	106	133	10	10	10	10	10	10	10	10	10	10
	117	100	117	134	159	155	114	123	94	89	10	10	10	10	10	10	10	10	10	10
AD751	92	113	135	122	111	101	85	116	106	122	10	10	10	11	11	11	11	11	11	11
	116	137	79	84	87	102	130	146	128	104	11	11	11	11	11	11	12	12	12	13
	105	119	130	104	94	82	117	111	80	75	13	13	13	13	13	13	13	13	12	12
	119	115	129	128	125	115	101	119	93	111	12	12	12	12	12	12	12	12	12	12
	84	89	79	88	114	102	119	122	121	112	12	12	12	12	12	12	12	12	12	12
AD801	105	114	101	81	79	78	101	82	111	117	12	12	12	12	12	12	12	11	11	11
	140	124	141	119	140	142	137	135	106	102	11	11	11	11	12	12	13	13	14	15
	108	112	102	156	157	180	129	156	146	126	14	13	13	14	13	12	12	13	14	14
	158	165	172	169	124	138	187	118	114	154	14	14	14	14	15	15	15	15	15	15
	181	158	135	162	172	157	138	113	121	138	15	15	15	16	17	17	19	20	20	22
AD851	119	160	162	141	147	150	140	127	131	128	23	24	24	25	25	25	25	25	25	26
	111	129	136	136	153	154	152	166	181	144	26	26	27	27	28	28	29	29	29	29
	122	95	147	116	154	196	143	152	163	191	30	30	30	30	31	31	31	31	32	33
	165	139	129	88	100	137	155	150	138	145	33	33	33	33	33	33	33	33	33	33
	158	158	138	129	146	142	120	124	115	146	34	34	34	34	34	34	34	34	34	34

Winchester chronology/cont

date	ring widths (0.01mm)										no of samples									
AD901	140	140	148	134	122	132	163	126	148	120	34	34	34	34	34	34	35	35	35	35
	138	162	148	138	130	117	152	125	125	114	35	35	34	34	34	35	35	35	35	35
	113	131	137	111	157	116	161	162	146	141	35	35	35	35	35	35	34	33	32	32
	109	124	102	124	114	132	161	126	117	112	32	31	31	30	30	30	30	30	29	27
	117	97	89	113	123	118	136	117	114	132	27	27	27	27	26	26	26	25	26	25
AD951	120	148	125	115	98	81	101	114	130	139	25	23	22	22	22	21	21	21	21	21
	149	123	129	117	87	104	119	127	117	129	21	21	21	21	20	20	19	17	17	17
	110	138	128	104	116	107	136	107	129	169	17	17	17	17	16	15	15	13	13	13
	112	143	178	108	140	143	158	120	194	139	11	11	9	9	9	9	8	8	6	5
	159	156	123	129	114	92	110	121	165	154	4	4	4	4	4	4	4	4	4	4
AD1001	136	121	154	198	150	211	168	228	190	164	4	4	4	4	3	3	3	3	3	3
	147	193	165	114	159	131	148	136	127	136	3	3	3	3	3	3	3	3	3	3
	157	153	132	135	125	171	162	126	114	149	3	3	3	3	3	3	3	3	3	3
	139	107	140	183	147	134	184	142	130	146	2	1	1	1	1	1	1	1	1	1
	202	211	179	110	176	123	166	138	128	63	1	1	1	1	1	1	1	1	1	1
AD1051	134	95	116	113	139	144	89	146	109	91	1	1	1	1	1	1	1	1	1	1
	125	103	146	106	72	113	158	125	111	142	1	1	1	1	1	1	1	1	1	1
	155	131	138	132	141	184	139	113	97	155	1	1	1	1	1	1	1	1	1	1
	104	145	127	127	156	119	120	142	128	126	1	1	1	1	1	1	1	1	1	1
	101	142	140	103	119	126	106	110	133	120	1	1	1	1	1	1	1	1	1	1
AD1101	86	89	104	83	88	94	126	110	156	100	1	1	1	1	1	1	1	1	1	1
	101	110	100	94	95	80	93	110	73	79	1	1	1	1	1	1	1	1	1	1
	74	58	55	78	64	66	58	74			1	1	1	1	1	1	1	1		

Table 15: Tree-ring data from dated beech sample, F1087/22.

date	ring widths (0.01mm)									
AD906					88	118	170	179	207	
	173	162	200	124	102	109	155	185	204	121
	102	116	137	186	159	151	155	124	169	135
	119	135	83	141	195	191	204	221	128	195
	251	210	214	150	152	190	248	222	204	144
AD951	101	140	122	88	54	43	98	145	147	184
	211	150	144	114	62	84	79	67	57	49
	93	45	65	98	90	42	53	65	67	38
	16	20	33	39	40	68	33	43	50	28
	65	71	61	79	47	85	77	64	87	130
AD1001	124	168	188	165	105	92	127	144	121	79
	92	86	49	71	56	43	41	54	35	80
	75	75	51	51	72	79	78	65	65	58
	33	49	76	89	28	17	26	46		

Table 16: Dating the Winchester chronology, AD443-1128. A few of the t values with independent reference chronologies.

chronology	t value
Beverley, Eastgate (Groves 1990)	6.1
Bristol, Dundas Wharf (Nicholson & Hillam 1987)	6.8
Droitwich, Upwich 2 (Groves & Hillam 1991)	6.8
Dublin (Baillie 1977a)	6.4
Exeter (Hillam 1980)	7.4
Hamwic (Hillam 1984)	9.7
London, Billingsgate periods 4-7 (Hillam 1991c)	10.4
Billingsgate periods 8-11 (Hillam unpubl)	6.1
Fennings Wharf (Tyers pers comm)	9.6
Merton Priory (Tyers pers comm)	7.8
Seal House (Hillam 1991c)	7.6
Swan Lane (Groves & Hillam 1987)	6.4
REF6 (Fletcher 1977)	10.5
REF8 (Fletcher 1977)	8.1
Southampton Friary (Hillam unpubl)	5.9