The Archaeology of York **Anglo-Scandinavian York** 8/5

# Anglo-Scandinavian Occupation at 16–22 Coppergate:

## Defining a Townscape

*Appendix 3:*

# Tree-Ring Analysis of the Anglo-Scandinavian Oak Timbers

*by Cathy Tyers and Jennifer Hillam*

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# Tree-Ring Analysis of the Anglo-Scandinavian Oak Timbers

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*Please note:* The full report which appears below appears in a shortened version in the published volume, AY8/5 *Anglo-Scandinavian Occupation at 16–22 Coppergate: Defining a Townscape* (Hall *et al*, 2014)

## Introduction

Excavations at 16–22 Coppergate revealed large quantities of waterlogged wood and timber. The dendrochronological investigation was initiated in 1977, since when over 400 timber samples have been submitted for analysis. As the analysis proceeded a series of archive reports were produced for the Anglo-Scandinavian and medieval phases of the main excavation (Hillam 1985; 1987; 1989) and of the watching brief (Groves and Hillam 1986; Hillam 1992a). This report draws together all the results from the timbers associated with the Anglian (Period 2) and Anglo-Scandinavian (Periods 3–5) deposits. The results from the medieval and post-medieval timbers (Period 6) are similarly synthesised in Hillam (2002) and Groves (2002).

Nearly a third (32%) of the samples were rejected as unsuitable for dendrochronological analysis but 200 samples were analysed from Periods 2–5 and 78 from Period 6. Dating proved very difficult initially because of the lack of suitable reference chronologies available in the late 1970s and early 1980s. Consequently the tree-ring dates have been produced over a period of 20 or so years as the network of reference chronologies available has been extended both temporally and geographically. Prior to the production of this report all the Coppergate data were re-analysed, primarily in order to confirm the results previously obtained but also to ascertain whether any additional dating evidence could now be produced. The data have also provided a valuable resource for the investigation of other aspects of dendrochronology, such as the development of cross-matching techniques (Okasha 1987) or the extraction of non-chronological information (Holman nd).

The earliest timbers analysed, assigned to Period 2, were associated with the pit in which the Coppergate Anglian helmet was found (Hillam 1992a). Relatively few timbers were obtained from either this period or Period 3, the earliest of the Anglo-Scandinavian levels. The tenement boundaries were laid down in Period 4, which also saw the erection of post and post-and-wattle structures. The wattle material was clearly unsuitable for dendrochronology but samples were obtained from some of the posts. Period 5A was a relatively short-lived episode of soil build up resulting from the accumulation of occupation debris, general dumping and the digging out of the foundations of the sunken buildings. Period 5B saw the construction of the sunken buildings and it is from this phase that the bulk of the tree-ring samples come.

When the Coppergate dendrochronological investigation was initiated the primary objective was to provide a precise dating framework. The application of dendrochronology to site-specific archaeological issues was in its pioneer phase and the development of a network of chronologies still very much in its infancy. During the subsequent 20 years the technique has been steadily developed and refined, its potential more widely recognised and its limitations more clearly understood. Current understanding would certainly have affected the way in which the Coppergate dendrochronological investigation was approached and the ability of the assemblage to achieve the primary objective more clearly understood but this can only now been said with the benefit of subsequent decades of experience and hindsight. The ability to provide precise dating evidence is the underlying strength of dendrochronology but the wider potential of the method to provide environmental and socio-economic information is now being increasingly exploited. Consequently the aims of the Coppergate dendrochronological analysis were gradually widened in an attempt to use the basic tree-ring data to provide information concerning the trees from which the timbers were derived, their environment and hence the historic landscape. Such information aids the understanding of past woodland economies, demonstrates the changes in tree utilisation patterns through time, and also indicates the origin of the timbers.

# Methods

Professional practice at the Sheffield Dendrochronology Laboratory is described in English Heritage (1998). The following summarises relevant methodological details used for the analysis of the Coppergate samples. Any variations due to the analysis having occurred over an extended period, during which the discipline has made a series of technical advancements, are noted as necessary.

Oak (*Quercus* spp.) is currently the only species used for routine dating purposes in the British Isles, although research on other species is being undertaken (e.g. Tyers 1997a; Groves 1997). Timbers with fewer than 50 annual growth rings are now generally considered unsuitable for analysis as their ring patterns may not be unique (Hillam *et al.* 1987). Thus oak timbers are generally sought which have at least 50 rings and if possible either bark or bark-edge of some sapwood surviving (see below). However, during the course of the study of the Coppergate material some samples with fewer than 50 rings were included for full analysis as part of a collaborative project with the Department of Probability and Statistics at Sheffield University.

The samples were prepared by being frozen for a minimum of 48 hours before their cross-sectional surface was cleaned with a surform plane and scalpels until the annual growth rings were clearly defined. Any samples which failed to contain the minimum number of rings or had unclear ring sequences were rejected. The equipment used to measure the ring widths varied as the analysis progressed (Hillam 1985, 1987, 1989, and 1992a; Groves and Hillam 1986). All the measuring machines were based on travelling stages which allow the sample to be moved from one ring to the next whilst being viewed under a binocular microscope. Ring widths were originally recorded by hand and later typed into the mainframe or microcomputer whereas they are now input directly into the computer using a PC Windows-based measuring system (Tyers 1997b). The sequence of growth rings in the samples selected for dating purposes were measured to an accuracy of 0.1mm, 0.02mm, or 0.01mm depending on when and how the measurement took place. All old system measurements were multiplied by the relevant factor in order to make them compatible with the current system measuring to an accuracy of 0.01mm. On oak, it is usual to measure a single radius as this is considered a reliable representation of the growth pattern of the tree. However, during the initial analysis at Coppergate two radii per sample were frequently measured and averaged to produce a single timber sequence in an attempt to increase the dating potential.

The ring sequences were plotted onto semi-logarithmic graph paper to enable visual comparisons to be made between them. In addition, cross-correlation algorithms (Baillie and Pilcher 1973; Munro 1984) were employed to search for positions where the ring sequences were highly correlated. The Student's $t$ test was then used as a significance test on the correlation coefficient and those quoted below are derived from the original CROS algorithm (Baillie and Pilcher 1973). A $t$ value of 3.5 or over is usually indicative of a good match (Baillie 1982, 82–5), provided that high $t$ values are obtained at the same relative or absolute position with a series of independent sequences and that the visual match is satisfactory.

Dating is usually achieved by cross-correlating, or cross-matching, ring sequences within a phase or structure and combining the matching patterns to form a phase or site master curve. This master curve and any remaining unmatched ring sequences are then tested against a range of reference chronologies, using the same matching criteria as above. The position at which all the criteria are met provides the calendar dates for the ring sequences. A master curve is used for scientific dating purposes whenever possible as it enhances the common climatic signal and reduces the background 'noise' resulting from the local growth conditions of individual trees. Although this method was used for the re-analysis immediately prior to the production of this report it was usually not possible during the initial study to undertake such a structured approach to the analysis because of the complex nature of the site and sample availability. In addition, due to problems encountered during the initial analysis of the Coppergate samples, a collaborative project was initiated with the Department of Probability and Statistics at Sheffield. New analytical programs were developed which, whilst generally based on the CROS program, incorporated other statistical methods (Okasha 1987). The results from these proved to be basically identical to those obtained through the 'traditional' methods, thus providing additional confirmation of the validity of the tree-ring dates.

During the cross-matching stage an additional important element of tree-ring analysis is the identification of 'same-tree' timber groups. The identification of 'same-tree' groups is based on very high levels of similarity in year to year variation, longer-term growth trends, and anatomical anomalies. Such information should ideally be used to support possible 'same-tree' groups identified from similarities in the patterns of knots/branches during detailed recording of timbers for technological and woodland characterisation studies. Timbers originally derived from the same parent log generally have $t$ values of greater than 10.0, though lower $t$ values do not necessarily exclude the possibility. It is a balance of the range of information available that provides the 'same-tree' link.

The cross-dating process provides precise calendar dates only for the rings present in the timber. The nature of the final ring in the sequence determines whether the date of this ring also represents the year the timber was felled. Oak consists of inner inert heartwood and an outer band of active sapwood. If the sample ends in the heartwood of the original tree, a *terminus post quem* for the felling of the tree is indicated by the date of the last ring plus the addition of the minimum expected number of sapwood rings which are missing. This is the date after which the timber was felled but the actual felling date may be many decades later depending on the number of outer rings removed during timber conversion. Where some of the outer sapwood or the heartwood/sapwood boundary survives on the sample, a felling date range can be calculated using the maximum and minimum number of sapwood rings likely to have been present. The sapwood estimate applied throughout this report is a minimum of 10 and a maximum of 46 rings, where these figures indicate the 95% confidence limits of the range and are applicable to oak trees from England and Wales (Tyers 2000a). Alternatively, if bark-edge survives, then a felling date can be obtained directly from the date of the last surviving ring. In some instances it may be possible to determine the season of felling according to whether the ring immediately below the bark is complete or incomplete. However, the onset of growth can vary within and between trees and this, combined with the natural variation in actual ring width, means that the determination of felling season must be treated cautiously. The delicate nature of sapwood, particularly on waterlogged timbers, increases the likelihood of damage/degradation to the outermost surface of the sample and hence increases the difficulties of positive identification of bark-edge.

The felling dates produced by the technique do not by themselves necessarily indicate the date of the structure from which they are derived. Evidence indicates that seasoning of timber for structural purposes was a fairly rare occurrence until relatively recent times and medieval timber was generally felled as required and used whilst green (e.g. Rackham 1990; Charles and Charles 1995). Physical evidence for the rapid use of trees is widespread in buildings as many show clear evidence of warping or splitting after having undergone conversion. Hollstein (1980) gives examples of use of green timber from earlier periods. However, it is necessary to incorporate other specialist evidence concerning the re-use of timbers and the repair or modification of structures, as well as factors such as stockpiling, seasoning, and transport, before dendrochronological dates can be reliably interpreted as reflecting the construction date of a structure or phases within it.

## The tree-ring dating evidence

Details of the timbers submitted for dendrochronological analysis are given in Tables 34 and 35. Information regarding the dating of most of the individual timbers are given in the archive reports, although some additional timbers have been dated during re-analysis. The dating evidence derived from the dendrochronological analysis is summarised below in terms of the main period subdivisions into which the site's development has been split during archaeological interpretation and also by the four tenement plots recognised within the excavated area. The precise felling dates obtained from timbers with bark-edge clearly show that the development sequence of the site, as represented by preserved timber remains, is intense and extremely compressed, with the bulk of the constructional activity occurring in the latter half of the 10th century. This is, however, based solely on the dendrochronological evidence and consequently excludes other archaeological evidence for activity. Dates of ring sequences for each timber, along with its individual felling date, are set out in Table 1 and are illustrated in **Figure 1**. A new Coppergate Anglo-Scandinavian chronology, YORKCPG3, was constructed in 2000 from the dated timbers. It spans the period 460–1011 and includes data from 168 ring sequences. This chronology and its individual components show particularly strong similarities with chronologies from surrounding areas but also, since it is so well-replicated (i.e. data included from many individual samples), it matches well with chronologies over much longer distances (Table 3). A summary of the dating evidence obtained is given in **Figure 2** and Table 4. Please note that all dates cited below are AD.

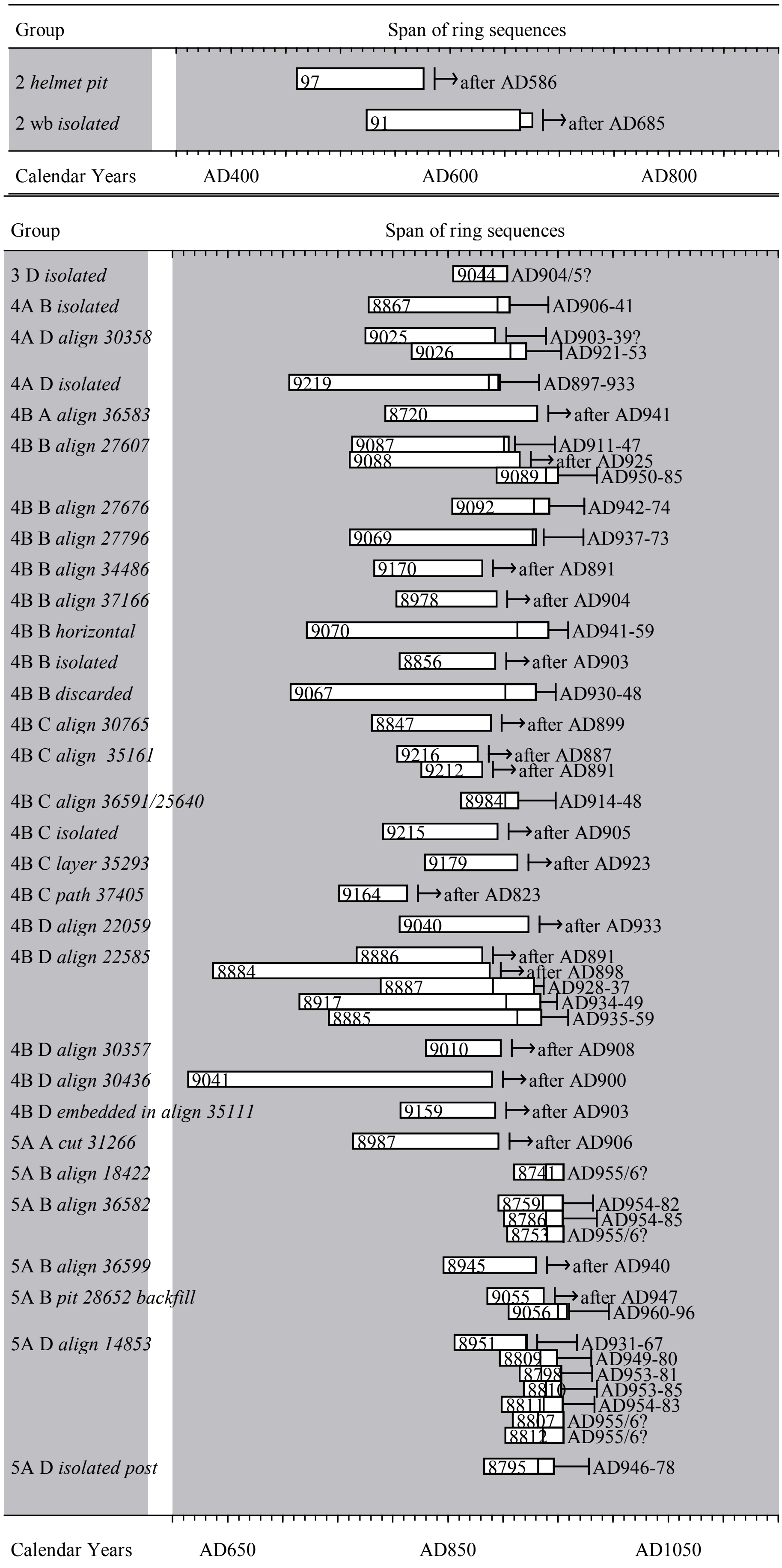
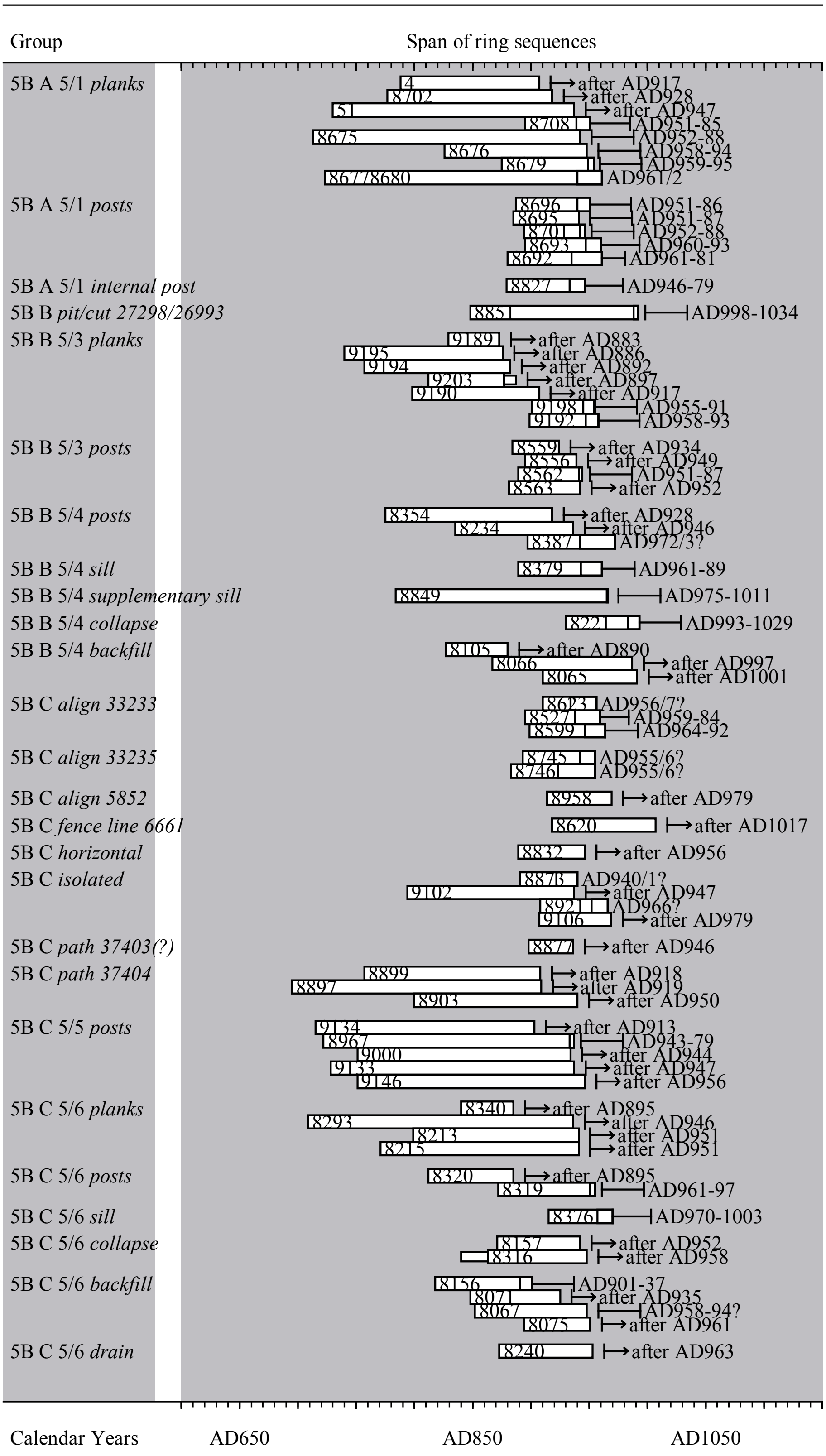



***Fig.1*** *Bar diagram showing the relative positions of the dated ring sequences from Periods 2-5 and their associated felling dates.*



Group
Span of ring sequences
5B A 5/1 planks
4 after AD917
8702 after AD928
51 after AD947
8708 AD951-85
8675 AD952-88
8676 AD958-94
8679 AD959-95
86778680 AD961/2
5B A 5/1 posts
8696 AD951-86
8695 AD951-87
8701 AD952-88
8693 AD960-93
8692 AD961-81
5B A 5/1 internal post
8827 AD946-79
5B B pit/cut 27298/26993
8851 AD998-1034
5B B 5/3 planks
9189 after AD883
9195 after AD886
9194 after AD892
9203 after AD897
9190 after AD917
9198 AD955-91
9192 AD958-93
5B B 5/3 posts
8559 after AD934
8556 after AD949
8562 AD951-87
8563 after AD952
5B B 5/4 posts
8354 after AD928
8234 after AD946
8387 AD972/3?
5B B 5/4 sill
8379 AD961-89
5B B 5/4 supplementary sill
8849 AD975-1011
5B B 5/4 collapse
8221 AD993-1029
5B B 5/4 backfill
8105 after AD890
8066 after AD997
8065 after AD1001
5B C align 33233
8623 AD956/7?
8527 AD959-84
8599 AD964-92
5B C align 33235
8745 AD955/6?
8746 AD955/6?
5B C align 5852
8958 after AD979
5B C fence line 6661
8620 after AD1017
5B C horizontal
8832 after AD956
5B C isolated
8878 AD940/1?
9102 after AD947
8921 AD966?
9106 after AD979
5B C path 37403(?)
8877 after AD946
5B C path 37404
8899 after AD918
8897 after AD919
8903 after AD950
5B C 5/5 posts
9134 after AD913
8967 AD943-79
9000 after AD944
9133 after AD947
9146 after AD956
5B C 5/6 planks
8340 after AD895
8293 after AD946
8213 after AD951
8215 after AD951
5B C 5/6 posts
8320 after AD895
8319 AD961-97
5B C 5/6 sill
8376 AD970-1003
5B C 5/6 collapse
8157 after AD952
8316 after AD958
5B C 5/6 backfill
8156 AD901-37
8071 after AD935
8067 AD958-94?
8075 after AD961
5B C 5/6 drain
8240 after AD963
Calendar Years
AD650
AD850
AD1050


***Fig.1*** *(cont'd).*

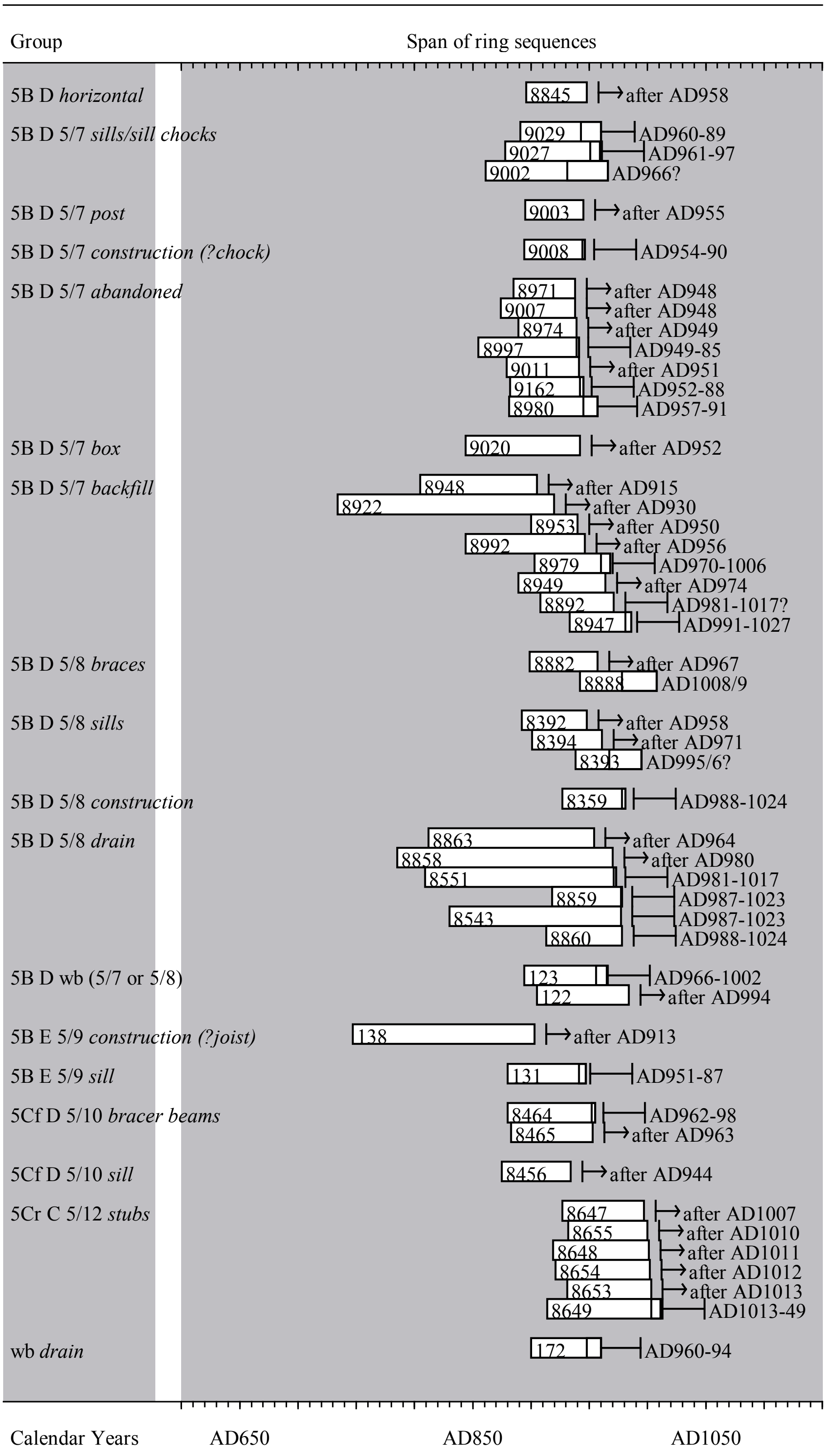

Group
Span of ring sequences
5B D horizontal
8845 after AD958
5B D 5/7 sills/sill chocks
9029 AD960-89
9027 AD961-97
9002 AD966?
5B D 5/7 post
9003 after AD955
5B D 5/7 construction (?chock)
9008 AD954-90
5B D 5/7 abandoned
8971 after AD948
9007 after AD948
8974 after AD949
8997 AD949-85
9011 after AD951
9162 AD952-88
8980 AD957-91
5B D 5/7 box
9020 after AD952
5B D 5/7 backfill
8948 after AD915
8922 after AD930
8953 after AD950
8992 after AD956
8979 AD970-1006
8949 after AD974
8892 AD981-1017?
8947 AD991-1027
5B D 5/8 braces
8882 after AD967
8888 AD1008/9
5B D 5/8 sills
8392 after AD958
8394 after AD971
8393 AD995/6?
5B D 5/8 construction
8359 AD988-1024
5B D 5/8 drain
8863 after AD964
8858 after AD980
8551 AD981-1017
8859 AD987-1023
8543 AD987-1023
8860 AD988-1024
5B D wb (5/7 or 5/8)
123 AD966-1002
122 after AD994
5B E 5/9 construction (?joist)
138 after AD913
5B E 5/9 sill
131 AD951-87
5Cf D 5/10 bracer beams
8464 AD962-98
8465 after AD963
5Cf D 5/10 sill
8456 after AD944
5Cr C 5/12 stubs
8647 after AD1007
8655 after AD1010
8648 after AD1011
8654 after AD1012
8653 after AD1013
8649 AD1013-49
wb drain
172 AD960-94
Calendar Years
AD650
AD850
AD1050

***Fig.1*** *(cont'd).*

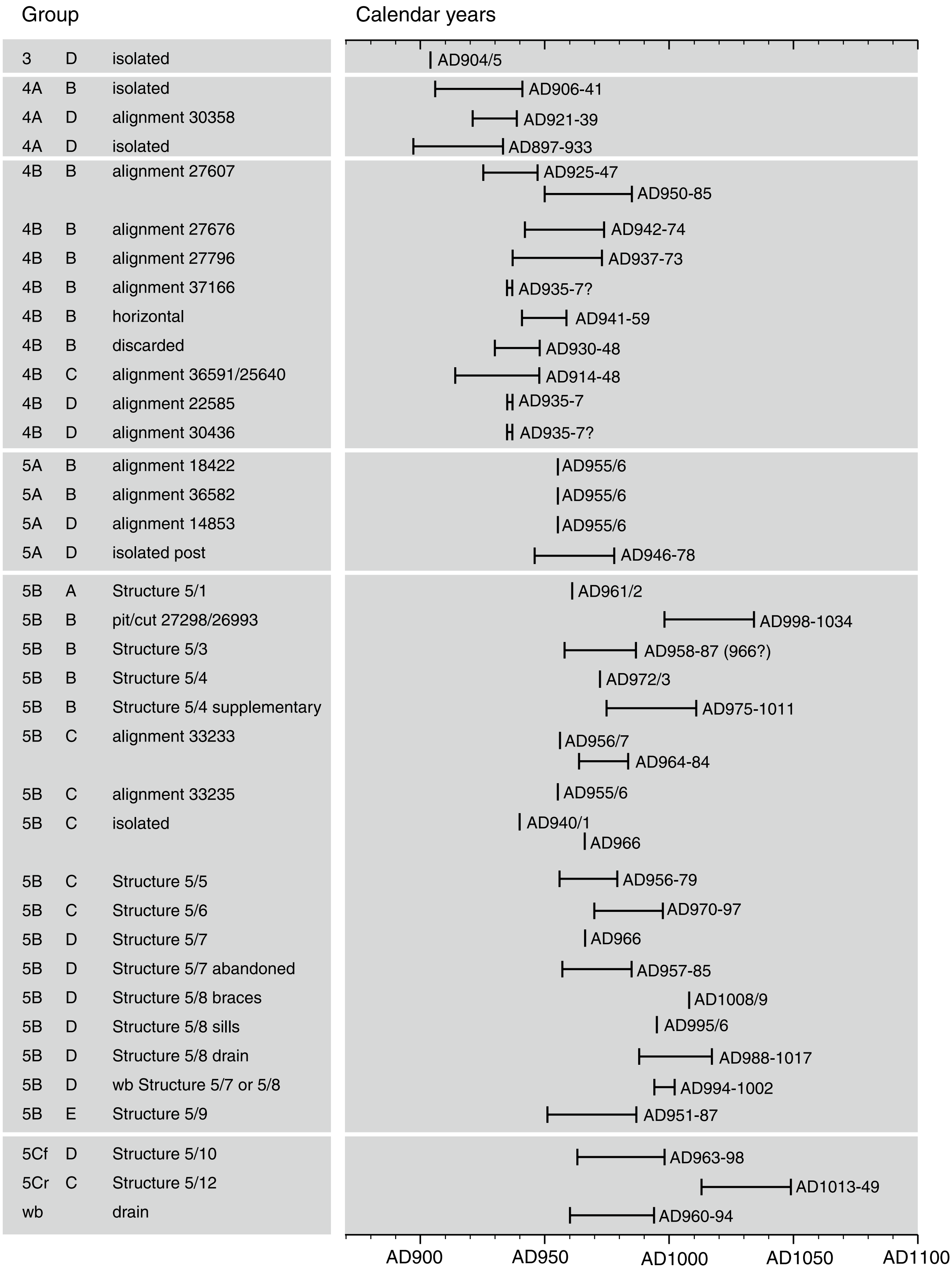



**Fig.2** *Summary of the interpreted felling dates or date ranges. Period 2 is excluded, as are all structures for which the results only produced a* terminus post quem *for felling.*

## *Period 2*

The only 'helmet pit' timber that was dated (97) was felled after 586. If this timber is taken to be representative of the date of construction of the pit then the strict dendrochronological interpretation is that the pit was dug and lined after 586. Although the backfill deposits have biological characteristics more similar to those of the Anglo-Scandinavian period, it is relatively unlikely that the timber represents the inner portion of a tree over 400 years old (ie from the 10th century), so this timber appears to date the construction of the pit to the Anglian period. The helmet itself was made c.750–75, and was not new at the time it was put into the pit (*AY* 17/8).

The only other dated timber from Period 2 is 91, an isolated timber found during the watching brief. This was felled some time after 685, and again probably indicates activity in the Anglian period.

The dendrochronological results for Period 2 suggest that there was activity in the vicinity during the Anglian period, though, in the absence of sapwood, precise dating evidence cannot be provided. This evidence is, however, based on only two dated samples.

## *Period 3*

A single isolated timber, 9044, was dated. The outermost measured ring was identified as likely to be that immediately under the bark. This indicates that the timber was probably felled in the winter of 904/05.

The dendrochronological results support other archaeological indications of activity on the site in the very early 10th century, though the evidence for this is provided by only a single timber.

## *Period 4A*

### Tenement B

An isolated timber, 8867, was felled during the period 906–41.

### Tenement D

Two posts (9025 and 9026) from alignment 30358 were dated. These timbers are components in a clearly defined single alignment and consequently a combined felling date range of 921–39, and a possible construction date, is indicated. An isolated timber, 9219, was felled during the period 897–933.

The dendrochronological results suggest that this period dates to the early/mid-10th century which supports other archaeological evidence. The activity is thought to be continuous and the few dated timbers imply that on Tenements B and D construction work is broadly contemporaneous, though in the absence of bark-edge it is not possible to determine whether these are precisely contemporary or whether the periods of felling are in fact several years apart.

## *Period 4B*

### Tenement B

Three timbers from alignment 27607 were dated. The similarities between **9087** and 9088 suggest they are likely to be contemporaneous, indicating a felling date range of 925–47. Timber 9089, however, was felled later during the period 950–85. These results may indicate the date of construction and a subsequent repair or alternatively could indicate the presence of re-used timber within the alignment. There is no other evidence to indicate re-use, however.

Timber 9092 from alignment 27676 was felled between 942 and 974. A single timber from alignment 27796 was dated; this had a felling date range of 937–73, suggesting a construction date in the mid-10th century. The only dated timber from alignment 34486 was felled after 891. The single dated timber, **8978**, from alignment 37166 was felled after 904. However, this timber appears to have been derived from the same tree as timber **8887** from Period 4B, Tenement D, alignment 22585, so it was probably actually felled during the period 935–37. Timber **9070**, a horizontal, was felled between 941 and 959. An isolated timber, **8856**, was felled after 903 and a discarded timber fragment, **9067**, was felled during 930–48.

Ten timbers were dated from Tenement B, the majority of which tend to indicate activity around the mid-10th century, with felling dates potentially as early as the 930s but as late as the 980s.

### Tenement C

The only dated timber from alignment 30765 was felled after 899. Two timbers from alignment 35161 were dated; if these are contemporaneous then both were felled after 891. The single dated timber from alignment 36591/25640 was felled during 914–48. An isolated timber, **9215**, was felled after 905. A horizontal in layer 35293 was felled after 923 and another horizontal in path 37405 was felled after 823.

Only one of the seven dated timbers from Tenement C produced a felling date range. This implied activity during the first half of the 10th century. The remaining timbers produced *termini post quem* for felling which range from as early as 823 to as late as 923.

### Tenement D

The only dated timber from alignment 22059 was felled after 933. Two timbers (8884, 8885) from alignment 22585 are probably derived from the same tree, with the possibility that a third timber (8886) is also derived from that tree. All five dated timbers from this alignment at the west side of the tenement appear likely to be contemporaneous and were therefore probably felled in the period 935–37 and used shortly afterwards in the construction of the alignment. In addition, 8887 appears to have been derived from the same tree as 8978 (Period 4B, Tenement B, alignment 37166), whereas 8884 and 8885 were probably derived from the same tree as 9041 (Period 4B, Tenement D, alignment 30436).

The only dated timber from alignment 30436, located at the east side of the tenement, has no sapwood and hence has a *terminus post quem* for felling of 900. However, timber 9041 appears to have been derived from the same tree as timbers 8884 and 8885 from alignment 22585 and was thus also probably felled and initially used in the period 935–37. The single dated post from alignment 30357 was felled after 908 and timber 9159, which was embedded in alignment 35111, was felled after 903.

Nine timbers were dated from Tenement D of which the six from alignments 22585 and 30436, lying at the west and east side of the tenement respectively, appear to have been felled in the mid-930s. The remaining timbers produced *termini post quem* for felling in the first third of the 10th century.

### Period 4B summary

The dendrochronological results indicate building activity during the mid-10th century on Tenements B, C and D. However, the evidence derived from later periods suggests that the constructional activity in Period 4B occurred prior to the mid-950s (see below). The identification of two timbers derived from the same tree but found on Tenements B and D provides a direct link, implying contemporaneous construction work in the mid-930s on these two tenements.

## *Period 5A*

### Tenement A

There were two dated timbers from Tenement A. One from alignment 37253, 8720, was felled after AD 941. The other, a barrel stave from cut 31266, was felled after 906. The cut is for a barrel-lined well/pit which has a well-defined stratigraphical relationship. It clearly pre-dates Structure 5/1 (Period 5B, Tenement A) which cuts into 31266, whereas 31266 itself cuts through Period 4B levels. Consequently it must have been felled before the 961/62 construction date indicated for Structure 5/1 (see below).

### Tenement B

The outermost ring on the only dated timber from alignment 18422 dates to 955 and has been identified as likely to be that immediately under the bark. This indicates that the timber was probably felled in the winter of 955/56 and hence may imply construction of this alignment shortly afterwards. The three dated timbers from alignment 36582 (8753, 8759, 8786) appear likely to be contemporaneous. The outermost measured ring of timber 8753 was identified as likely to be that immediately under the bark. This indicates that these timbers were also all probably felled in the winter of 955/56, again implying a possible construction date shortly after felling for this alignment.

The single dated timber from alignment 36599 was felled after 940. Two timbers from the backfill of pit 28652 were dated. The timbers have very different visual characteristics and their ring patterns show no similarity, although the overlap is only 33 years. In the absence of bark-edge and hence the provision of precise felling dates, it is possible that these timbers represent two felling phases both of which probably occur in the second half of the 10th century. The implication is that the pit was probably backfilled some years after these two timbers were originally used. The earliest possible primary use of timber 9056 is 960 which clearly post-dates the 955/56 felling phase obtained for other timbers from Period 5A.

The seven dated Tenement B timbers indicate felling activity in the mid–late 10th century, with two alignments containing timbers felled in 955/56 but with the backfill of a pit containing timber felled after this in the later 10th century.

### Tenement D

The seven dated timbers from alignment 14853, two of which are probably derived from the same tree (8807, 8809), appear likely to be contemporaneous. The heartwood-sapwood boundaries date to within a few years of each other with the possible exception of 8951. The outermost measured ring was identified as likely to be that immediately under the bark on timbers 8807 and 8812. This implies that all seven timbers were likely to have been felled in the winter of 955/56 and hence probably used shortly afterwards in the construction of the alignment. An isolated post, timber 8795, was felled during the period 946–78.

The eight dated timbers from Tenement D again indicate felling activity in the mid–late 10th century, with two timbers from the dated alignment being felled in 955/56.

### Period 5A summary

Building activity appears to have occurred on Tenements A, B and D in the mid-10th century, and more specifically Tenements B and D appear to be linked by the presence of timbers felled in 955/56. The archaeological evidence indicates that these timbers are primary material and hence neither re-used nor dumped. There are therefore clear implications for the results from the Period 4B timbers, all of which have felling date ranges compatible with pre-dating the 955/56 felling phase identified in Period 5A. In addition, the evidence from later periods suggests that activity associated with Period 5A is likely to have occurred prior to the early 960s, indicating that this period may well have lasted for only a relatively short time span during the Anglo-Scandinavian phase.

Timber 172 from a covered drain found during the watching brief has a felling date range of 960–94. This felling date range suggests that this timber is most likely to be associated with Period 5A.

## *Period 5B*

The vast majority of the dated timbers (64% or 108/168) are associated with this period.

### Tenement A

### Structure 5/1

Eight planks were dated, of which six (8675, 8676, 8679, 8702, 8708, 8680) are known to be from the east wall of Structure 5/1 and one from the west wall (0051). Planks 0051, 8675, 8676 and 8680 are probably derived from the same tree. It appears likely that all the planks are contemporary. The outermost measured ring of 8680 was identified as that immediately under the bark, implying that all eight planks were probably felled in the winter of 961/62.

Five posts from the east wall of Structure 5/1 were dated, including two derived from the same tree (8695, 8696). These all appear to be contemporaneous and have a combined felling date range of 961–81 which is clearly compatible with the 961/62 felling date obtained from the planks.

The results indicate that both the planks and posts from Structure 5/1 are likely to be contemporary so, in the absence of any evidence of re-use, a construction date shortly after felling in 961/62 is indicated for this double-skinned basemented structure fronting Tenement A. This also provides a date before which cut 31266 (Period 5A, Tenement A) must have been made due to their stratigraphical relationship.

Post 8827 is from a series of paired posts within Structure 5/1. This has a felling date range of 946–79 and was therefore potentially felled at the same time as the timbers used in the construction of Structure 5/1. The similarities between this timber and the posts from the east wall of the structure imply that this post was potentially also felled in 961/62 and that the alignment is likely to be contemporary with the erection of Structure 5/1.

The fourteen dated timbers from Tenement A, all associated with Structure 5/1, indicate building work in the latter half of the 10th century, with the construction of 5/1 probably occurring in the early 960s.

### Tenement B

A horizontal in pit/cut 27298/26993 was felled between 998 and 1034.

### Structure 5/3

Seven planks were dated from the south, east and west walls of this building. 9192 and 9198 are both tangentially converted base planks. These appear contemporary and produce a combined felling date range of 958–91. The remaining five are all radial planks which are thinner than the tangential planks. These have no trace of sapwood and so have *termini post quem* for felling ranging from 883 to 917. The latest rings of the radial planks only overlap those of the tangential planks by nine years. The lack of evidence for re-use suggests that these may well be the inner sections of larger trees. Consequently the five radial planks may be contemporary with planks 9192 and 9198 and hence potentially also felled and used in 958–91.

Four posts from the east wall of the structure were dated. They all appear to be contemporaneous and have a combined felling date range of 952–87 which is clearly compatible with the felling date range obtained from the planks. Post 8556 appears to have been derived from the same tree as timber 9008 which is associated with the Period 5B Structure 5/7 in Tenement D.

If it is assumed that the planks and posts from Structure 5/3 are contemporary they were all probably felled during the period 958–87. In the absence of any evidence of re-use this felling date range reflects the probable construction date of Structure 5/3. However, the same-tree link to a timber in the construction levels of Structure 5/7, possibly a chock, leads to the tenuous suggestion of a construction date of 966 or shortly after for Structure 5/3. Additional weight is given to this suggestion by examination of the quality of the cross-matching between the ring sequences of the Structure 5/3 posts and the Structure 5/7 timbers (see Table 5).

### Structure 5/4

A post from the west wall (8354) and what is believed to be a drain capping (8387), together with another post from the east wall (8234), were dated. The outermost measured ring of 8387 was identified as likely to be that immediately under the bark. If all three are contemporary, they were probably felled in the winter of 972/73, but it may be that the drain was not part of the original construction. Timber 8379, a sill from the east wall, was felled between 961 and 989, which is clearly potentially contemporaneous with the 972/73 felling date indicated by the posts and drain capping. Timber 8849 appears to be a supplementary sill beam at the south end of the west wall though as a result of modern intrusions this archaeological interpretation must be considered tentative. It was felled during 975–1011. The results suggest that Structure 5/4 was constructed shortly after felling in 972/73, with sill 8849 as a later modification.

One plank found in the collapse of 5/4, and possibly part of the structure, was felled between 993 and 1029. This may indicate late 10th- or early 11th-century repairs or modifications being undertaken on Structure 5/4. Three timbers of uncertain origin found in the backfill associated with Structure 5/4 were dated. These give a combined *terminus post quem* for felling of 1001, thereby indicating that Structure 5/4 remained in use for the rest of the 10th century and was not abandoned until the beginning of the 11th century at the very earliest.

The results from 21 dated timbers from Tenement B indicate constructional work in the later 10th century, with some felling activity as late as the early 11th century associated with Structure 5/4 and pit/cut 27298/26993. Structure 5/3, which fronts the tenement, appears to have been constructed during the period 958–87, possibly in 966. Structure 5/4, further back on the tenement, appears likely to have been erected in the early 970s and subsequently modified towards the end of the 10th century or possibly the very early 11th century, indicating that it was in use for a minimum of two decades.

### Tenement C

Three timbers from alignment 33233 were dated. Two of these (8527, 8599) appear likely to be contemporary and have a combined felling date of 964–84. However, the outermost ring of 8623 was thought to be that immediately under the bark, indicating that it was felled in 956/57. This suggests that the alignment was either constructed in the mid-950s and repaired over a decade later or alternatively that it was constructed shortly after felling in 964–84 using both primary and secondary timber, potentially re-using some material from the short-duration Period 5A.

Two timbers from alignment 33235 were dated. The outermost measured ring of both timbers was identified as likely to be that immediately under the bark. This indicates that they were felled in the winter of 955/56. As this alignment is associated with Period 5B it is suggested that these timbers may have been re-used from Period 5A, though it does raise a stratigraphical issue concerning the transition between the two periods.

The only dated timber from alignment 5852 was felled after 979. Timber 8620 is tentatively associated with fence line 6661 which is located to the rear of Structure 5/6. It was felled after 1017 and hence supports other evidence that this fence line is later than Structure 5/6 (see below). Timber 8832, a horizontal, was felled after 956.

Four isolated timbers associated with this tenement have been successfully dated. Two of these have a *terminus post quem* for felling in the mid–late 10th century. However, timber 8873 was probably felled in the winter of 940/41, whilst timber 8921 has a felling date in the summer of 966. A horizontal, possibly associated with path 37403, was felled after 946. Two (8897, 8899) of the three dated horizontals from path 37404 are likely to be derived from the same tree and were therefore both felled after 919. The third timber, 8903, was felled after 950.

### Structure 5/5

Five posts, one of which is from the north wall of the structure, were dated. Two of the posts (9133, 9146) may have been derived from the same tree. These all appear to be contemporaneous and have a combined felling date range of 956–79. In the absence of any evidence of re-use this felling date range reflects the probable construction date of Structure 5/5.

### Structure 5/6

Three planks (8213, 8215, 8293) from the west wall were dated. These appear likely to be contemporaneous and could have derived from the same tree, so were therefore all felled after 951. In addition, one plank from the east wall was dated which has a *terminus post quem* for felling of 895. This may indicate that it has been trimmed heavily, resulting in the loss of a large number of outer rings or alternatively it could be a re-used timber, although no evidence for this was noted. Two posts, also from the west wall, were dated. One has a *terminus post quem* for felling in the late 9th century whilst the other was felled during the period 961–97. The dated sill from the north wall was felled during the period 970–1003. If the planks, posts and sill are contemporaneous a combined felling date of 970–97 is indicated which, in the absence of any evidence for re-use, suggests a construction date for Structure 5/6 in the late 10th century.

Two timbers associated with the collapse of Structure 5/6 both have a *terminus post quem* for felling in the 950s, and could consequently be contemporary with the 970–97 felling date indicated for the timbers from the primary construction of Structure 5/6. Four timbers were dated from the backfill of Structure 5/6. Timber **8156** was felled during the period 901–37, whilst 8067 was probably felled in the period 958–94. Of the remaining two dated timbers, 8071 is probably derived from the same tree as 8067 and was thus also probably felled in 958–94, whilst 8075 was felled after 961. These are broadly contemporaneous with, or even earlier than, the suggested construction date of Structure 5/6 and are consequently unable to assist in determining when the structure was abandoned.

Timber 8240, a horizontal from the drain in Structure 5/6, was felled after 963 which shows that the drain could be broadly contemporary with the initial construction of Structure 5/6.

Thirty-five timbers were dated from Tenement C, the majority of which tend to indicate activity in the later 10th century, though there are a number of outliers. One of the isolated timbers (8873) was felled in 940/41 and is thought likely to be re-used in this context, whilst timber 8156 has a felling date range in the first half of the 10th century but is from the backfill associated with Structure 5/6. In addition, the felling date of 955/56 obtained for the two timbers from alignment 33235 is precisely that obtained for a number of timbers associated with Period 5A which suggests that these may be re-used in this context. This re-use theory is supported by the identification of two felling phases for the timbers used in alignment 33233, one of which was felled in 956/57. The only other obvious outlier is timber 8620, from fence line 6661, which was likely to have been felled in the 11th century. Structure 5/5, the earliest of two superimposed buildings on Tenement C, was probably constructed between 956 and 979. Structure 5/6 which overlies 5/5 was erected no more than 40 years later, and more likely only around 15–20 years later, during the period 970–97.

### Tenement D

Timber 8845, a horizontal, was felled after 958.

### Structure 5/7

Two sills (9002, 9027) and an associated chock under a sill (9029) were dated. The outermost measured ring of timber 9002 was identified as likely to be that immediately under the bark, indicating that this sill was probably felled in the summer of 966. The remaining two timbers are clearly contemporaneous and were therefore also likely to have been felled in 966. Post 9003 was felled after 955 which is clearly compatible with the 966 felling date. In the absence of any evidence of re-use, the above results imply a construction date for Structure 5/7 shortly after felling in 966.

Timber 9008, is a scrap of wood, possibly a chock, found in the construction levels, although on archaeological grounds not necessarily part of the construction. It has a felling date range of 954–90. However, it appears to be derived from the same tree as post 8556 from Period 5B Tenement B Structure 5/3, and so was actually probably felled in the period 958–87 (see above). It is clearly broadly contemporary with the erection of Structure 5/7 and consequently may also have been felled in 966.

The seven dated timbers lying apparently abandoned in the base of the construction cut appear to be contemporaneous and have a combined felling date of 957–85. The ring sequences from some of these timbers show good similarity with the timbers associated with the construction of Structure 5/7 and may therefore be contemporary with the 966 felling phase (see Table 6). Timber 9020, from the stave-built box, was felled after 952.

Eight timbers from the backfill were dated. Three of these (8892, 8947, 8979) have felling dates in the late 10th or early 11th centuries, whilst the remaining samples have *termini post quem* for felling ranging from the early to the mid-10th century. The earliest possible felling date for timber 8947 is 991 which suggests that the backfill episode occurred sometime after this date. In addition, timber 8947 may have been derived from the same tree as timber 8359 from the construction levels of Structure 5/8 which lies directly above Structure 5/7. This same-tree link implies that the abandonment of Structure 5/7 and subsequent construction of Structure 5/8 directly above it are basically contemporaneous.

### Structure 5/8

One (8882) of the two dated braces from the east wall has a *terminus post quem* for felling in the mid-10th century whilst the other, 8888, was felled in the winter of 1008/09. Three sills associated with Structure 5/8 were dated. Two (8392, 8394) have *termini post quem* for felling in the mid–late 10th century, whilst one (8393) was probably felled in the winter of 995/96. These therefore could all be contemporaneous. Sill 8394 is likely to have been derived from the same tree as brace 8882. The 995/96 felling date indicated by sill 8393 is obviously earlier than that of 1008/09 indicated by brace 8888, whilst all other dated structural timbers from 5/8 are compatible with either of these felling dates. This could imply that the construction of 5/8 took place in the very late 10th century, with repair work being undertaken some twelve to fourteen years later, or alternatively that the structure incorporates re-used timbers although there was no evidence of re-use.

The dated timber from the construction levels associated with Structure 5/8 was felled between 988 and 1024 and is clearly broadly contemporary with the either late 10th- or early 11th-century date for the demolition of 5/7. It may have been derived from the same tree as timber 8947 from the backfill of Structure 5/7 in which case it must have been felled after 991 but probably before 1024.

Six planks from the dog-leg drain associated with, and believed to be contemporary with the construction of, Structure 5/8 were dated. Planks 8858 and 8863 are clearly derived from the same tree, as are 8859 and 8860. It appears probable that all the planks are contemporary. They were therefore felled, and probably used in the construction of the drain, during the period 988–1017. This clearly demonstrates that the drain is broadly contemporary with Structure 5/8 but in the absence of bark-edge cannot assist in determining whether Structure 5/8 was constructed in the very late 990s or towards the end of the first decade of the 11th century.

Two timbers from the watching brief were dated that are clearly from the same structure, but stratigraphically it is not possible to determine whether this was Structure 5/7 or 5/8. Timber 123 is probably an edge-set horizontal plank, part of a classic sunken-structure wall, and was felled between 966 and 1002. Timber 122, interpreted as a lipped sill beam, was felled after 994. The evidence that these two timbers are from the same structure implies that this is more likely to be the later Structure 5/8, though the quality of the cross-matching between 122 and 123 and the timbers from Structures 5/7 and 5/8 is inconclusive (see Table 7).

The majority of the 36 timbers dated from Tenement D indicate activity in the second half of the 10th century, though some felling is identified in the early 11th century. A construction date shortly after felling in 966 is suggested for Structure 5/7 which is stratigraphically the earliest structure on Tenement D and is located under the rear room of Structure 5/8. Structure 5/8 contains timbers felled in the late 10th century and the early 11th century. This implies that Structure 5/7 was in existence for a minimum of nearly three decades before being replaced by Structure 5/8.

## Tenement E

### Structure 5/9

Timber 138, possibly a joist or an abandoned timber related to construction, was felled after 913. Timber 131, interpreted as a sill beam, was felled between 951 and 987. In the absence of any evidence for re-use the results suggest a construction date in the latter half of the 10th century but this is based on the felling date range obtained from only one timber.

### Period 5B summary

Building activity seems to have taken place on these Period 5B tenements in the latter half of the 10th century and the early 11th century which supports other archaeological evidence indicating that the occupation associated with these buildings continued into the early 11th century. The early 960s date indicated for Structure 5/1 provides further evidence for the short duration of Period 5A, at least on Tenement A. It appears to be the earliest Period 5B structure, whilst Structure 5/8, built at least 34 years later, is the latest. A probable same-tree link between Tenement B Structure 5/3 and the Tenement D Structure 5/7 construction levels implies a connection between the two tenements and may suggest that Structures 5/3 and 5/7 were constructed at the same time. Re-use of timber from Period 5A is also highlighted as a possibility in some structures.

## *Period 5Cf*

### Tenement D

### Structure 5/10

The similarities between the two dated bracer beams indicate that they are likely to be contemporary. Both were therefore felled and initially used in 963–98. Sill 8456 was felled after 944 and therefore could be contemporary with the two bracer beams. Both bracer beams show signs that they have been re-used in this context so the felling date obtained indicates the construction of an earlier building and not Structure 5/10. Structure 5/10 clearly post-dates Structure 5/8, which it overlies, indicating that the former is likely to be constructed sometime after 1008/09. This shows that the bracer beams were re-used at least a decade after their initial use and probably significantly longer.

The dendrochronological results show felling activity in the mid–late 10th century. However, Structure 5/10 overlies part of Structure 5/8 from Period 5B for which a construction date in the very late 10th or early 11th century is indicated by the dendrochronological evidence. Evidence for the use of secondary (re-used) timber resolves this apparent incompatibility.

## *Period 5Cr*

### Tenement C

### Structure 5/12

Six stubs were dated. The dates of the outermost measured heartwood rings are within five years of each other which suggests they are likely to be contemporary and thus have a combined felling date of 1013–49. In the absence of any evidence for re-use a construction date shortly after felling is indicated.

The dendrochronological results indicate constructional activity in the first half of the 11th century at the riverward end of Tenement C.

# Discussion

The following discussion attempts to place the Coppergate dendrochronological analysis in its historical perspective and provides a revised overview of the major issues raised in earlier archive reports.

## *The historical perspective*

Coppergate was one of the first complex urban archaeological sites in England to employ dendrochronology in order to attempt to clarify the complex and stratigraphically obscure inter-relationships between dense clusters, or even intermingled alignments, of timbers. It remains one of the largest single-site sources of tree-ring data in this country outside London, along with the Roman site of Annetwell Street in Carlisle (Groves 1990). The analysis of the Coppergate assemblage was valuable in developing appropriate strategies with which to handle large diverse groups of excavated timbers. Such strategies are designed to maximise the archaeological potential of the assemblage, whilst enabling efficient yet comprehensive analysis.

The Coppergate samples arrived at Sheffield in numerous batches stretching over a period of many years. Due to the complexity of the archaeological remains, timbers from different periods were extracted simultaneously and enclosed within these batches. It was therefore not possible to examine the samples in a logical order, structure by structure and period by period. The relationship between the requirement for dendrochronological sampling and issues of conservation and display had only just started to be addressed so initially some timbers were held back in their entirety and only became available for analysis at a later date. With hindsight, and also using accumulated experience subsequently gained from the excavation and analysis of other urban waterlogged timber assemblages, it is clear that a more carefully planned strategic approach may well have led to a more efficient dendrochronological analysis.

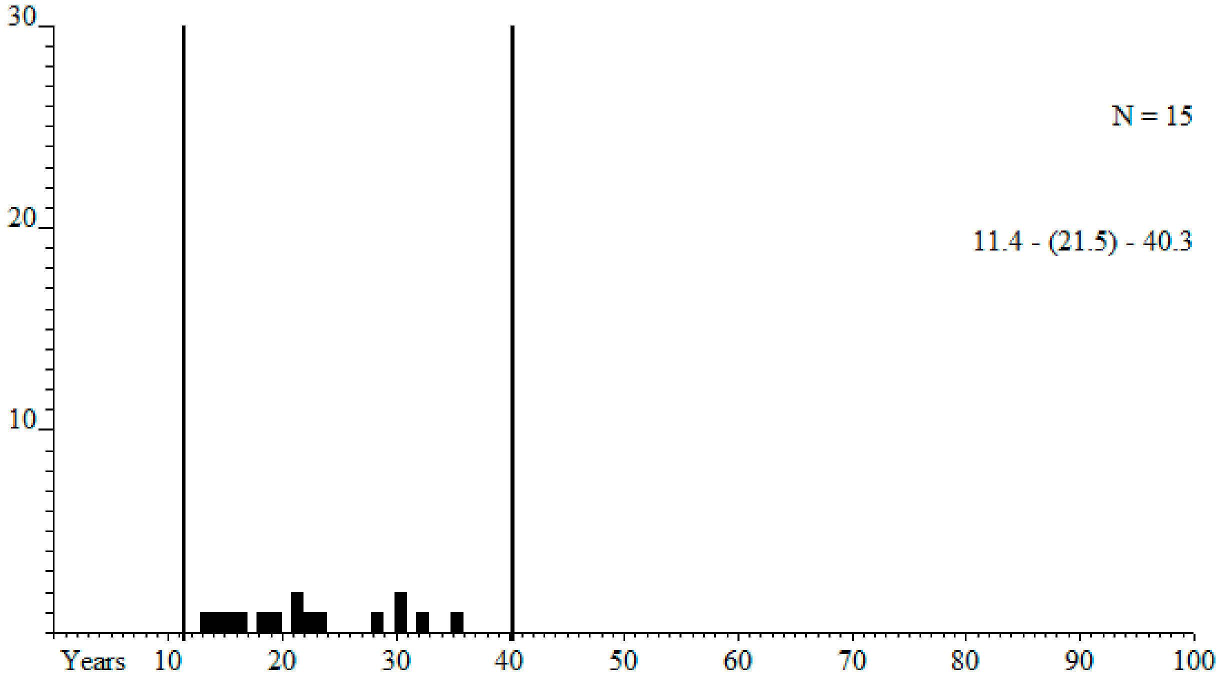



***Fig. 3*** *Histogram showing the distribution of the sapwood values for the 13 measured samples with bark edge and the 2 sigma range of logarithmic values for the sapwood range.*

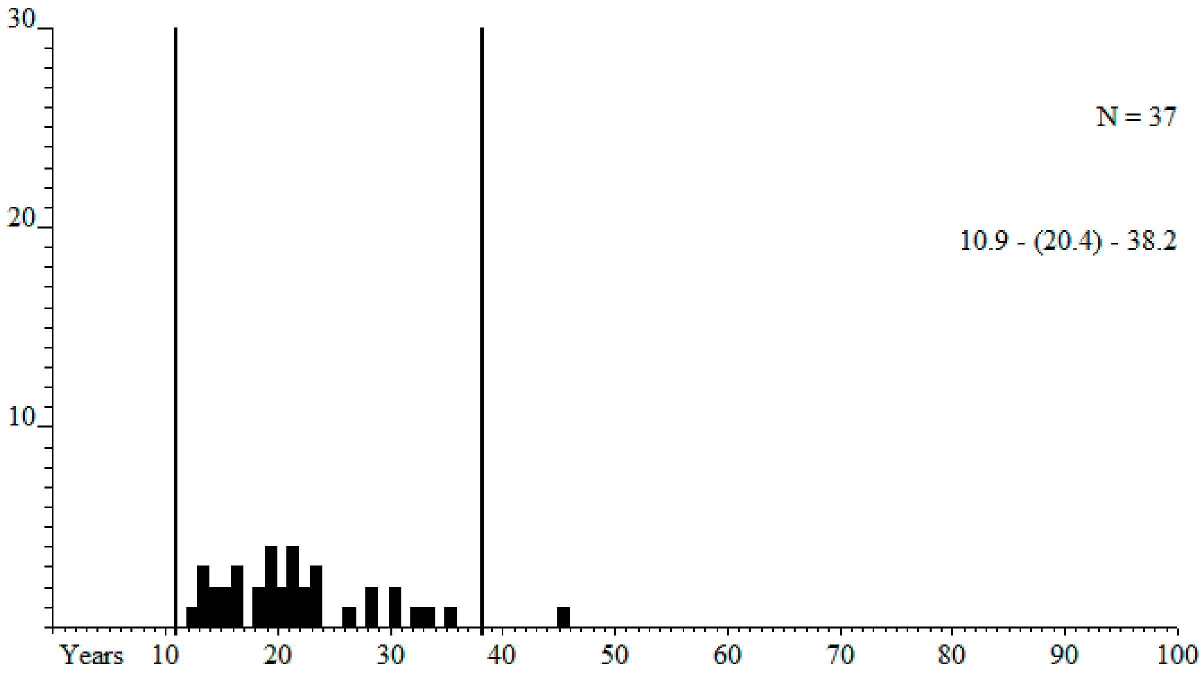



***Fig. 4*** *Histogram showing the distribution of the pseudo-sapwood values derived by assuming simultaneous felling of timbers with sapwood within structures with at least one timber with bark edge and the 2 sigma range of logarithmic values for the sapwood range.*

The fact that Coppergate was a complex urban site with timber structures spanning a millennium brought its own complications since dating timbers from such a site is very different to dating a group of timbers from, for example, a single-phase standing building. In the latter case the process is relatively easy because not only are all the samples from a phase available at once, but also more often than not the timbers appear to have originated in a single woodland stand. When the Coppergate analysis began, it very soon became apparent that the timbers came from a diverse woodland source since there was often relatively poor cross-matching between timbers from the same structure. As a consequence it initially proved difficult to construct site master curves. This made dating more difficult, as did the fact that there were very few reference chronologies in the late 1970s against which to test the Coppergate ring sequences. During the subsequent decades many of these problems were overcome as the technique was developed and refined, the network of reference chronologies hugely extended, and advances in computer technology allowed large amounts of tree-ring data to be analysed far more rapidly than in the late 1970s.

## *Dating precision*

The dendrochronological analysis reported here has successfully provided a basic framework for the development of the Coppergate tenements over a period of about a century. A number of structures have been precisely dated, thus providing a series of fixed points within the complex stratigraphical sequence (Figure 2). This has assisted in the estimation of the duration of each period and has also provided an indication of how long some structures were in use within a period. However, the relative scarcity of timbers that were recognised as having retained bark-edge and the sheer complexity of the timber remains combine to prevent the analysis providing the detailed chronological framework that had perhaps been originally envisaged or hoped for. In some instances the dendrochronology has also raised questions concerning possible re-use of timber and the transition phases between periods.

The analysis has proved remarkable in that the success rate, as indicated by the number of dated samples as a percentage of processed samples, is 84%. This compares favourably with medieval Coppergate at 53% (Hillam 2002) and the usual 50–60% success rate on complex urban archaeological excavation assemblages (e.g. Groves 1990; 1996a). It also exceeds the 72% success rate for medieval and post-medieval standing buildings (Groves 2002).

The presence of sapwood and bark-edge on timbers is vital in the production of detailed dating evidence. In order to maximise the potential of any large assemblage careful sampling within a well-defined sampling strategy is essential to the future success of the analysis and should thus be undertaken in close consultation with the dendrochronologist. Sampling of timbers must be focused on the section of a timber likely to provide the greatest number of annual growth rings but must also take into account the presence of bark-edge or any trace of sapwood, which may occasionally result in a timber being sampled twice. It is possible that sites such as Coppergate, excavated in the late 1970s and early 1980s, may not have had their potential fully exploited. Sites excavated from the mid-1980s onwards have seen a noticeable increase in the presence of sapwood on samples: compare Trig Lane, London (1974–78; Tyers 1992), The Lanes, Carlisle (1978–82; Groves 1993a; Groves 1996a; Groves 1996b), and Billingsgate, London (1982; Hillam 1988; Hillam 1992b), to Fennings Wharf, London (1984; Tyers forthcoming), Annetwell Street, Carlisle (1981–84; Groves 1990), and No. 1 Poultry, London (1995–96; Tyers 2000b). However, sapwood is notoriously friable and will degrade rapidly if the waterlogged conditions required for preservation are not maintained. If sapwood is preserved it is usually extremely fragile and it may well have suffered crushing prior to excavation that can make the recognition of bark-edge or heartwood/sapwood boundary very difficult or make the outermost rings unmeasurable. The process of sampling and subsequent cleaning can also inadvertently exacerbate this problem, however carefully the timbers are handled.

Crushing and the resultant distortion of the outermost rings was certainly a recognised problem at Coppergate, particularly with planks on which the area of likely bark-edge is very small (Hillam 1987). Of the processed timbers 92 (46%) have either some sapwood or the heartwood/sapwood boundary; only 15 (7.5%) samples have retained the bark-edge; this is a very low percentage considering the number of structures sampled but it is typical of other excavations of this date. It is possible that with two decades of accumulated experience of the analysis of waterlogged timbers bark-edge or the heartwood/sapwood boundary, even if crushed, would have been more confidently recognised on more of the Coppergate timbers during either sampling or analysis. Timbers 8798, 8810, 8811 from alignment 14853 in Period 5A

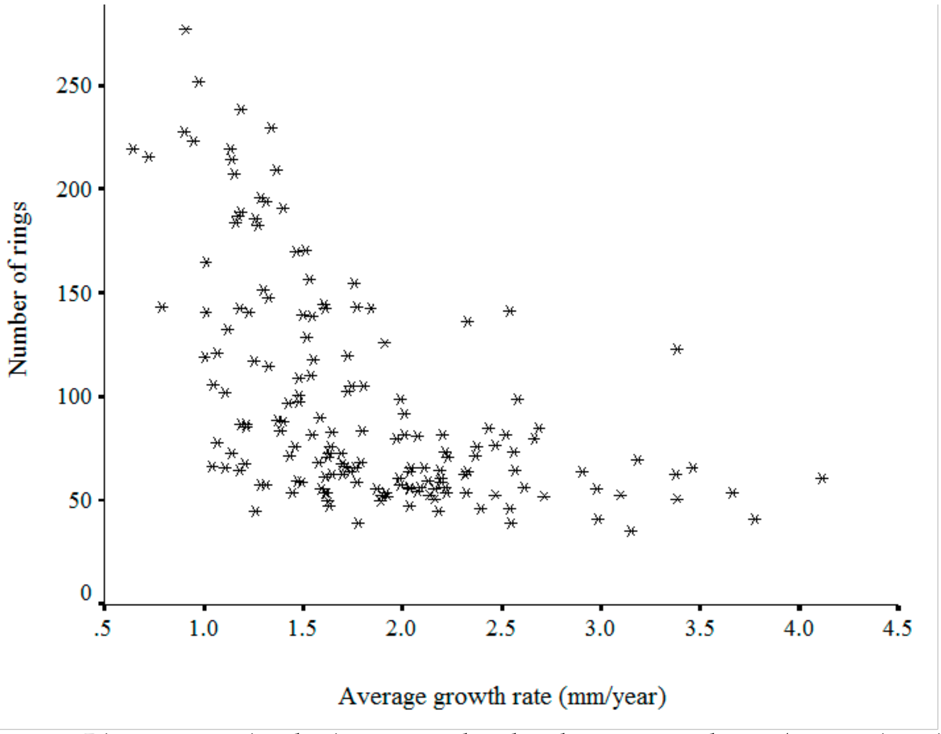



**Fig. 5a** *Diagram comparing the ring sequence length and average growth rates (average ring widths) of all of the dated timbers. Ring sequence lengths are, in the absence of pith and bark, an underestimate of tree age.*

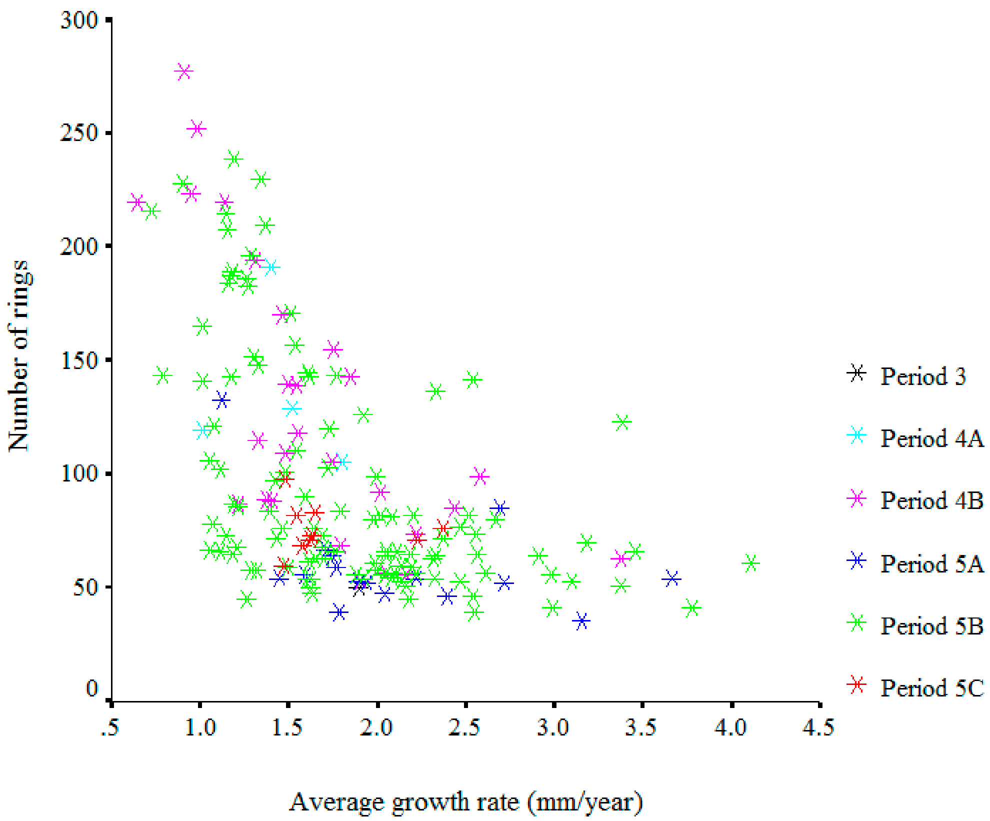



**Fig.5b** *Diagram comparing the ring sequence length and average growth rates (average ring widths) of the dated timbers from each Period, excluding Period 2. Ring sequence lengths are, in the absence of pith and bark, an underestimate of tree age.*

Tenement D, for instance, all look to have only one or two rings missing to the bark-edge. These are all tangentially converted planks which appear likely to have suffered slight damage to the outermost surface resulting in the crushing/loss of the outer ring(s), preventing the recognition of bark-edge. Timbers 8692 and 8693, posts from Structure 5/1, Tenement A, Period 5B, also appear likely to have suffered slight damage which has prevented recognition of the presence of bark-edge. The dates of the outermost measured heartwood rings on the stubs from Period 5Cr Structure 5/12 in Tenement C range from 997 to 1003, with the heartwood/sapwood boundary on **8649** also dating to 1003. Such a narrow range of end dates implies that the stubs are only missing the sapwood rings and that the outermost measured ring is likely to mark the heartwood/sapwood boundary. If this assumption is correct then it has the effect of slightly narrowing the felling date range to 1013–43. The same is true for the group of abandoned timbers in Period 5B Structure 5/7 in Tenement D whose outermost heartwood rings range from 938 to 945.

In an attempt to refine the felling date ranges given for many of the structures and timbers and hence the overall dating framework a sapwood estimate based on the Coppergate data was produced. The number of measured samples with complete sapwood was only fifteen, too few for a statistically reliable estimate to be created (see **Fig. 3**). This number was increased to 37 by assuming that all timbers with some sapwood or the heartwood/sapwood boundary were felled simultaneously in those structures where one or more timbers had bark-edge, thus creating a pseudo-sapwood estimate (see **Figure 4**). The 95% ranges based on skewed distribution are 11–40 and 11–38 which, considering the small sample size, are not felt to be sufficiently different from the 10–46 range standardly employed to warrant any re-interpretation of the Coppergate results.

## *Timber source and trade*

The quality of the intra-site cross-matching obtained is variable, though this is now known to be not uncommon on large urban complexes. The cross-matching between timbers within some structures (e.g. Period 5B, Tenement C, Structure 5/5; see Table 8) is uniformly very good, whilst in others it is variable or poor (Period 4B, Tenement D, alignment 22585; Period 5B, Tenement C, Structure 5/6; see Tables 15 and 16). This variation could be due to the use of discrete woodland sources and/or extensive re-use of timber resulting in the mixing of timbers from different sources within a structure. Evidence for re-use from the excavation records is scarce, though this does not entirely exclude the possibility. Re-use can be difficult to recognise without direct evidence provided by non-functional carpentry features, such as mortices or peg-holes for instance, which may well be trimmed off during secondary conversion, thus removing vital evidence of prior use. However, the dendrochronological results also imply that re-use is not widespread. On sites where re-use is extensive, such as The Lanes, Carlisle (Groves 1993a; 1996a; 1996b), there is no distinct progression of the dates of the outermost rings through the various phases. At Coppergate the outermost rings of the assemblage show a clear progression through the periods. In addition, there are recognisable changes between periods in the characteristics of the timbers, relating to age and size of trees (see below), that also suggest that re-use is unlikely to be extensive.

The cross-dating of the site master chronology and its individual components with reference chronologies from throughout the British Isles and elsewhere in Europe (Table 3) shows no evidence of long-distance importation of timber. They match particularly well with other reference chronologies from York and its surrounding region and thus the timbers appear likely to be of local origin. Coppergate and other sites in the York environs have highlighted that this is an area in which trees do show wide variation in their growth patterns over relatively short distances. This, combined with the evidence from other large urban sites of either Roman or medieval date, suggests that the timber was derived from an extensive area of woodland in the surrounding region rather than a series of discrete sources. This implies that the inhabitants of Coppergate and the rest of the rapidly expanding York had relatively open access to the entire surrounding woodlands. Large urban settlements have a considerable requirement for timber and other woodland products and are therefore automatically exploiting extensive areas of woodland.

The identification of a same-tree pair of timbers in Period 4B on Tenements B and D and also in Period 5B on Tenements B and D implies synchronous construction work, as does the common felling date of 955/56 indicated in Period 5A also on Tenements B and D. This suggests co-operation between the occupants at some level but whether the development as a whole was the product of an organised municipal arrangement or on an *ad hoc* basis remains to be seen. If timber was being obtained through a single central supply route it would be reasonable to

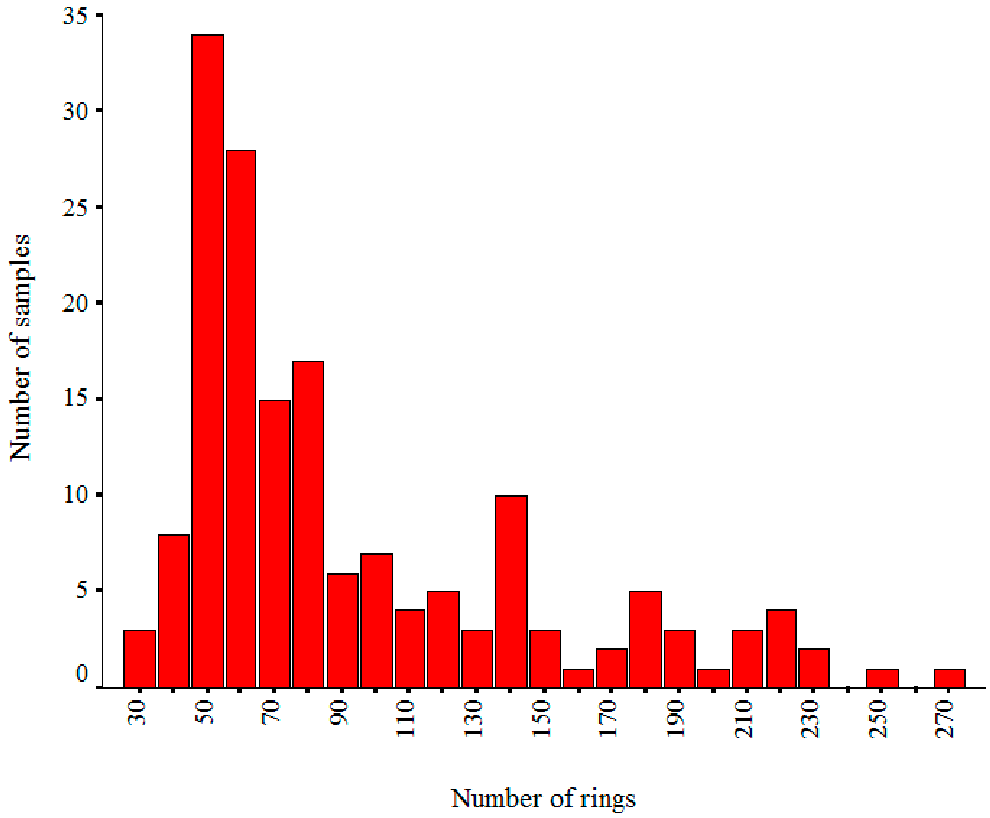



***Fig. 6a*** *Histogram showing ring sequence length for all Periods, except Period 2*

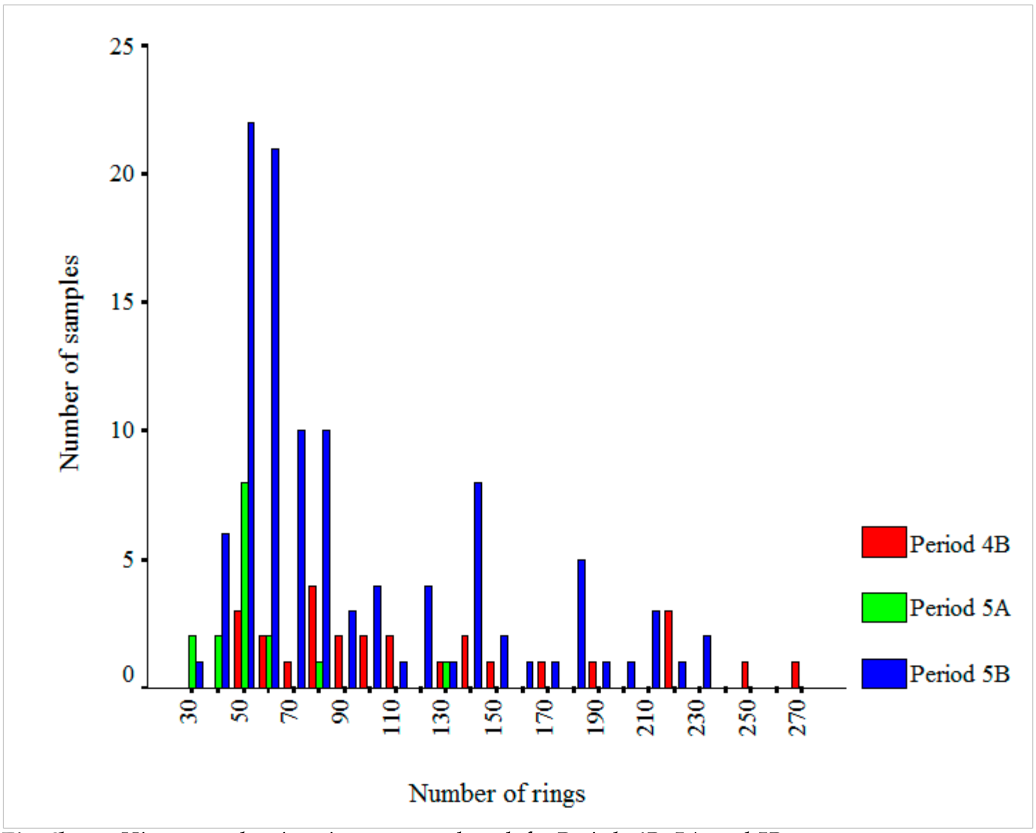



***Fig. 6b*** *Histogram showing ring sequence length for Periods 4B, 5A, and 5B*

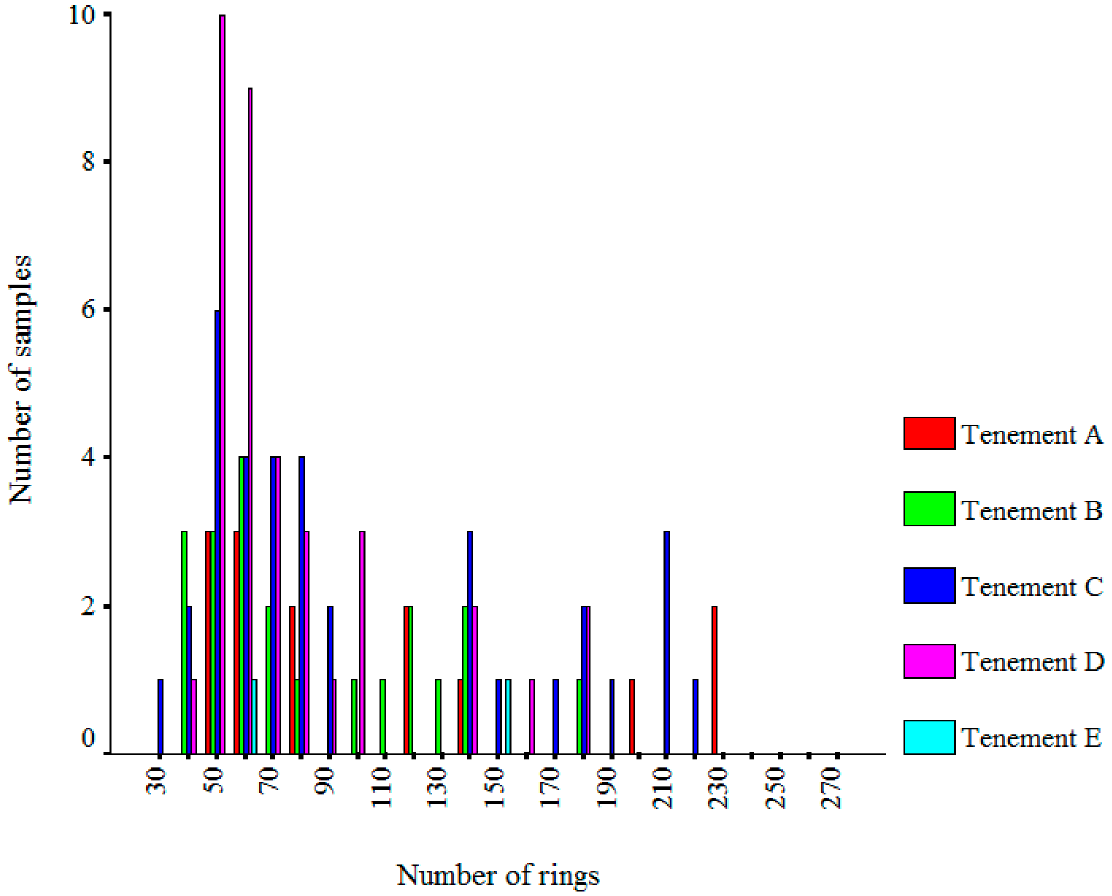



***Fig. 6c*** *Histogram showing ring sequence length for the Tenements in Period 5B.*

suggest that there should perhaps be more same-tree pairs and higher overall levels of similarity (*t* values) between tenements. In addition, the construction work might have been expected to be more intense, with a whole series of structures being erected perhaps over a couple of years rather than decades apart. Conversely there does seem to be a potential link between the occupants of Tenements B and D. In general though, the dendrochronological results can neither confirm nor refute the possibility of a central timber supply. The likelihood or otherwise of this depends on the social organisation in place, whether individuals were entirely self-reliant for construction and repair work or whether there was communal co-operation.

## *Trees and woodland composition*

As indicated above, the results attest to the use of local timber. Consequently the timber assemblage must give some reflection of the woodland available for exploitation. The dendrochronological analyses can clearly not reconstruct a woodland as the analysed assemblage is only a very small percentage of the woodland product. However, it can add valuable information to a multi-disciplinary approach aimed at landscape reconstruction.

The Anglo-Scandinavian timbers indicate that they were derived from trees which had a wide variation in both age and size. This variation is demonstrated in **Figures 5a and 6a**, though it must be noted that the ring sequence length is generally an underestimate of tree age due to the lack of both pith and bark-edge on the majority of the assemblage. It has previously been proposed that the timbers used in the Anglo-Scandinavian phases were derived from two main classes of tree:

1. Those producing radially split planks. They have diameters of at least 500mm and sometimes over 1m. The trees were often over 200 years old when felled and occasionally over 300 years. Sapwood was frequently removed and, in some cases, heartwood rings as well.

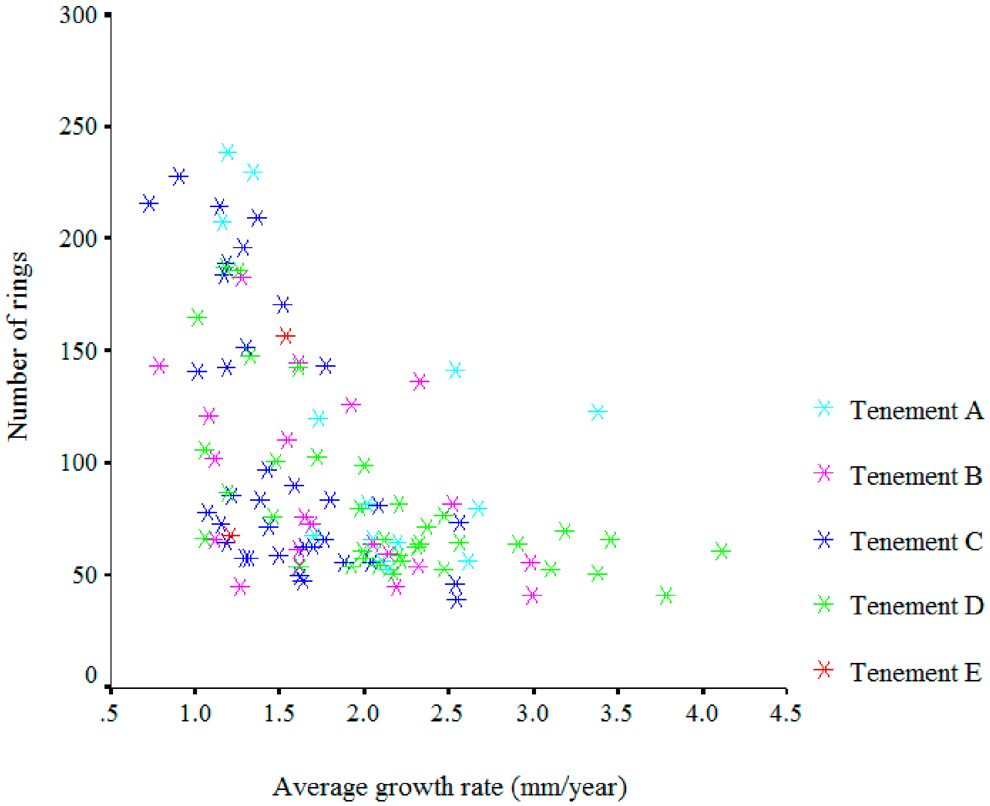



***Fig. 7*** *Diagram comparing the ring sequence length and average growth rates (average ring widths) of the dated timbers from each Tenement from Period 5B. Ring sequence lengths are, in the absence of pith and bark, an underestimate of tree age.*

2. Those producing the tangential planks or trunks which had been trimmed, halved or quartered. They are usually less than 500mm in diameter, generally under 100 years old and never more than 150 years when felled. This is the type of oak tree which one might get in the classic coppice-with-standards woodland (e.g. Rackham 1980, frontispiece; Rackham 1990).

However, there is no distinct grouping of the material apparent in **Figure 5** and the overall assemblage probably represents a mature natural or semi-natural multi-aged woodland. This is likely to contain trees ranging from fast-grown young trees, perhaps on the peripheral areas where the canopy is more open, to slower-grown long-lived trees in denser areas of the same extensive woodland. Consequently the apparent grouping is more likely to be a result of selection for function prior to conversion into structural elements and then the method by which the conversion was undertaken rather than the use of two discrete sources.

This grouping is perhaps over emphasised in the assemblage as a whole by some structures. Structure 5/1 for instance contains a series of radial planks which are clearly derived from trees in the order of 250–300 years old and in excess of 0.5m diameter when felled, though it should be noted that four of these planks are derived from the same tree. However, the posts, all halved or quartered sections, and the tangentially converted planks tend to be derived from trees that were probably about 100 years old and less than c.0.4m diameter when felled. The selection process has potentially ensured efficient use of the available resource with minimal working and minimal wastage. The ring sequences do show more similarity within the groups but also show some similarity between groups and therefore are all likely to have been derived from the same, though potentially very large, area of woodland (see Table 5). Structure 5/3 shows a similar selection process where the trees used as posts are likely to have been selected for their size and subsequently required minimal working, as have the tangentially converted base planks. The radial planks appear to represent the inner sections of longer-lived trees which have been more heavily trimmed, possibly resulting in the production of small but structurally useful outer sections. In general, however, it appears that when planks are required they are usually derived from a small number of large trees, perhaps suggesting that the long-lived large trees may have been perceived as a valuable resource. The possible exception to this are the posts from Structure 5/5 which are derived from relatively long-lived slow-grown trees that have been heavily trimmed during conversion.

The age range distribution does appear to be more uniform in the earlier periods than in Period 5B which has a higher proportion of short-lived material (**Figures 5b and 6b**), though direct comparisons are difficult due to the small number of dated timbers from the earlier periods. This increase in the use of young trees could be due to exploitation of woodland that has regenerated (i.e. secondary woodland) on areas previously cleared or heavily exploited during the early Anglo-Scandinavian periods. Intense exploitation has the effect of opening up woodland, decreasing the competition for the remaining trees, and allowing a flush of regeneration which would potentially result in the availability of young relatively fast-grown material in the later 10th century. There is no clear evidence from the dendrochronological analysis to indicate deliberate management of the woodland resource but other archaeological sources may provide further information. Within Period 5B it is also noticeable that Tenement D has proportionally fewer longer-lived timbers than Tenements A, B and C (**Figures 6c and 7**). This presumably may reflect the lack of survival of planks associated with the walls of structures rather than indicating increased exploitation of secondary woodland.

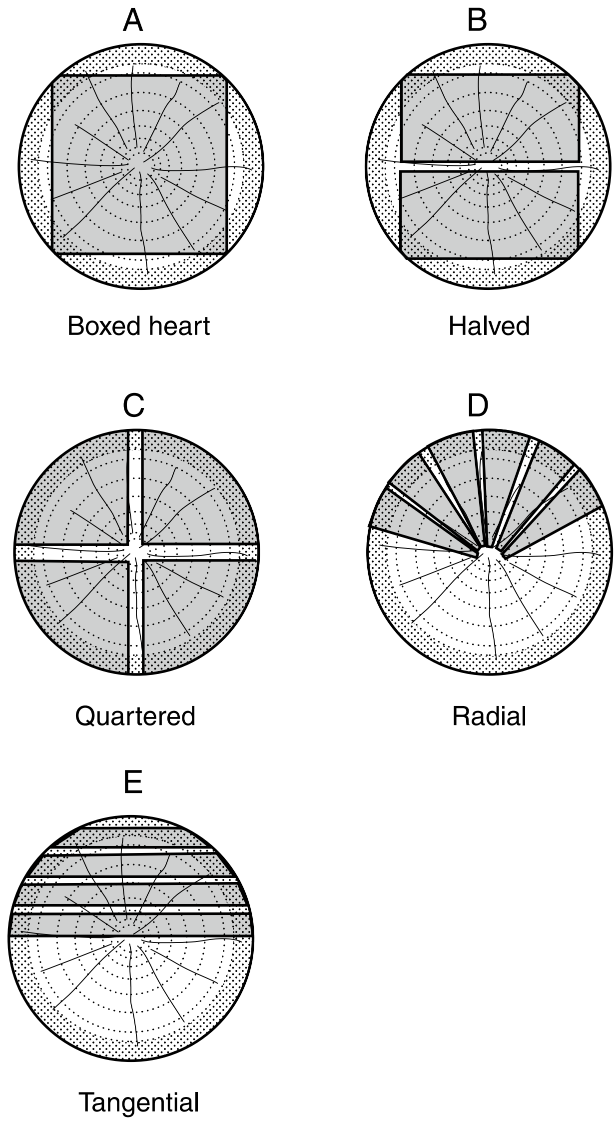



***Fig.8*** *Typical conversion types found in wooden structures*

# Conclusion

The dendrochronological analysis of the Coppergate timbers played an important role in the development of the dendrochronological approaches currently employed on complex archaeological assemblages. This analysis proved successful in that 84% of the timbers were dated, providing independent dating evidence for structures associated with the intense activity on the tenements during the 10th and early 11th centuries. The resultant site chronology spans the period 460–1011 and is particularly well replicated during the mid-8th to mid-10th centuries. The timber appears to be derived from multi-aged natural or semi-natural woodland some of which, by the latter part of the Anglo-Scandinavian phase, may be young secondary woodland. The apparent diversity of the timber indicates that the area of exploitation was likely to encompass an extensive area of the surrounding region as would now be expected for any large urban development. Links have been identified between some tenements but on current evidence from this site and other large urban excavations there is little to indicate whether the supply of timber is already becoming a specialised occupation within the social organisation of an increasingly urbanised settlement.

**Table 1** Details of tree-ring samples. wb – watching brief; +nn – unmeasured outer rings (unmeasured inner rings are not recorded); ARW – average ring width; HS – heartwood-sapwood transition; B – bark edge; fs – outer ring incomplete and not measured, indicates summer felling.
Timber conversion types – see Fig.346

| Timber no | Context no | Period & Tenement | Function | Total no of rings | Sapwood rings | ARW (mm) | Timber conversion | Dimensions (mm) | Date span (AD) | Felled (AD) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0004 | 1218 | 5B A | 5/1 plank | 120 | – | 1.73 | D | 235x40 | 788–907 | after 917 |
| 0032 | 1306 | 5B A | 5/1 post | *48 +10* | – | 1.99 | CX | 135x120 | – | – |
| 0051 | 1308 | 5B A | 5/1 west wall plank | 208 | – | 1.16 | D | 275x35 | 730–937 | after 947 |
| 0055 | 1313 | 5B A | 5/1 post | 86 | – | 1.78 | CX | 150x125 | – | – |
| 0090 | 1715 | 2 (wb) | isolated timber | 77 | – | 2.15 | D | 180x70 | – | – |
| 0091 | 1716 | 2 (wb) | isolated timber | *141 +11* | – | 1.23 | DE | 225x30 | 524–664 | after 685 |
| 0095 | ? | 2 | helmet pit | 72 | – | 1.74 | D | ?x? | – | – |
| 0096 | ? | 2 | helmet pit | 53 | – | 1.49 | DE | 85x20 | – | – |
| 0097 | ? | 2 | helmet pit | 117 | – | 1.26 | D | 150x20 | 460–576 | after 586 |
| 0098 | ? | 2 | helmet pit | 69 | – | 1.99 | DE | 145x30 | – | – |
| 0099 | ? | 2 | helmet pit | 63 | – | 1.99 | DE | 135x25 | – | – |
| 0100 | ? | 2 | helmet pit | 106 | – | 1.27 | DE | 135x20 | – | – |
| 0101 | ? | 2 | helmet pit | 114 | – | 1.27 | CX | 150x40 | – | – |
| 0103 | ? | 2 | helmet pit | 73 | – | 1.57 | DE | 120x30 | – | – |
| 0104 | 1956 | wb | post & wattle alignment | 48 | 5 | 1.36 | E | 155x50 | – | – |
| 0121 | 2036 | wb | covered drain 2133 | 82 | – | 1.87 | CX | 195x110 | – | – |
| 0122 | 2037 | 5B D (wb) | 5/7 | 80 | – | 1.97 | CX | 165x155 | 905–984 | after 994 |
| 0123 | 2035 | 5B D (wb) | 5/7 or 5/8 | 72 | 9 | 2.37 | E | 295x65 | 894–965 | 966–1002 |
| 0131 | 2109 | 5B E (wb) | 5/9 sill | 68 | 6 | 1.21 | CX | 115x85 | 880–947 | 951–87 |
| 0135 | 2110 | 5B E (wb) | 5/9 sill | *91 +27* | – | 2.75 | CX | 280x180 | – | – |
| 0138 | 2089 | 5B E (wb) | 5/9 joist/construction | 157 | – | 1.53 | CX | 300x230 | 747–903 | after 913 |
| 0172 | 2137 | 5A (wb) | covered drain 2133 | 61 | 12 | 2.20 | E | 260x65 | 900–960 | 960–94 |
| 0187 | 2153 | 5B E | 5/9 sill beam | 50 | 7 | 2.22 | CX | 170x105 | – | – |
| 8065 | 2970 | 5B B | 5/4 backfill – plank | 82 | – | 2.52 | D | 210x30 | 910–991 | after 1001 |
| 8066 | 2955 | 5B B | 5/4 backfill – plank | 121 | – | 1.07 | D | 135x30 | 867–987 | after 997 |
| 8067 | 7025 | 5B C | 5/6 backfill | 97 | HS? | 1.43 | D | ?x? | 852–948 | 958–94? |
| 8071 | 7047 | 5B C | 5/6 backfill | 78 | – | 1.07 | CX | 140x100 | 848–925 | after 935 |
| 8075 | 7096 | 5B C | 5/6 backfill | 58 | – | 1.32 | CX | 80x60 | 894–951 | after 961 |
| 8105 | 2876 | 5B B | 5/4 backfill | 54 | – | 1.61 | D | 90x20 | 827–880 | after 890 |

**Table 1** *(cont'd)*

| Timber no | Context no | Period & Tenement | Function | Total no of rings | Sapwood rings | ARW (mm) | Timber conversion | Dimensions (mm) | Date span (AD) | Felled (AD) |
|---|---|---|---|---|---|---|---|---|---|---|
| 8156 | 7085 | 5B C | 5/6 backfill | 84 | 10 | 1.39 | BX | 210x100 | 818–901 | 901–37 |
| 8157 | 7240 | 5B C | 5/6 collapse | 72 | – | 1.43 | CX | 120x80 | 871–942 | after 952 |
| 8213 | 7081 | 5B C | 5/6 west wall plank | 143 | – | 1.18 | DE | 180x35 | 799–941 | after 951 |
| 8215 | 7319 | 5B C | 5/6 west wall plank | 171 | – | 1.52 | D | 250x40 | 771–941 | after 951 |
| 8221 | 8201 | 5B B | 5/4 collapse | 64 | 10 | 2.04 | BX | 280x65 | 930–993 | 993–1029 |
| 8234 | 8038 | 5B B | 5/4 east wall post | 102 | – | 1.11 | B1 | 200x105 | 835–936 | after 946 |
| 8240 | 5228 | 5B C | 5/6 drain | 81 | – | 2.08 | DE | 190x50 | 873–953 | after 963 |
| 8275 | 7091 | 5B C | 5/6 east wall post | 50 | ?7 | 2.37 | BX | 240x120 | – | – |
| 8293 | 7306 | 5B C | 5/6 west wall plank | 228 | – | 0.90 | D | 210x40 | 709–936 | after 946 |
| 8316 | 7448 | 5B C | 5/6 collapse | 109 | – | 1.15 | CX | 140x110 | 840–948 | after 958 |
| 8319 | 1488 | 5B C | 5/6 west wall post | 84 | 4 | 1.79 | E | 260x100 | 872–955 | 961–97 |
| 8320 | 1487 | 5B C | 5/6 west wall post | 74 | – | 2.56 | CX | 190x100 | 812–885 | after 895 |
| 8330 | 7088 | 5B C | 5/6 | 68 | – | 1.38 | AX | 170x170 | – | – |
| 8340 | 7095 | 5B C | 5/6 east wall plank | 46 | – | 2.54 | DC | 285x110 | 840–885 | after 895 |
| 8354 | 2777 | 5B B | 5/4 west wall post | 144 | – | 0.79 | AX | 220x130 | 775–918 | after 928 |
| 8359 | 9403 | 5B D | 5/8 construction | 55 | 3 | 2.08 | AX | 210x140 | 927–981 | 988–1024 |
| 8360 | 7547 | 5B C | 5/6 west wall post | 78 | – | 0.91 | CX | 210x90 | – | – |
| 8362 | 8658 | 5B B | 5/4 west wall | 98 | ?5 | 1.74 | DC | 180x70 | – | – |
| 8376 | 7581 | 5B C | 5/6 north wall sill | 56 | 13 | 1.87 | E | 205x55 | 915–970 | 970–1003 |
| 8379 | 8047 | 5B B | 5/4 east wall sill | 73 | 18 | 1.69 | BX | 280x70 | 889–961 | 961–89 |
| 8387 | 8744 | 5B B | 5/4 drain capping | 76 | 30 ?B | 1.64 | E | 250x65 | 897–972 | 972/3? |
| 8392 | 1582 | 5B D | 5/8 west wall sill | 57 | – | 2.22 | BX | 275x140 | 892–948 | after 958 |
| 8393 | 1600 | 5B D | 5/8 partition sill | 58 | 28 ?B | 1.99 | A1 | 210x120 | 938–995 | 995/6? |
| 8394 | 1587 | 5B D | 5/8 west wall sill | 61 | – | 1.98 | AX | 240x160 | 901–961 | after 971 |
| 8456 | 14065 | 5Cf D | 5/10 sill beam | 60 | – | 1.47 | AX | 190x80 | 875–934 | after 944 |
| 8464 | 14214 | 5Cf D | 5/10 bracer beam | 76 | ?3 | 2.37 | BX | 330x120 | 880–955 | 962–98 |
| 8465 | 14219 | 5Cf D | 5/10 bracer beam | 71 | – | 2.23 | BX | 320x140 | 883–953 | after 963 |
| 8470 | 14257 | 5B D | backfill of 5/8 | 73 | – | 1.12 | BX | 200x90 | – | – |
| 8527 | 14391 | 5B C | alignment 33233 | 65 | 21 | 1.19 | AX | 150x110 | 895–959 | 959–84 |
| 8539 | 14607 | 5B D | 5/8 drain | 70 | – | 2.65 | D | 195x20 | – | – |
| 8543 | 14614 | 5B D | 5/8 drain | 148 | HS | 1.33 | D | 200x30 | 830–977 | 987–1023 |

**Table 1** *(cont'd)*

| Timber no | Context no | Period & Tenement | Function | Total no of rings | Sapwood rings | ARW (mm) | Timber conversion | Dimensions (mm) | Date span (AD) | Felled (AD) |
|---|---|---|---|---|---|---|---|---|---|---|
| 8551 | 14582 | 5B D | 5/8 drain | 165 | 2 | 1.01 | D | 185x30 | 809–973 | 981–1017 |
| 8556 | 15211 | 5B B | 5/3 east wall post | 45 | – | 2.18 | A1 | 200x125 | 895–939 | after 949 |
| 8559 | 15215 | 5B B | 5/3 east wall post | 41 | – | 2.99 | AX | 200x115 | 884–924 | after 934 |
| 8562 | 15461 | 5B B | 5/3 east wall post | 56 | ?3 | 2.98 | BX | 190x110 | 889–944 | 951–87? |
| 8563 | 15462 | 5B B | 5/3 east wall post | 62 | – | 1.61 | A1 | 190x110 | 881–942 | after 952 |
| 8599 | 14089 | 5B C | alignment 33233 | 66 | 18 | 1.76 | BX | 210x70 | 899–964 | 964–92 |
| 8620 | 6631 | 5B C | fence line 6661 | 90 | – | 1.59 | EX | 250x100 | 918–1007 | after 1017 |
| 8623 | 14724 | 5B C | alignment 33233 | 47 | 22 ?B | 1.63 | BX | 165x70 | 910–956 | 956/7? |
| 8647 | 19122 | 5Cr C | 5/12 west wall stub | 71 | – | 1.62 | A1 | 210x140 | 927–997 | after 1007 |
| 8648 | 19123 | 5Cr C | 5/12 west wall stub | 83 | – | 1.65 | A1 | 210x130 | 919–1001 | after 1011 |
| 8649 | 19124 | 5Cr C | 5/12 west wall stub | 98 | 8 | 1.48 | AX | 250x150 | 914–1011 | 1013–49 |
| 8653 | 19210 | 5Cr C | 5/12 south-east corner stub | 73 | – | 1.63 | CX | 140x130 | 931–1003 | after 1013 |
| 8654 | 19121 | 5Cr C | 5/12 west wall stub | 82 | – | 1.55 | A1 | 220x140 | 921–1002 | after 1012 |
| 8655 | 19248 | 5Cr C | 5/12 west wall stub | 69 | – | 1.58 | AX | 240x140 | 932–1000 | after 1010 |
| 8675 | 20025 | 5B A | 5/1 east wall plank | 230 | HS | 1.34 | D | 370x30 | 713–942 | 952–88 |
| 8676 | 20644 | 5B A | 5/1 east wall plank | 123 | HS | 3.38 | D | 400x30 | 826–948 | 958–94 |
| 8680 | 20646 | 5B A | 5/1 east wall plank | 239 | 21 Bw | 1.19 | DE | 285x40 | 723–961 | 961/2 |
| 8679 | 20645 | 5B A | 5/1 east wall plank | 80 | 5 | 2.67 | D | 210x35 | 875–954 | 959–95 |
| 8690 | 18466 | 5A B | alignment 36598 | 279 | HS? | 0.96 | D | 300x120 | – | – |
| 8692 | 20033 | 5B A | 5/1 east wall post | 82 | 26 | 2.01 | B1 | 300x100 | 880–961 | 961–81 |
| 8693 | 20601 | 5B A | 5/1 east wall post | 66 | 13 | 2.06 | CX | 150x100 | 895–960 | 960–93 |
| 8695 | 20237 | 5B A | 5/1 east wall post | 57 | HS | 2.10 | BX | 210x120 | 885–941 | 951–87 |
| 8696 | 20738 | 5B A | 5/1 east wall post | 65 | 11 | 2.19 | BX | 235x100 | 887–951 | 951–86 |
| 8701 | 20600 | 5B A | 5/1 east wall post | 53 | 4 | 2.13 | CX | 120x110 | 894–946 | 952–88 |
| 8702 | 20029 | 5B A | 5/1 east wall plank | 142 | – | 2.54 | D | 360x45 | 777–918 | after 928 |
| 8708 | 20735 | 5B A | 5/1 east wall plank | 57 | 12 | 2.61 | B1 | 330x80 | 895–951 | 951–85 |
| 8720 | 20705 | 5A A | alignment 37253 | 139 | – | 1.54 | DX | 200x90 | 793–931 | after 941 |
| 8741 | 18404 | 5A B | alignment 18422 | 46 | 16 ?B | 2.40 | E | 210x80 | 910–955 | 955/6? |
| 8745 | 14478 | 5B C | alignment 33235 | 63 | 13 ?B | 1.70 | E | 210x70 | 893–955 | 955/6? |
| 8746 | 14688 | 5B C | alignment 33235 | 73 | 32 ?B | 1.15 | E | 190x70 | 883–955 | 955/6? |
| 8753 | 20691 | 5A B | alignment 36582 | 52 | 15 ?B | 2.72 | CX | 150x100 | 904–955 | 955/6? |

**Table 1** *(cont'd)*

| Timber no | Context no | Period & Tenement | Function | Total no of rings | Sapwood rings | ARW (mm) | Timber conversion | Dimensions (mm) | Date span (AD) | Felled (AD) |
|---|---|---|---|---|---|---|---|---|---|---|
| 8759 | 18558 | 5A B | alignment 36582 | 59 | 18 | 1.77 | E | 210x90 | 896–954 | 954–82 |
| 8786 | 18464 | 5A B | alignment 36582 | 54 | 15 | 1.44 | E | 230x60 | 901–954 | 954–85 |
| 8795 | 14638 | 5A D | isolated post | 64 | 14 | 1.74 | AX | 220x160 | 883–946 | 946–78 |
| 8798 | 14640 | 5A D | alignment 14853 | 39 | 18 | 1.78 | EX | 210x60 | 915–953 | 953–81 |
| 8807 | 14639 | 5A D | alignment 14853 | 47 | 23 ?B | 2.04 | E | 220x60 | 909–955 | 955/6? |
| 8809 | 14636 | 5A D | alignment 14853 | 53 | 15 | 1.90 | E | 260x60 | 897–949 | 949–80 |
| 8810 | 14641 | 5A D | alignment 14853 | 35 | 14 | 3.15 | E | 260x80 | 919–953 | 953–85 |
| 8811 | 14637 | 5A D | alignment 14853 | 56 | 17 | 1.59 | E | 200x80 | 899–954 | 954–83 |
| 8812 | 14774 | 5A D | alignment 14853 | 54 | 19 ?B | 2.22 | E | 220x60 | 902–955 | 955/6? |
| 8827 | 20519 | 5B A | 5/1 internal paired post | 68 | 13 | 1.70 | CX | 130x120 | 879–946 | 946–79 |
| 8832 | 21459 | 5B C | horizontal | 58 | – | 1.29 | AX | 170x120 | 889–946 | after 956 |
| 8833 | 20405 | 5B B | post associated with 5/1 | 85 | – | 1.51 | D | 140x50 | – | – |
| 8845 | 21522 | 5B D | horizontal | 53 | – | 3.10 | DE | 180x70 | 896–948 | after 958 |
| 8847 | 25676 | 4B C | alignment 30765 | 109 | – | 1.48 | CX | 180x140 | 781–889 | after 899 |
| 8849 | 8550 | 5B B | 5/4 west wall supplementary sill | 183 | 1 | 1.28 | DX | 250x100 | 784–966 | 975–1011 |
| 8851 | 27300 | 5B B | horizontal in pit/cut 27298/26993 | 145 | 4 | 1.61 | D | 250x80 | 848–992 | 998–1034 |
| 8856 | 28509 | 4B B | isolated | 88 | – | 1.40 | CX | 170x130 | 806–893 | after 903 |
| 8858 | 21806 | 5B D | 5/8 drain | 186 | – | 1.26 | DE | 250x25 | 785–970 | after 980 |
| 8859 | 21890 | 5B D | 5/8 drain | 61 | 1 | 4.11 | D | 270x40 | 918–978 | 987–1023 |
| 8860 | 21891 | 5B D | 5/8 drain | 66 | HS | 3.46 | D | 230x30 | 913–978 | 988–1024 |
| 8863 | 21892 | 5B D | 5/8 drain | 143 | – | 1.61 | DE | 245x20 | 812–954 | after 964 |
| 8865 | 21797 | 5B D | 5/8 | 60 | 1 | 0.80 | AX | 170x110 | – | – |
| 8867 | 27553 | 4A B | isolated | 129 | 11 | 1.52 | DE | 220x70 | 778–906 | 906–41 |
| 8873 | 21959 | 5B C | isolated | 50 | 18 ?Bw | 1.62 | A1 | 160x140 | 891–940 | 940/1? |
| 8877 | 21867 | 5B C | horizontal in ?path 37403 | 39 | – | 2.55 | E | 250x40 | 898–936 | after 946 |
| 8882 | 21794 | 5B D | 5/8 east wall brace | 59 | – | 2.20 | BX | 220x110 | 899–957 | after 967 |
| 8884 | 22293 | 4B D | alignment 22585, west side of D | 252 | – | 0.98 | D | 270x90 | 637–888 | after 898 |
| 8885 | 22291 | 4B D | alignment 22585, west side of D | 194 | 22 | 1.32 | D | 270x100 | 742–935 | 935–59 |
| 8886 | 22514 | 4B D | alignment 22585, west side of D | 115 | – | 1.33 | D | 210x70 | 767–881 | after 891 |
| 8887 | 22294 | 4B D | alignment 22585, west side of D | 140 | 37 | 1.50 | D | 240x70 | 789–928 | 928–37 |
| 8888 | 21796 | 5B D | 5/8 east wall brace | 67 | 30 Bw | 1.05 | A1 | 140x90 | 942–1008 | 1008/9 |

**Table 1** *(cont'd)*

| Timber no | Context no | Period & Tenement | Function | Total no of rings | Sapwood rings | ARW (mm) | Timber conversion | Dimensions (mm) | Date span (AD) | Felled (AD) |
|---|---|---|---|---|---|---|---|---|---|---|
| 8892 | 29097 | 5B D | 5/7 backfill | 64 | HS? | 2.32 | D | 150x30 | 908–971 | 981–1017? |
| 8897 | 29106 | 5B C | horizontal in path 37404 | 215 | – | 1.14 | D | 270x35 | 695–909 | after 919 |
| 8899 | 29107 | 5B C | horizontal in path 37404 | 152 | – | 1.30 | DE | 340x40 | 757–908 | after 918 |
| 8903 | 29120 | 5B C | horizontal in path 37404 | 141 | – | 1.01 | E | 260x50 | 800–940 | after 950 |
| 8905 | 29127 | 5B D | horizontal sealing 5/7 | 76 | 25 | 1.26 | AX | 200x130 | – | – |
| 8917 | 22424 | 4B D | alignment 22585, west side of D | 220 | 31 | 0.65 | EX | 210x70 | 715–934 | 934–49 |
| 8921 | 21958 | 5B C | isolated | 59 | 14 ?Bs | 1.49 | A1 | 150x150 | 908–966 | 966? |
| 8922 | 21976 | 5B D | 5/7 backfill | 187 | – | 1.18 | DX | 230x110 | 734–920 | after 930 |
| 8945 | 8163 | 5A B | alignment 36599 | 85 | – | 2.69 | D | 280x30 | 846–930 | after 940 |
| 8947 | 29460 | 5B D | 5/7 backfill | 54 | 5 | 1.62 | E | 220x60 | 933–986 | 991–1027 |
| 8948 | 29263 | 5B D | 5/7 backfill | 101 | – | 1.48 | D | 170x130 | 805–905 | after 915 |
| 8949 | 29464 | 5B D | 5/7 backfill | 76 | – | 1.46 | BX | 230x100 | 889–964 | after 974 |
| 8951 | 22117 | 5A D | alignment 14853 | 67 | 1 | 1.71 | AX | 190x120 | 856–922 | 931–67 |
| 8952 | 25960 | 4A D | isolated | 158 | 28 | 1.38 | D | 230x50 | – | – |
| 8953 | 29469 | 5B D | 5/7 backfill | 41 | – | 3.78 | DE | 210x70 | 900–940 | after 950 |
| 8958 | 29056 | 5B C | alignment 5852 | 56 | – | 2.04 | DE | 130x60 | 914–969 | after 979 |
| 8967 | 29567 | 5B C | 5/5 post | 216 | 4 | 0.72 | BX | 240x120 | 722–937 | 943–79 |
| 8971 | 29546 | 5B D | 5/7 abandoned | 54 | – | 1.92 | BX | 230x70 | 885–938 | after 948 |
| 8974 | 29542 | 5B D | 5/7 abandoned | 51 | – | 2.17 | BX | 260x120 | 889–939 | after 949 |
| 8978 | 20845 | 4B B | alignment 37166 | 92 | – | 2.01 | D | 185x70 | 803–894 | after 904 |
| 8979 | 29626 | 5B D | horizontal associated with 5/7 | 66 | 8 | 2.11 | EX | 200x80 | 903–968 | 970–1006 |
| 8980 | 29600 | 5B D | 5/7 abandoned | 77 | 12 | 2.47 | CX | 190x100 | 881–957 | 957–91 |
| 8984 | 25422 | 4B C | alignment 36591/25640 | 53 | 12 | 1.90 | BX | 180x90 | 862–914 | 914–48 |
| 8987 | 31268 | 5A A | cut 31266 | 133 | – | 1.12 | D | 145x20 | 764–896 | after 906 |
| 8988 | 31270 | 5A A | cut 31266 | 88 | – | 1.56 | D | 135x20 | – | – |
| 8992 | 29555 | 5B D | backfill of 5/7 | 103 | – | 1.72 | CX | 170x100 | 844–946 | after 956 |
| 8995 | 29537 | 5B D | 5/7 horizontal | 100 | – | 1.18 | D | 230x25 | – | – |
| 8997 | 29539 | 5B D | 5/7 abandoned | 87 | 2 | 1.19 | B1 | 135x110 | 855–941 | 949–85 |
| 9000 | 29564 | 5B C | 5/5 post | 184 | – | 1.16 | D | 220x70 | 751–934 | after 944 |
| 9002 | 29518 | 5B D | 5/7 sill | 106 | 35 ?Bs | 1.05 | AX | 220x160 | 861–966 | 966? |
| 9003 | 29508 | 5B D | 5/7 post | 51 | – | 3.38 | BX | 290x130 | 895–945 | after 955 |

**Table 1** *(cont'd)*

| Timber no | Context no | Period & Tenement | Function | Total no of rings | Sapwood rings | ARW (mm) | Timber conversion | Dimensions (mm) | Date span (AD) | Felled (AD) |
|---|---|---|---|---|---|---|---|---|---|---|
| 9007 | 29512 | 5B D | 5/7 abandoned | 65 | – | 2.56 | B1 | 260x100 | 874–938 | after 948 |
| 9008 | 29515 | 5B D | 5/7 construction – ?chock | 53 | 2 | 2.47 | DX | 130x45 | 894–946 | 954–90 |
| 9010 | 25576 | 4B D | alignment 30357 post | 69 | – | 1.79 | CX | 150x130 | 830–898 | after 908 |
| 9011 | 29543 | 5B D | 5/7 abandoned | 63 | – | 2.31 | B1 | 230x110 | 879–941 | after 951 |
| 9020 | 29605 | 5B D | 5/7 stave built box | 99 | – | 1.99 | D | 210x40 | 844–942 | after 952 |
| 9025 | 25485 | 4A D | alignment 30358 post | 119 | HS? | 1.01 | CX | 220x100 | 775–893 | 903–39? |
| 9026 | 25478 | 4A D | alignment 30358 post | 105 | 14 | 1.80 | CX | 180x120 | 817–921 | 921–53 |
| 9027 | 29519 | 5B D | 5/7 sill | 82 | 8 | 2.20 | E | 330x100 | 878–959 | 961–97 |
| 9029 | 29773 | 5B D | 5/7 associated chock under sill | 70 | 17 | 3.18 | D | 210x70 | 891–960 | 960–89 |
| 9036 | 30008 | 4A D | isolated | 69 | – | 2.67 | D | 190x80 | – | – |
| 9040 | 25820A | 4B D | alignment 22059 | 118 | – | 1.55 | D | 190x60 | 806–923 | after 933 |
| 9041 | 25824 | 4B D | alignment 30436, east side of D | 277 | – | 0.91 | DX | 250x80 | 614–890 | after 900 |
| 9044 | 30461 | 3 D | isolated | 50 | 21 ?Bw | 1.89 | A1 | 150x105 | 855–904 | 904/5? |
| 9055 | 32165 | 5A B | pit 28652 backfill | 52 | – | 1.93 | E | 210x70 | 886–937 | after 947 |
| 9056 | 32166 | 5A B | pit 28652 backfill | 54 | 8 | 3.66 | D | 210x90 | 905–958 | 960–96 |
| 9067 | 31478 | 4B B | discarded timber fragment | 224 | 28 | 0.95 | D | 210x60 | 707–930 | 930–48 |
| 9069 | 8612 | 4B B | alignment 27796 | 170 | 3 | 1.47 | D | 240x110 | 761–930 | 937–73 |
| 9070 | 34378 | 4B B | horizontal | 220 | 28 | 1.14 | D | 250x50 | 722–941 | 941–59 |
| 9073 | 19750 | 3 C | isolated | 92 | 1 | 1.39 | BX | 240x110 | – | – |
| 9087 | 8315 | 4B B | alignment 27607 | 143 | 4 | 1.85 | D | 290x80 | 763–905 | 911–47 |
| 9088 | 8919 | 4B B | alignment 27607 | 155 | – | 1.75 | D | 270x60 | 761–915 | after 925 |
| 9089 | 8920 | 4B B | alignment 27607 | 57 | 11 | 2.04 | E | 250x60 | 894–950 | 950–85 |
| 9092 | 2992 | 4B B | alignment 27676 | 89 | 14 | 1.37 | CX | 130x80 | 854–942 | 942–74 |
| 9102 | 29418 | 5B C | isolated | 144 | – | 1.77 | DX | 260x130 | 794–937 | after 947 |
| 9106 | 35009 | 5B C | isolated | 63 | – | 1.64 | D | 170x25 | 907–969 | after 979 |
| 9117 | 34538 | 4B B | alignment 27607 | *161* | – | 1.41 | D | 230x50 | – | – |
| 9119 | 21929 | 5B C | isolated | 72 | 8 | 2.49 | CX | 190x110 | – | – |
| 9133 | 29562 | 5B C | 5/5 post | 210 | – | 1.37 | D | 280x110 | 728–937 | after 947 |
| 9134 | 29563 | 5B C | 5/5 post | 189 | – | 1.19 | D | 210x100 | 715–903 | after 913 |
| 9139 | 35209 | 4B C | horizontal in path 37405 | 103 +40 | (+25) | 1.59 | D | 210x80 | – | – |
| 9146 | 29565 | 5B C | 5/5 north wall post | 196 | – | 1.29 | D | 240x100 | 751–946 | after 956 |

**Table 1** *(cont'd)*

| Timber no | Context no | Period & Tenement | Function | Total no of rings | Sapwood rings | ARW (mm) | Timber conversion | Dimensions (mm) | Date span (AD) | Felled (AD) |
|---|---|---|---|---|---|---|---|---|---|---|
| 9159 | 35104 | 4B D | embedded in alignment 35111 | 87 | – | 1.22 | D | 250x20 | 807–893 | after 903 |
| 9162 | 35264 | 5B D | 5/7 abandoned | 64 | 3 | 2.91 | CX | 190x120 | 882–945 | 952–88 |
| 9164 | 35300 | 4B C | horizontal in path 37405 | 63 | – | 3.37 | D | 210x30 | 751–813 | after 823 |
| 9170 | 34471 | 4B B | alignment 34486 | 99 | – | 2.58 | D | 250x80 | 783–881 | after 891 |
| 9179 | 35320 | 4B C | horizontal in layer 35293 | 85 | – | 2.44 | D | 190x20 | 829–913 | after 923 |
| 9189 | 15210 | 5B B | 5/3 south wall plank above 9190 | 45 | – | 1.26 | D | 165x30 | 829–873 | after 883 |
| 9190 | 18278 | 5B B | 5/3 south wall plank above 9192 | 110 | – | 1.54 | DX | 230x40 | 798–907 | after 917 |
| 9192 | 18279 | 5B B | 5/3 south wall plank | *60* | 11 | 2.13 | E | 270x60 | 899–958 | 958–93 |
| 9194 | 15209 | 5B B | 5/3 east wall plank above 9195 | 126 | – | 1.92 | D | 320x30 | 757–882 | after 892 |
| 9195 | 18270 | 5B B | 5/3 east wall plank above 9198 | 137 | – | 2.33 | DE | 335x25 | 740–876 | after 886 |
| 9198 | 18272 | 5B B | 5/3 east wall plank | 54 | 9 | 2.32 | E | 295x55 | 901–954 | 955–91 |
| 9203 | 18260 | 5B B | 5/3 west wall plank | 66 +10 | – | 1.11 | D | 95x25 | 812–877 | after 897 |
| 9212 | 35507 | 4B C | post in alignment 35161 | 56 | – | 2.16 | CX | 130x120 | 826–881 | after 891 |
| 9215 | 35517 | 4B C | isolated | 105 | – | 1.74 | DX | 190x90 | 791–895 | after 905 |
| 9216 | 35725 | 4B C | post in alignment 35161 | 74 | – | 2.22 | DX | 170x80 | 804–877 | after 887 |
| 9219 | 30011 | 4A D | isolated | 191 | 9 | 1.40 | D | 260x40 | 706–896 | 897–933 |

**Table 2** Details of the tree-ring samples which were unsuitable for dating purposes. Timber conversion types – see Fig.346

| Timber no | Context no | Total no of rings | Timber conversion | Dimensions (mm) |
|---|---|---|---|---|
| 8214 | 7089 | 30 | A | 90x90 |
| 8314 | – | – | BX | 220x80 |
| 8430 | 8841 | 44 | B1 | 210x110 |
| 8453 | 13863 | 37 | CX | 140x100 |
| 8460 | 14213 | 45 | AX | 250x130 |
| 8471 | 14184 | 37 | AX | 140x100 |
| 8475 | 7557 | 37 | BX | 230x100 |
| 8509 | 14048 | 43 | AX | 180x140 |
| 8528 | 14422 | 26 | A1 | 190x120 |
| 8601 | 14721 | 33 | D | 210x40 |
| 8605 | 14728 | 35 | D | 200x40 |
| 8650 | 6956 | 33 | D | 240x50 |
| 8656 | 19230 | 30 | A | 90x80 |
| 8668 | 6863 | 20 | A | 140x100 |
| 8669 | 6861 | 26 | A | 140x120 |
| 8671 | 6883 | 30 | B | 190x100 |
| 8678 | – | – | – | 310x60 |
| 8737 | 20881 | 35 | BD | 170x60 |
| 8754 | 18533 | 41 | AX | 140x130 |
| 8775 | 23489 | 40 | CX | 160x140 |
| 8799 | 23682 | 27 | CX | 160x70 |
| 8814 | 20820 | 41 | C1 | 170x70 |
| 8828 | 20295 | 34 | C1 | 140x120 |
| 8846 | 26871 | 26 | CX | 130x80 |
| 8850 | 27009 | 28 | BX | 200x100 |
| 8857 | 25022 | 28 | D | 210x60 |
| 8864 | 28168 | 45 | BD | 140x60 |
| 8876 | 27612 | 38 | A1 | 150x120 |
| 8879 | 25423 | 22 | CX | 230x80 |
| 8930 | 18777 | 39 | B1 | 180x120 |
| 8931 | 27361 | 21 | A1 | 240x240 |
| 8946 | 25642 | 37 | C1 | 170x110 |
| 8975 | 29536 | 49 | AX | 310x165 |
| 8977 | 25286 | 44 | B | 170x70 |
| 8985 | 31167 | 24 | CX | 160x130 |
| 8990 | 28547 | 38 | CX | 125x85 |
| 9006 | 27908 | 39 | CX | 120x70 |
| 9016 | 29781 | 36 | BD | 190x50 |
| 9017 | 29782 | 26 | B1 | 200x80 |
| 9023 | 25575 | 43 | AX | 180x120 |
| 9024 | 25477 | 47 | C1 | 150x150 |
| 9028 | 29601 | 42 | CX | 140x100 |
| 9030 | 29813 | 37 | DE | 205x50 |
| 9032 | 30306 | 19 | A | 150x120 |

**Table 2** *(cont'd)*

| Timber no | Context no | Total no of rings | Timber conversion | Dimensions (mm) |
|---|---|---|---|---|
| 9035 | – | knotty | CX | 240x150 |
| 9042 | 22264 | 35 | AX | 160x120 |
| 9048 | 31446 | 24 | B1 | 170x80 |
| 9051 | 27314 | knotty | A | 240x200 |
| 9053 | 27302 | 38 | A1 | 200x150 |
| 9054 | 27303 | 36 | A1 | 200x150 |
| 9057 | 27306 | 32 | A | 260x200 |
| 9058 | 6637 | 47 | AX | 190x150 |
| 9064 | 8353 | 31 | B1 | 220x80 |
| 9065 | 18767 | 15 | A | 140x120 |
| 9090 | 32465 | 28 | D | 200x40 |
| 9107 | 34197 | 30 | C1 | 170x75 |
| 9110 | 35011 | knotty | CX | 210x180 |
| 9122 | 35133 | 36 | AX | 260x110 |
| 9124 | 29890 | knotty | X | 200x100 |
| 9125 | 34591 | 17 | A | 140x120 |
| 9128 | 35124 | 25 | AX | 210x190 |
| 9140 | 35071 | 42 | C1 | 170x80 |
| 9144 | 29882 | knotty | BX | 160x100 |
| 9148 | 35269 | 41 | B1 | 180x90 |
| 9154 | 35267 | 39 | C1 | 200x90 |
| 9163 | 35200 | knotty | BX | 210x150 |
| 9178 | 35276 | 20 | A1 | 140x70 |
| 9188 | 35720 | knotty | CX | 140x120 |
| 9193 | 12259 | knotty | CX | 160x140 |

**Table 3** Results of comparisons between some relevant reference chronologies and the 168-sample Coppergate site master chronology, YORKCPG3, at 460–1011 inclusive (all dates AD unless specified)

| Region | Reference chronology | Date span | *t* value |
|---|---|---|---|
| Cambridgeshire | Peterborough Cathedral nave roof (Tyers 1999) | 887–1225 | 8.12 |
| Cumbria | Carlisle The Lanes southern (Groves 1993a) | 917–1193 | 5.14 |
| | Carlisle The Lanes northern (Groves 1996c) | 892–1275 | 5.45 |
| Hampshire | The Brooks, Winchester (Hillam 1992c) | 443–1128 | 6.27 |
| London | Barking Abbey (Tyers 1988) | 413–793 | 5.44 |
| | Fennings Wharf (Tyers forthcoming) | 802–1435 | 4.69 |
| N Lincolnshire | Barton on Humber Coffins – interim (Tyers 2000c) | 811–1130 | 9.27 |
| Staffordshire | St Mary's and Eastgate (Groves 1987a; 1987b) | 884–1189 | 6.71 |
| West Midlands | Tamworth (Baillie, pers. comm.) | 404–825 | 5.46 |
| Yorkshire | Dyer Lane, Beverley (Groves and Hillam 1985) | 903–1183 | 5.76 |
| | Eastgate, Beverely (Groves 1992) | 858–1310 | 7.23 |
| | Lurk Lane, Beverley (Groves and Hillam 1991) | 885–1124 | 5.80 |
| | Skerne (Hillam unpubl) | 440–647 | 9.09 |
| | Queens Hotel, York (Groves 1993b) | 769–1036 | 12.95 |
| | Swinegate, York (Tyers and Bagwell unpubl) | 749–986 | 12.11 |
| | | | |
| Ireland | Dublin (Baillie 1977) | 855–1306 | 5.26 |
| Ireland | North horizontal mills (Baillie, pers. comm.) | 358–894 | 4.19 |
| Ireland | South horizontal mills (Baillie, pers. comm.) | 261–881 | 4.98 |
| Denmark | West Denmark (Bonde, pers. comm.) | 109 BC–AD 1986 | 5.48 |
| Germany | Trier region (Hollstein 1980) | 546 BC–AD 1975 | 5.58 |

**Table 4** Summary of the tree-ring dates. wb – watching brief; only the latest felling date(s) indicated for backfills are given

| Period | Tenement | Structure or Timber | Felled (AD) |
|---|---|---|---|
| 2 | – | helmet pit timber **97** | after 586 |
| | | isolated timber **91** | after 685 |
| 3 | D | isolated timber **9044** | 904/05? |
| 4A | B | isolated timber **8867** | 906–41 |
| | D | alignment 30358, timbers **9025–6** | 921–39 |
| | | isolated timber **9219** | 897–933 |
| 4B | B | alignment 27607, timbers **9087–9** | 925–47 and 950–85 |
| | | alignment 27676, timber **9092** | 942–74 |
| | | alignment 27796, timber **9069** | 937–73 |
| | | alignment 34486, timber **9170** | after 891 |
| | | alignment 37166, timber **8978** | after 904 (probably 935–37) |
| | | horizontal timber **9070** | 941–59 |
| | | isolated timber **8856** | after 903 |
| | | discarded timber fragment **9067** | 930–48 |
| | C | alignment 30765, timber **8847** | after 899 |
| | | alignment 35161, timber **9212** | after 891 |
| | | alignment 36591/25640, timber **8984** | 914–48 |
| | | isolated timber **9215** | after 905 |
| | | horizontal in layer 35293, timber **9179** | after 923 |
| | | horizontal in path 37405, timber **9164** | after 823 |
| | D | alignment 22059, timber **9040** | after 933 |
| | | alignment 22585, timber **8885/8887** | 935–37 |
| | | alignment 30357, timber **9010** | after 908 |
| | | alignment 30436, timber **9041** | after 900 (probably 935–37) |
| | | embedded in alignment 35111, timber **9159** | after 903 |
| 5A | A | alignment 36583, timber **8720** | after 941 |
| | | cut 31266, timber **8987** | after 906 (probably before 961/62) |
| | B | alignment 18422, timber **8741** | 955/56? |
| | | alignment 36582, timber **8753** | 955/56? |
| | | alignment 36599, timber **8945** | after 940 |
| | | pit 28652 backfill, timber **9056** | 960–96 |
| | D | alignment 14853, timbers **8807/8812** | 955/56 |
| | | isolated post **8795** | 946–78 |
| | D/E wb | covered drain, timber **0172** | 960–94 |
| 5B | A | Structure 5/1 plank, timber **8680** | 961/62 |
| | | Structure 5/1 post, timber **8692** | 961–81 (probably 961/62) |
| | | Structure 5/1 internal post, timber **8827** | 946–79 (possibly 961/62) |
| | B | horizontal in pit/cut 27298/26993, timber **8851** | 998–1034 |
| | | Structure 5/3 planks, timbers **9192/9198** | 958–91 (probably 958–87, possibly 966) |
| | | Structure 5/3 posts, timbers **8562/8563** | 952–87 (probably 958–87, possibly 966) |
| | | Structure 5/4 post, timber **8234** | after 946 |
| | | Structure 5/4 drain cap, timber **8387** | 972/73? |
| | | Structure 5/4 sill, timber **8379** | 961–89 (probably 972/73) |
| | | Structure 5/4 sill replacement, timber **8849** | 975–1011 |
| | | Structure 5/4 collapse, timber **8221** | 993–1029 |
| | | Structure 5/4 backfill, timber **8065** | after 1001 |

**Table 4** *(cont'd)*

| Period | Tenement | Structure or Timber | Felled (AD) |
|---|---|---|---|
| 5B | C | alignment 33233, timbers **8527/8599** | 956/57? and 964–84 |
| | | alignment 33235, timbers **8745–6** | 955/56 |
| | | alignment 5852, timber **8958** | after 979 |
| | | horizontal timber **8832** | after 956 |
| | | isolated timbers **8873, 9102, 8921, 9106** | 940/41?, after 947, 966?, after 979 |
| | | horizontal in path 37403, timber **8877** | after 946 |
| | | horizontals in path 37404, timber **8903** | after 950 |
| | | fence line 6661, timber **8620** | after 1017 |
| | | Structure 5/5 posts, timbers **8967/9146** | 956–79 |
| | | Structure 5/6 planks, timbers **8213/8215** | after 951 (probably 970–97) |
| | | Structure 5/6 post, timber **8319** | 961–97 (probably 970–97) |
| | | Structure 5/6 sill, timber **8376** | 970–1003 (probably 970–97) |
| | | Structure 5/6 collapse, timber **8316** | after 958 (possibly 970–97) |
| | | Structure 5/6 backfill, timber **8067/8075** | after 961, 958–94 |
| | | Structure 5/6 drain, timber **8240** | after 963 |
| | D | horizontal timber **8845** | after 958 |
| | | Structure 5/7 sill/sill chock, timber **9002** | 966? |
| | | Structure 5/7 post, timber **9003** | after 955 (probably 966) |
| | | Structure 5/7 construction (chock?), timber **9008** | 954–90 (probably 966) |
| | | Structure 5/7 abandoned, timber **8980/8997** | 957–85 (possibly 966) |
| | | Structure 5/7 stave-built box, timber **9020** | after 952 |
| | | Structure 5/7 backfill, timber **8947** | 991–1027 |
| | | Structure 5/8 brace, timber **8888** | 1008/09 |
| | | Structure 5/8 sill, timber **8393** | 995/96? |
| | | Structure 5/8 construction, timber **8359** | 988–1024 (possibly 995/96 or 1008/09) |
| | | Structure 5/8 drain, timber **8551** | 988–1017 (possibly 995/96 or 1008/09) |
| | D wb | Structure 5/7, timber **0122** | after 994, 966–1002 |
| | E wb | Structure 5/9 construction (joist?), timber **0138** | after 913 |
| | | Structure 5/9 sill, timber **0131** | 951–87 |
| 5Cf | D | Structure 5/10 bracer beams, timbers **8464–5** | 963–98 |
| | | Structure 5/10 sill, timber **8456** | after 944 (possibly 963–98) |
| 5Cr | C | Structure 5/12 stubs, timber **8649** | 1013–49 |

**Table 5** Matrix showing the *t* values obtained between the individual timber ring sequences from Period 5B Tenement B Structure 5/3 and Period5B Tenement D Structure 5/7. \ = overlap less than 15 years; – = *t* values less than 3.00

| Samples | **5/3→** | 9189 | 9190 | 9192 | 9194 | 9195 | 9198 | 9203 | 8556 | 8559 | 8562 | 8563 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **5/7** ↓ | | | | | | | | | | | | |
| 9002 | | \ | – | – | – | – | – | – | – | – | – | – |
| 9027 | | \ | – | – | \ | \ | – | \ | 3.00 | – | – | – |
| 9029 | | \ | – | 3.42 | \ | \ | 3.56 | \ | 5.32 | – | 6.69 | 5.35 |
| 9003 | | \ | \ | – | \ | \ | – | \ | – | – | – | – |
| 9008 | | \ | \ | 3.43 | \ | \ | – | \ | 10.28 | 4.27 | 5.77 | 3.59 |
| 9020 | | – | – | – | – | – | – | – | – | – | – | 3.69 |
| 8971 | | \ | – | – | \ | \ | – | \ | – | 3.46 | – | 4.00 |
| 8974 | | \ | – | – | \ | \ | – | \ | 4.13 | – | 5.73 | 4.24 |
| 8980 | | \ | – | – | \ | \ | – | \ | 6.58 | 3.30 | 5.79 | 4.10 |
| 8997 | | – | – | – | – | – | – | – | – | – | – | – |
| 9007 | | \ | – | – | \ | \ | – | \ | 3.24 | – | 3.93 | 3.63 |
| 9011 | | \ | – | – | \ | \ | – | \ | 3.52 | 3.11 | 4.09 | 3.92 |
| 9162 | | \ | – | 3.05 | \ | \ | – | \ | 6.49 | 4.29 | 6.43 | 4.47 |

**Table 6** Matrix showing the *t* values obtained between the individual timber ring sequences from Period 5B Tenement D Structure 5/7 and the abandoned timbers found in Structure 5/7. \ = overlap less than 15 years; – = *t* values less than 3.00

| Samples | **abandoned→** | 8971 | 8974 | 8980 | 8997 | 9007 | 9011 | 9162 |
|---|---|---|---|---|---|---|---|---|
| **structural** ↓ | | | | | | | | |
| 9002 | | – | – | – | – | – | – | – |
| 9027 | | – | – | – | – | – | – | 3.67 |
| 9029 | | – | 5.62 | 4.67 | – | 4.95 | 3.86 | 6.79 |
| 9003 | | – | – | – | – | 3.91 | – | 3.51 |
| 9008 | | 3.35 | 4.01 | 7.68 | – | 3.41 | 3.07 | 5.37 |
| 9020 | | – | – | 3.41 | – | – | 3.15 | – |

**Table 7** Matrix showing the *t* values obtained between the individual timber ring sequences from Period 5B Tenement D Structures 5/7 and 5/8 compared with timbers 122 and 123 from the watching brief. \ = overlap less than 15 years; – = *t* values less than 3.00

| **Samples** | **0122** | 0123 |
|---|---|---|
| **5/7** | | |
| **9002** | – | – |
| **9027** | – | – |
| **9029** | – | – |
| 9003 | – | – |
| 9008 | 3.03 | 4.46 |
| 8971 | – | 4.00 |
| 8974 | – | 3.16 |
| 8980 | – | – |
| 8997 | – | – |
| 9007 | – | 3.50 |
| 9011 | – | – |
| 9162 | – | 3.55 |
| 9020 | – | – |
| | | |
| **5/8** | | |
| 8882 | – | – |
| 8888 | – | – |
| 8392 | – | 3.86 |
| 8393 | – | – |
| 8394 | – | – |
| 8359 | – | 4.09 |
| 8543 | – | 4.04 |
| 8551 | – | – |
| 8858 | – | 4.48 |
| 8859 | – | – |
| 8860 | – | – |
| 8863 | – | – |

**Table 8** Matrix showing the *t* values obtained between the individual timber ring sequences from Period 5B Tenement C Structure 5/5. \ = overlap less than 15 years; – = *t* values less than 3.00

| Samples | 9000 | 9133 | 9134 | 9146 |
|---|---|---|---|---|
| 8967 | 3.93 | 4.77 | 6.63 | 4.03 |
| 9000 | | 5.96 | 7.61 | 5.38 |
| 9133 | | | 7.44 | 10.03 |
| 9134 | | | | 8.08 |

**Table 9** Matrix showing the *t* values obtained between the individual timber ring sequences from Period 4B Tenement D alignment 22585. \ = overlap less than 15 years; – = *t* values less than 3.00

| Samples | 8885 | 8886 | 8887 | 8917 |
|---|---|---|---|---|
| 8884 | 10.35 | 8.17 | – | – |
| 8885 | | 8.33 | – | – |
| 8886 | | | – | 3.39 |
| 8887 | | | | – |

**Table 10** Matrix showing the *t* values obtained between the individual timber ring sequences from Period 5B Tenement C Structure 5/6. \ = overlap less than 15 years; – = *t* values less than 3.00

| Samples | 8215 | 8293 | 8340 | 8319 | 8320 | 8376 |
|---|---|---|---|---|---|---|
| 8213 | 9.04 | 9.49 | – | – | 3.83 | – |
| 8215 | | 9.99 | – | – | – | – |
| 8293 | | | – | – | 3.22 | – |
| 8340 | | | | \ | 5.64 | \ |
| 8319 | | | | | \ | – |
| 8320 | | | | | | \ |

**Table 11** Matrix showing the *t* values obtained between the individual timber ring sequences from Period 5B Tenement C Structure 5/1. \ = overlap less than 15 years; – = *t* values less than 3.00

| Samples | 0051 | 8675 | 8676 | 8677/8680 | 8679 | 8702 | 8708 | 8692 | 8693 | 8695 | 8696 | 8701 | 8827 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0004 | – | 3.26 | – | 3.03 | – | – | \ | – | \ | – | – | \ | – |
| 0051 | | 14.94 | 8.03 | 18.17 | 6.05 | 5.29 | – | – | – | 3.12 | 3.38 | – | 3.03 |
| 8675 | | | 10.15 | 20.34 | 6.13 | 4.58 | – | – | – | – | – | – | – |
| 8676 | | | | 9.41 | 9.31 | 4.12 | – | – | – | – | – | – | – |
| 8677/8680 | | | | | 7.59 | 5.72 | – | 3.58 | – | – | – | – | – |
| 8679 | | | | | | 3.57 | – | – | – | 3.35 | 3.55 | 3.21 | – |
| 8702 | | | | | | | – | 3.97 | – | 4.30 | 5.04 | – | – |
| 8708 | | | | | | | | – | – | 4.50 | 3.37 | 3.27 | – |
| 8692 | | | | | | | | | 5.10 | 3.29 | 4.59 | 4.25 | 3.83 |
| 8693 | | | | | | | | | | 3.14 | 3.60 | 6.87 | 4.07 |
| 8695 | | | | | | | | | | | 11.29 | 4.91 | 3.68 |
| 8696 | | | | | | | | | | | | 3.53 | 4.51 |
| 8701 | | | | | | | | | | | | | 3.47 |

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