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DENDROCHRONOLOGICAL ANALYSIS OF TIMBERS FROM THE LANES, CARLISLE, CUMBRIA, 1978-82: VOLUME 1

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Summary

Dendrochronological analysis of 143 wood samples from archaeological investigations in the southern part of The Lanes, Carlisle, produced two absolutely dated chronologies covering the periods 372BC-AD93 and AD917-1193. Tree-ring dates were obtained for a number of structures from late first and early second century AD phases and also timbers associated with a later medieval well and pit. A single timber was dated to the Anglo-Scandinavian period and had a felling date range of AD771-816.

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Dendrochronological analysis of timbers from The Lanes, Carlisle, Cumbria, 1978-82: Volume 1

Introduction

The proposed redevelopment of an area in Carlisle known as The Lanes resulted in a major archaeological investigation being carried out by the Carlisle Archaeological Unit. The Lanes area occupies over six acres on the east side of the city centre (Figure 1) and is currently the most extensive urban investigation that has been carried out in northern England.

A building survey was undertaken to record the standing structures, some of which dated back as far as the late 17th century AD, and various areas within The Lanes were excavated throughout the period 1978-1982. The investigation revealed deposits ranging from prehistoric to post-medieval date, although there is relatively little archaeological evidence for the period between the late 4th to the 12th or early 13th centuries AD (McCarthy pers comm).

Over 100 timber samples from The Lanes were examined during the late 1970s and early 1980s in the Tree-Ring Laboratory at the Queen's University, Belfast, as part of their research into the production of a continuous chronology for the British Isles on which to base the radiocarbon calibration curve (eg Brown *et al* 1986). The remaining 289 samples are to be included in the work programme at the Sheffield Dendrochronology laboratory during 1991-1993. The data for all samples measured at Belfast were made available and where relevant will be re-examined and incorporated into the reports from Sheffield. The main aims of this study were to provide a detailed and precise dating framework for the development of The Lanes and to provide links between the phasing sequences of sites not joined by other stratigraphical evidence. It was hoped that the new samples would provide tree-ring dates for additional structures and trenches and also refine the results obtained at Belfast.

This report is concerned with the excavations in Crown and Anchor Lane, Old Grapes Lane, Lewthwaites Lane and Old Bush Lane, all located at the south end of The Lanes (Figure 2). This involved the analysis of 143 samples, 13 of which were originally examined at Belfast.

The sites and samples

Many of the timbers used in the construction of buildings or other features attributed to the early Roman phases survived. Later phases were less well preserved but some timbers from the Anglo-Scandinavian and medieval periods were still extant. The phasing sequences identified in trenches A and B at Old Grapes Lane (site codes: OGL A, OGL B) can be directly linked (Table 1). Both trenches C and J at Old Grapes Lane (OGL C, OGL J) contain the remains of a rampart structure so their phasing sequences are also directly comparable but can only be indirectly linked with trenches OGL A and OGL B. The other sites which have provided tree-ring samples are trench A at Crown and Anchor Lane (CAL A), trench A at Lewthwaites Lane (LEL A) and trench B at Old Bush Lane (OBL B), none of which have definite stratigraphic links in the relevant phases.

CAL A

The seven timbers from Crown and Anchor Lane were all originally analysed at Belfast but the data were made available for re-examination. The sample (015) from a plank fragment in the fill of a timber-lined pit (66) is either of late Roman or post-Roman date (Table 2). (Timber sample numbers are under-lined throughout this report.) Five samples were associated with the timber-lined pit 64 of post-Roman date. Other archaeological evidence suggested that the pit 64 timbers were probably re-used, apart from 014. Post 008 from pit 70, also of post-Roman date, appears to be re-used.

OGL A

A total of 84 samples, representing 82 timbers, were obtained from trench A (Table 2). The Roman deposits (phases 3-10), which span the 1st-4th centuries AD, provided 49 samples. The medieval

deposits (phases 11-13) provided 27 samples and 8 samples were unphased.

Only two tree-ring samples were taken from phases 3 and 4. The phase 4 plank (285) appeared not to be *in situ*, but it and the phase 3 post (306) were considered important as they were associated with the earliest Roman activity on the site. A single sample was obtained from a phase 5 plank (102) and two timbers (344, 353) either from phase 5 or later were also sampled.

Thirty samples were taken from 28 timbers associated with phase 6 of which 13 were from the main building 674. Other archaeological evidence suggests that timber 171 from building 674 may be re-used. Two timbers (189, 234) were also taken from minor features associated with building 674. Five of the remaining 15 samples from phase 6 were from feature 739; two were from feature 698; three were from fences; plank 139 was from a revetment and four samples are of unknown function.

All ten phase 7A samples were taken from a collapsed wall or fence (structure 659). The final four samples (018, 078, 083, 351) from the Roman deposits are associated with phases 8 and 9. Sample 083 is a post from a boundary fence but the function of the other three samples is unknown.

Twenty-five of the 27 medieval timbers were from well 1237 (phase 13). A series of posts and braces formed a free-standing frame within the well shaft. Behind the frame, the well shaft was lined by planks which rested against the sides of the shaft. The two remaining medieval timbers, originally analysed at Belfast, were associated with a pit.

The eight unphased samples include five from context 430 and three (017, 019, 036) originally submitted to Belfast from unknown features.

OGL B

Samples were obtained from 19 timbers associated with Roman levels and one unphased timber. The single phase 2B sample (132) is a post from a wall or fence on the gulley 303 east-west alignment. It is the earliest Roman timber submitted for tree-ring analysis in this trench. No samples were available from phase 3. Eight samples were obtained from phase 4, two (103, 164) of which are from wall 281 associated with the OGL A building 674. Three samples were from a collapsed wall (feature 230) and two are posts from a fence line. The remaining phase 4 sample (059) is an isolated timber, not apparently connected with any structure.

Phase 5A is represented by four samples from well 184 which was lined with oak planks. Five samples were taken from phase 6: the phase 6A sample (022) was from a post; 028, 232 and 236 from phase 6B were associated with the walls of the main building; and 233 from phase 6E appears to be associated with a rebuild of the west wall of the phase 6 building. The presence of apparently redundant mortises in timber 232 suggests that it was probably re-used (McCarthy pers comm).

Phase 9, the latest phase in this trench provided one sample (008) from a fragmented plank in pit 10. Timber 137 is from context 331. This is an isolated feature that cannot be phased by stratigraphical evidence.

OGL C

A total of five samples from Roman phases and one currently unphased timber were obtained from this trench. Two of these samples are associated with phase 2: 007 is a major post from a building; and 029 is a timber of unknown function. Sample 001 is also a major post associated with a building but is attributed to phase 2 or 3. Phase 3 sample 027 is a post from a rampart revetment of possible mid 2nd century AD date. The other phase 3 sample (030) is a plank from a lined drain, adjacent to the rampart revetment, which may be contemporary with 027. The unphased plank (034) may be of medieval date.

OGL J

All seven of the samples are from the Roman phase 2. Posts 002 and 003 are on an alignment that appears to be associated with the rampart. Post 004 is not apparently related to any structural feature but it does mark the edge of a road. The other four samples are from a roadside drain (feature 23-4) lined with oak planks.

LEL A

A total of 10 samples were taken from timbers revealed in Roman deposits. Timber 134 (context 624), a phase 3 post thought to date to the late 1st century AD, was sampled twice. Phases 4 and 5 are each represented by a single sample, but 092 (phase 4) may have been incorrectly labelled (McCarthy pers comm). Other dating evidence indicates that the timber-lined drain 615 (phase 5) dates to the turn of the 1st and 2nd centuries AD. Phase 7B provided four samples from a well of probable 2nd century AD date. The two remaining samples are associated with phase 10B. They are both major posts from a large building of possible mid 2nd-early 3rd century AD date.

OBL B

Nine timbers, all thought to date to around the late 1st-early 2nd centuries AD, were sampled. The single timber (037) from phase 2 was from the fill of a gulley. The only phase 6 timber (030) was a post on a stone pad. The other 7 samples are from 6 timbers associated with a Roman rectilinear timber building (117) whose stratigraphical relationship to the phasing sequence at OBL B is uncertain. The timbers from building 117 have therefore been allocated to the phase range 2-7.

Method

The samples received at Sheffield were prepared following the method given by Hillam (1985a). The non-oak samples, 1 alder (*Alnus glutinosa* Gaertn.) and 1 elm (*Ulmus* spp), were identified by taking thin sections of wood from the transverse, tangential and radial planes and making temporary slides. The identification of these slides was carried out using reference

material in the form of permanent slides and an identification key (Schweingruber 1978; 1990).

Any samples unsuitable for dating purposes were rejected before measurement but a note was made of the number and orientation of the rings, the dimensions and the average growth rate. Unsuitable samples are usually those with unclear ring sequences or less than 50 rings. Ring patterns with fewer than 50 rings are generally unsuitable for absolute dating as they may not be unique (Hillam *et al* 1987). However samples with 30-49 rings and sapwood or bark edge, which therefore have the potential to provide precise felling dates, may be included for measurement if there are several of them associated with a single structure.

The growth rings of all suitable samples were measured to an accuracy of 0.01mm on a travelling stage, built by the City of London Polytechnic. The travelling stage is connected to an Atari microcomputer which uses a suite of dendrochronology programs written by Ian Tyers (pers comm). The ring sequences were plotted as graphs using either a graphing program on the Sheffield University Prime mainframe (Okasha 1987) or an HI-80 Epson plotter attached to the Atari. The graphs were then compared with each other to check for any similarities between the ring patterns which might indicate contemporaneity. This process of crossmatching is aided by the use of programs on the Atari microcomputer. The crossdating routines are based on versions of CROS (Baillie & Pilcher 1973, Munro 1984) and measure the amount of correlation between two ring sequences. The Student's *t* test is then used as a significance test on the correlation coefficient. All *t* values quoted in this report are identical to those produced by the original CROS program (Baillie & Pilcher 1973). Generally a *t* value of 3.5 or over represents a match, provided that the visual match is acceptable (Baillie 1982: 82-85). Although there is no precisely defined limit, individual oak samples which match with *t* values over approximately 10.0 are likely to have originated from the same tree. However it is possible to have ring patterns on opposite sides of the same tree which crossmatch with *t* values of less

than 10. Consequently other samples from the same tree could be present on the site but this cannot be confirmed by tree-ring analysis.

Dating is achieved by crossmatching ring sequences within a phase or building and combining the matching patterns to produce a site master curve. All previously unmatched sequences from the site are compared with this master curve and if any additional patterns are found to crossmatch these are incorporated into the site master curve. If two or more samples appear to have been split from the same tree, a tree mean curve is constructed. This is included in the site master curve as a single sequence to prevent any bias within the master. The site master curve and all unmatched ring sequences are then tested against reference chronologies to obtain absolute dates. The most commonly used reference chronologies were the Roman chronologies from Castle Street and Annetwell Street, Carlisle (Groves 1991; forthcoming), medieval Carlisle (Baillie pers comm), Papcastle (Hillam 1988), Vindolanda (Hillam 1991), Droitwich (Groves & Hillam 1992) and Scotland (Baillie 1977). A master curve is used for absolute 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.

The results only date the rings present in the timber and therefore do not necessarily represent the felling date. If the bark or bark edge is present on a sample the exact felling year can be determined. If the outermost ring has both early and latewood present and therefore appears to be complete, the timber was felled during late summer-early spring (ie out of the growing season). This is referred to as winter felled. If only the earlywood is present then the timber was probably felled during late spring-early summer (Baillie 1982, fig 2.1), which is referred to as summer felled.

In the absence of bark surface the felling date is calculated using the sapwood estimate of 10-55 rings. This is the range of the 95% confidence limits for the number of sapwood rings on

British oak trees over 30 years old (Hillam *et al* 1987). In the total absence of sapwood the addition of 10 rings (the minimum number of sapwood rings expected) to the date of the last measured heartwood ring produces a probable *terminus post quem* for felling. During timber conversion a large number of outer rings could be removed but as this is unquantifiable the actual felling date could be much later.

Once the felling date range or *terminus post quem* for felling has been calculated, factors such as stockpiling, re-use and seasoning of timber must be considered since they might affect the interpretation of the tree-ring dates. Seasoning of timber is thought to have been a fairly rare occurrence until relatively recent times. Evidence indicates that timber was generally felled as required and used whilst green (eg Hanson 1978; Hanson & Macinnes 1981; Rackham 1990: 69). Construction which utilizes primary rather than re-used timber is therefore likely to have occurred shortly after felling. The possibility of a timber structure having undergone repair work should also be taken into account. Thus, whilst the date obtained for the measured tree-ring sequence is precise and has been achieved by a completely independent process, the interpretation of tree-ring dates can be refined by studying other archaeological and documentary evidence.

Results

The recorded details of the tree-ring samples and the results of the analysis are presented in full in Tables 3 and 4 but are described trench by trench below. A total of 104 oak samples were considered suitable for measurement of which 54 (52%) were absolutely dated. The ring width data from the individual samples are stored at the Sheffield Dendrochronology Laboratory. The dated individual curves from the Roman phases were combined to form a composite Roman chronology for all trenches in the southern part of The Lanes, LANES/ROMI (Table 5). The data from the site master curve for the medieval period (LANES/MEDI) and the data from the single dated timber (CALA012) from the Anglo-Scandinavian period are presented in Tables 6 and 7.

CAL A

All seven timbers, containing 61-251 rings, were measured at Belfast. Intra-site comparison did not produce any conclusive matches. The individual ring patterns were tested against British, Irish and other European chronologies spanning AD404-1981. Timber 012 dated to the period AD512-649 (Table 7; 8). No consistent results could be obtained for any of the other individual sequences.

OGL A

Twenty-five of the 84 samples from OGL A were discarded before measurement, including 18 Roman, 2 medieval and 5 unphased timbers (Table 3). The majority of rejected samples did not contain a sufficient number of rings (eg 066, 383). However some samples had degraded and partly dried out so a clean cross-sectional surface could not be obtained (eg 062, 347). Sample 168 had bands of rings which were too narrow to be distinguished for accurate measurement and the ring pattern of 018 was distorted by knots. The two other rejected timbers (078, 346) were not oak.

The remaining 31 samples, representing 29 timbers, from the Roman phases contained 46-227 rings but only three (145, 158, 285) had retained any sapwood. Samples 103/1, originally measured at Belfast, and 103/2 matched (t = 13.0) and were combined to form a single sequence for timber 103. A single ring pattern was also obtained for timber 272 from the two samples (272/1, 272/2) submitted for analysis.

The ring sequences of the measured timbers from all the Roman phases were compared. The visual match between 145 and 158 was excellent and produced a t value of 9.7. This suggests that timbers 145 and 158 were probably derived from the same tree (see above). Planks 054 and 059 also matched very well (t = 8.3). The visual similarity between the timber samples themselves suggests that, although the t value is somewhat below the arbitrary value of 10.0, these two timbers may also have been cut from the same tree. These two pairs of sequences were combined

to produce single ring patterns for each tree, 145/158 and 054/059.

The three curves 145/158, 148 and 184 crossmatched, as did 271 and 272. These sequences were combined to form the master curves OGLA/T3 and OGLA/T2 respectively. No other conclusive matches were found amongst the Roman sequences. Consequently OGLA/T2, OGLA/T3 and all the unmatched ring patterns from the individual timbers were tested against reference chronologies from Carlisle and the rest of the British Isles spanning the Roman period. Precise dates were obtained for OGLA/T2, OGLA/T3, 054/059 and seven other individual sequences (Figure 3). These sequences were combined to form a master curve, OGLA/T13, which was dated to 197BC-AD93 by comparison with reference chronologies.

The medieval phase provided 25 samples suitable for measurement which had between 53 and 191 rings. Thirteen of the 14 measured timbers from the plank lining of the well shaft 1237 (phase 13) crossmatched (Figure 4). These were combined to produce a 271 year master curve, LINING/T13. This was dated, by comparison with reference chronologies from northern England, to the period AD923-1193.

Three (425, 426, 427) of the ring sequences from the timber framework of well 1237 crossmatched and were averaged together to produce a 90 year master curve, FRAME/T3 (Table 9). Two other timbers (429, 430) also matched and were combined to produce another master curve, FRAME/T2 (Figure 4). These two master curves were tested against LINING/T13. FRAME/T2 produced a *t* value of 9.2 when it spanned the period AD1044-1162. This date was confirmed by visual and statistical comparison of FRAME/T2 with other dated reference chronologies.

The two medieval timbers from a pit which were originally analysed at Belfast were also checked against LINING/T13. These were dated to AD999-1067 and AD917-990 respectively. Consequently LINING/T13, FRAME/T2 and the individual sequences 001 and 007 were combined to produce a medieval site master

curve, LANES/MEDI, covering the period AD917-1193 (Table 6; 10). All previously unmatched medieval sequences were tested with LANES/MEDI and other reference chronologies from the British Isles and elsewhere in Europe. No further conclusive dating was obtained.

Three of the unphased samples were suitable for measurement. Samples 336 and 345, from context 430, contained 65 and 147 rings respectively. Sample 019, originally analysed at Belfast, had 286 rings. These three sequences were compared with reference chronologies from Britain and Europe which cover the Roman period to the present day. No reliable results were obtained so these unphased samples remain undated.

OGL B

Nine of the 20 samples from OGL B were discarded as unsuitable for dating purposes. Five samples with too few rings were rejected, as were two that had decayed. B103 was considered unsuitable as its ring pattern was distorted by knots and B059, a very thin plank, was badly broken and a ring sequence of sufficient length could not be obtained.

The measured samples contained 82-212 rings. Four samples (022, 061, 132, 176) crossmatched and were combined to produce a 121 year trench master curve, OGLB/T4. A good match (t = 5.2) was also found between 208 and 209. The curve OGLB/T4 and all other individual curves were tested against the trench A master curve OGLA/T13. Good visual matches and high t values were obtained for OGLB/T4 and the three individual curves 207, 208 and 209 (Figure 3). These dates were confirmed by comparison with other dated reference chronologies.

OGL C

Two (001, 029) of the six samples from this trench were rejected as they contained only 46 and 30 rings respectively. The remaining samples had 130-280 rings. The three samples (007, 027, 030) from Roman phases crossmatched and were dated by comparison with OGLA/T13 and reference chronologies from

northern England (Figure 3). The unphased plank was compared with numerous reference chronologies from all over Europe but could not be conclusively dated.

OGL J

Samples J003 and J005 were rejected as they had only 33 and 45 growth rings respectively. The remaining five samples contained 107-195 rings, apart from J006 which had only 54 rings. Three samples (J004, J007, J008) crossmatched and were dated by comparison with OGLA/T13 and other British reference chronologies (Figure 3).

LEL A

The 10 samples contained 59-257 rings and all were considered suitable for dating purposes. Samples 044 and 092 had both retained some sapwood. The internal crossmatching was poor, although tentative matches were found between 038, 045 and 092. All the individual ring patterns were compared with OGLA/T13 and other British reference chronologies. Absolute dates were obtained for 038, 045 and 092 confirming the tentative matches previously found between these samples (Figure 3). Sample 012 was also dated and spanned the period 372-121BC.

OBL B

One (009) of the nine samples submitted was rejected as its ring pattern was badly distorted. Although samples 013 and 031 contained only 40 and 43 rings respectively both were measured; sample 013 had bark edge and 031 had retained 6 sapwood rings. The remaining 6 timbers had 74-154 rings. Sample 018 had also retained its full complement of sapwood but as the outermost ring was incomplete it appears to have been summer felled.

Samples 007/1 and 007/2 were initially assumed to be duplicate samples from the same timber. However their visual appearance and patently different ring patterns indicate that they probably represent either different timbers or the inner and outer sections of a single timber (Figure 5). As with the timbers from trench LEL A the internal comparisons produced no conclusive

matches. However 030 and 037 were successfully dated by comparison with OGLA/T13 and reference chronologies from northern England (Figure 3).

Interpretation of the tree-ring dates

The dating framework implied by the tree-ring results is summarised in Table 11. The lack of sapwood, and hence the lack of precise felling dates prevents any exact comparisons being made between the tree-ring results and the phasing sequences identified in the various trenches.

CAL A

The dated sequence (012) from pit 64 spans the period AD512-649. Its outer 113 rings, including 1 sapwood, had broken away from the measured sequence. The felling date range for this timber was originally quoted by Belfast as AD793+/-9. However if the sapwood estimate now used at Sheffield is applied, a felling date range of AD771-816 is produced (Table 4). This date indicates the period in which plank 012 was initially used for building purposes. However it does show signs of re-use which therefore suggests that the pit was constructed some time after AD771.

OGL A

The dated phase 5 plank (102) spans the period 116-1BC. Its outermost 5 heartwood rings were unmeasureable so, in the absence of sapwood, a *terminus post quem* for felling of AD15 is produced (Table 4).

Six timbers from building 674 (phase 6) were dated. Bark surface was present on the corner post 145 and its outermost sapwood ring was complete, indicating that it was winter felled in AD93/94. Timber 158, also a corner post, had retained some sapwood but did not have bark edge. However as it is thought to have been derived from the same tree as 145, timber 158 must also have a felling date of AD93/94. The remaining four dated timbers (149, 184, 148, 174) from building 674 were felled after 51BC, AD63, AD68 and AD71 respectively (Table 4). It is therefore possible for them to be contemporary with the AD93/94 felling period but

this cannot be proved from the tree-ring analysis. In this instance 149 would have a large number of heartwood rings missing implying that it was split from the inner portion of a trunk (Figure 5). If the timbers are all contemporary and primary (ie not re-used), the above felling date produced indicates that building 674 was probably constructed shortly after felling in AD93/94. This is based on the precise felling date obtained for a single timber, but it is compatible with major felling events at both Castle Street and Annetwell Street, Carlisle, in the early AD90's (eg McCarthy 1991; Caruana forthcoming; Groves 1991; forthcoming). The results for building 674 imply that construction in the Roman phases 3-5 probably occurred before AD94.

It is not possible to determine precise felling dates for the other 4 timbers (089, 272, 103, 271) from phase 6 due to a lack of sapwood. Sample 089 gives a *terminus post quem* for felling of AD39 for the timbers from feature 739; the post (272) from fence 1024 which provided two samples was felled after 14BC; the timbers from contexts 771 (103) and 788 (271) were felled after AD40 and AD60 respectively.

None of the phase 7A timbers from the collapsed wall/fence 659 had retained any sapwood. The end dates range from 101BC to AD66 which, assuming that they are contemporary, implies a *terminus post quem* for felling of AD76. However as a felling date of AD93/94 has been produced from phase 6 it appears likely that the timbers from the collapsed wall/fence were probably felled and used in construction after AD94. It is therefore likely that timber 049 has lost a large number of heartwood rings during conversion and probably represents the inner section of a tree trunk.

There are thirteen dated timbers from the plank lining of the medieval well shaft 1237 (phase 13). The sapwood of 401 was complete although, due to damage to the outer edge, it was not possible to determine whether the outermost measured ring was immediately below the bark surface or within 2-3 rings of it.

Consequently a felling date range of AD1193-96 is obtained for 401. The first sapwood ring of 392 dates to AD1163, so this timber was felled after AD1172 but probably before AD1218. The 11 timbers have *termini post quem* for felling varying from the late 10th to mid 12th centuries AD (Table 4). It is therefore possible for 392 and these 11 other timbers to be contemporary with 401.

The two timbers (429, 430) from the framework in the well shaft were felled after AD1180 and AD1163 respectively. If these two timbers are contemporary and associated with the initial construction of the well, it cannot have been built before AD1180. However if the timbers from the plank lining are also primary a construction date of AD1193-96, shortly after felling, is implied for well 1237.

The remaining two dated medieval timbers (001, 007), both originally analysed at Belfast, were felled after AD1077 and AD1000 respectively (Table 4). Both are associated with a medieval pit but it is not known whether they were structural timbers or stray timbers from the infill.

OGL B

The single dated timber (132) from the phase 2B wall/fence has a *terminus post quem* for felling of AD83. If 132 is associated with the initial erection of this structure it is unlikely to have been constructed before AD83.

Timbers 061 and 176, from the phase 4E-F collapsed wall (230) were felled after AD88 and AD94 respectively. There is no other archaeological evidence indicating that the timbers are re-used so, if they are contemporary, the wall was probably built after AD94. This date is consistent with that obtained from OGL A phase 6 with which this phase is to be equated (Table 1).

None of the dated phase 5A timbers from the well had retained any sapwood. The end dates of the three sequences (207, 208, 209) are 101BC, AD21 and AD19 respectively which, assuming that they

are contemporary, implies a probable *terminus post quem* for felling of AD31. However as the phase 4E-F timbers were felled after AD94 it is likely that this phase 5A well was also constructed after AD94. This suggests that 207 must represent the inner portion of a trunk and have had a large number of outer rings removed during conversion (Figure 5).

The phase 6A post (022) is unlikely to have been felled before AD99. The visual appearance of the timber indicates that it is a whole trunk which, although shaped, has been left virtually intact. This implies that it was probably used in construction during the 2nd century AD and was not a re-used post from phase 4.

OGL C

Timber 007, a major post from a phase 2 building, has a *terminus post quem* for felling of AD6. The other two dated samples are from phase 3. Post 027, associated with the rampart revetment, has 12 unmeasured outer rings so it was felled after AD84 (Table 4). The date of the outermost ring of the plank (030) from a lined drain is AD5. However as the other phase 3 timber (027) was probably felled after AD84, it is likely that plank 030 was also felled and used after this date.

OGL J

It is not possible to determine precise felling dates for the three timbers due to an absence of sapwood. The outermost measured heartwood ring of post 004 dates to AD8, so its *terminus post quem* for felling is AD18. Planks 007 and 008 associated with a roadside drain (23-4) were probably derived from the same tree, which was felled after 15BC. However as these timbers may be associated with the rampart structure which is also present in OGL C, it seems likely that they were too were felled after AD84.

LEL A

Timber 092 (phase 4) had retained 8 sapwood rings. The date of its outermost heartwood ring is AD65 which indicates that it was felled during the period AD75-120. However the stratigraphical

relationship of this timber with those from other Roman phases is uncertain as it may have been labelled incorrectly.

The two phase 7B samples (038, 045) from well 548 were felled after AD56 and AD60 respectively (Table 4). Post 012 from phase 10B has a *terminus post quem* for felling of 111BC. However if timber 092 is definitely associated with phase 4 both the phase 7B and 10B samples were probably felled after AD75.

OBL B

Timber 037 (phase 2) was from the fill of a gulley and has a *terminus post quem* for felling of AD6. The phase 6 post (030) which also has no sapwood was felled after 103BC. The results can therefore neither confirm or refute the late 1st-early 2nd century AD date indicated by other archaeological evidence for these features.

The timbers

The vast majority of the structural timbers from all phases were heavily trimmed or worked. Over half of the Roman timbers were radial or tangential planks (eg OGLA059, OGLB213). The majority of the remaining Roman timbers are halved or quartered trunks which have been hewn into the required shape (eg LELA012, OGLA171). There are very few (<10%) structural timbers which obviously represent a trunk which has been left virtually intact (eg OBLB013, OGLB022). The post-Roman timbers are all either radial planks (eg OGLA392) or halved and quartered trunks that have been trimmed to the required shape (eg OGLA425).

It is not possible to give an accurate assessment of the size and age of the parent trees due to the infrequent occurrence of sapwood and pith on the vast majority of samples. The trees used in the Roman phases must have ranged from less than 50 to well over 300 years old when felled, and the dimensions of the samples suggest diameters of approximately 100mm to over 600mm. Although the average growth rate ranges from 0.3-7.1mm per year, over 60% of the trees have average growth rates of less than 1.6mm. This implies that many of the trees must have grown under

conditions that were limiting, possibly dense woodland, where competition from neighbouring trees would result in slow growth. This, combined with the fact that at least 60% of the Roman timbers must have been derived from trees over 100 years old, indicates that the timber was being obtained from well established woodland. It is possible that some timbers were derived from very mature trees over 350 years old (eg OGLC007, LELA012). However this assumes that they were felled in the latter part of the 1st century AD and not reclaimed from pre-Roman native structures.

Similar variation in sequence length and average ring width is apparent in the timbers used in the post-Roman phases. The timbers appear to have been derived from trees ranging from approximately 100 to 300 years old with diameters varying from about 250-350mm when felled. The average growth rate varies from 0.8-3.5mm but the majority of the post Roman timbers are in the range 1.0-2.0mm. The post-Roman timbers were therefore also mostly derived from relatively slow grown mature trees.

Discussion

Tree-ring dates were obtained for 52% of the measured samples. This success rate is about average for a large complex urban site where woodlands over an extensive area were probably being exploited (see below). 64% of the undated sequences contain less than 100 rings compared with only 30% of those dated. This is frequently the case but these less long lived trees tend to be trimmed to a lesser extent during conversion and so are usually more likely to have retained a full or partial complement of sapwood. It is therefore these shorter sequences that are often important in the determination of precise felling dates (see Hillam *et al* 1987). However it has not been possible to produce a precise dating framework for any of the trenches in the southern part of The Lanes due to the scarcity of sapwood.

Only 17 of the 143 samples submitted for analysis had retained any trace of sapwood. One of these (OBLB009) was unsuitable for analysis, and only six samples with sapwood were dated. This is

in stark contrast to Annetwell Street (Groves forthcoming) where over 300 of the 500 samples analysed had retained at least some sapwood. The close nature of the dating of the Roman period 3-5 at Annetwell Street shows the precision of which dendrochronology is capable, and clearly demonstrates the importance of sapwood and bark edge in the production of a precise dating framework. Unfortunately sapwood is less robust than heartwood and less likely to survive in conditions of poor preservation. However, apart from a small minority of samples (eg OGLB232), the timbers from The Lanes were generally in good condition. The wide range of end dates of the 36 dated Roman timbers (Table 4) is not indicative of a group of timbers which have merely lost their sapwood and possibly a few outer heartwood rings. It is possible that many of the trees used were sufficiently large enough to allow timbers to be split/cut from the inner and outer parts of the heartwood (Figure 5), but the apparent heavy working/trimming of many of the timbers (see above) combined with the scarcity of sapwood and pith may be a result of re-use. Secondary conversion would involve additional trimming resulting in the loss of both inner and outer heartwood rings. However other archaeological evidence would be required to support this suggestion and it is noticeable that re-use had only been positively identified for two Roman timbers (OGLA171, OGLB232).

The generally poor quality and frequently inconsistent matching obtained between the individual Roman sequences may result from the exploitation of a large area of local woodland or may possibly be due to the timber being obtained from several diverse sources. Also, if much of the timber was re-used (see above) this would probably aggravate the mixing of timber groups.

The lack of intra-site crossmatching within the Anglo-Scandinavian phase is also suggestive of the timbers having been obtained from a variety of sources, as would be expected if all pit 64 timbers had been re-used. In contrast the internal crossmatching of the medieval well and pit timbers is more consistent implying that, unlike the Roman and Anglo-Scandinavian material, the timber may have been the product of a single

source.

The Roman master curve, LANES/ROMI, extends the period covered by existing oak chronologies for this area by 23 years back to 372BC. It produced very high *t* values with reference chronologies from other sites in Carlisle, north west England and Ireland (Table 12). LANES/MEDI, the medieval site master sequence, crossdates particularly well with local reference chronologies and others from northern England and Scotland, whilst the single dated Anglo-Scandinavian timber matches local and western England reference curves (Table 8; 10). The tree-ring analysis therefore suggests that the timber from all periods is likely to be of local origin, although it is as yet impossible to source timber in any detail using dendrochronology. This problem is enhanced because the regional distribution of British tree-ring chronologies is different in the Roman, Saxon, medieval and post-medieval periods.

Further analysis of the quality of the within-site crossmatching obtained at The Lanes and other previously analysed sites from Carlisle may produce more detailed evidence of the sources of timber utilised in construction work at Carlisle. Further research into the provenancing of timber could also provide an insight into the difficulties encountered during intra-site crossmatching of timbers from Carlisle.

The importance of producing a site master for absolute dating is clearly shown as relatively few of the individual sequences, particularly those from Roman phases, produced consistent results at their correct dating positions with reference chronologies from outside of the Carlisle area. In the site master the common climatic signal has been enhanced and the 'noise' from local environmental growth conditions clearly reduced. The isolation of this common climatic signal from the individual sequences has frequently proved problematical with Carlisle material from the Roman period which has previously been subjected to dendrochronological analysis. At The Lanes this may be due in part to the presence of a distinct nine year cycle in the raw

data (ie a particularly narrow growth ring every ninth year) during the 1st century BC and part of the 1st century AD. This has been noted at various other Roman Carlisle sites but is especially strong in a number of timbers on The Lanes (eg OGLC030).

Conclusion

The results of the dendrochronological analysis generally appear to support the dates suggested by other archaeological dating evidence. It has not been possible to produce a detailed dating framework due to the scarcity of sapwood. However felling date ranges in the late 1st and 12th centuries AD have been obtained for timbers from OGL A phase 6 and OGL A phase 13. *Termini post quem* for felling were produced for various other phases. Local sources of timber appear to have been used throughout the Roman and post-Roman phases, although the quality of the intra-site crossmatching suggests the exploitation of a large area of woodland.

The construction of two further chronologies for Carlisle was achieved. The medieval curve does not extend the period covered by existing oak chronologies for this area but the Roman curve extends the chronological coverage back by 23 years to 372BC. This therefore begins to consolidate the initial link, provided by the Castle Street Roman master chronology (Groves 1991), between the English Roman chronologies and the two Iron Age chronologies from Fiskerton (Hillam 1985b) and Hasholme (Hillam 1987a). It is hoped that future work on timbers from the northern area of The Lanes may, as well as aiding the production of a chronological framework for the development of the whole area, also further strengthen this link and contribute additional information concerning the possibility of re-use of timber.

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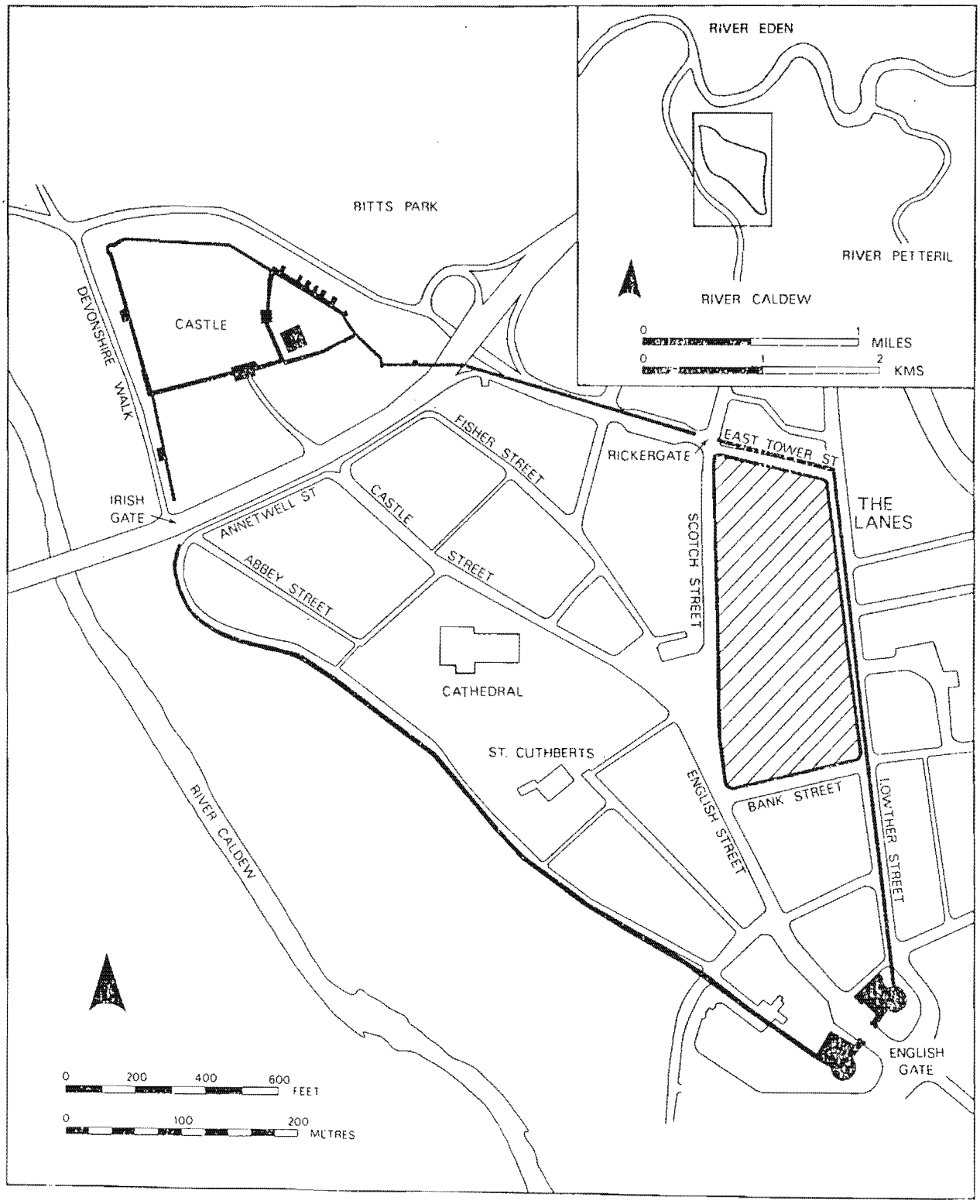


Figure 1: Location plan of The Lanes in Carlisle (reproduced from CAU plan).

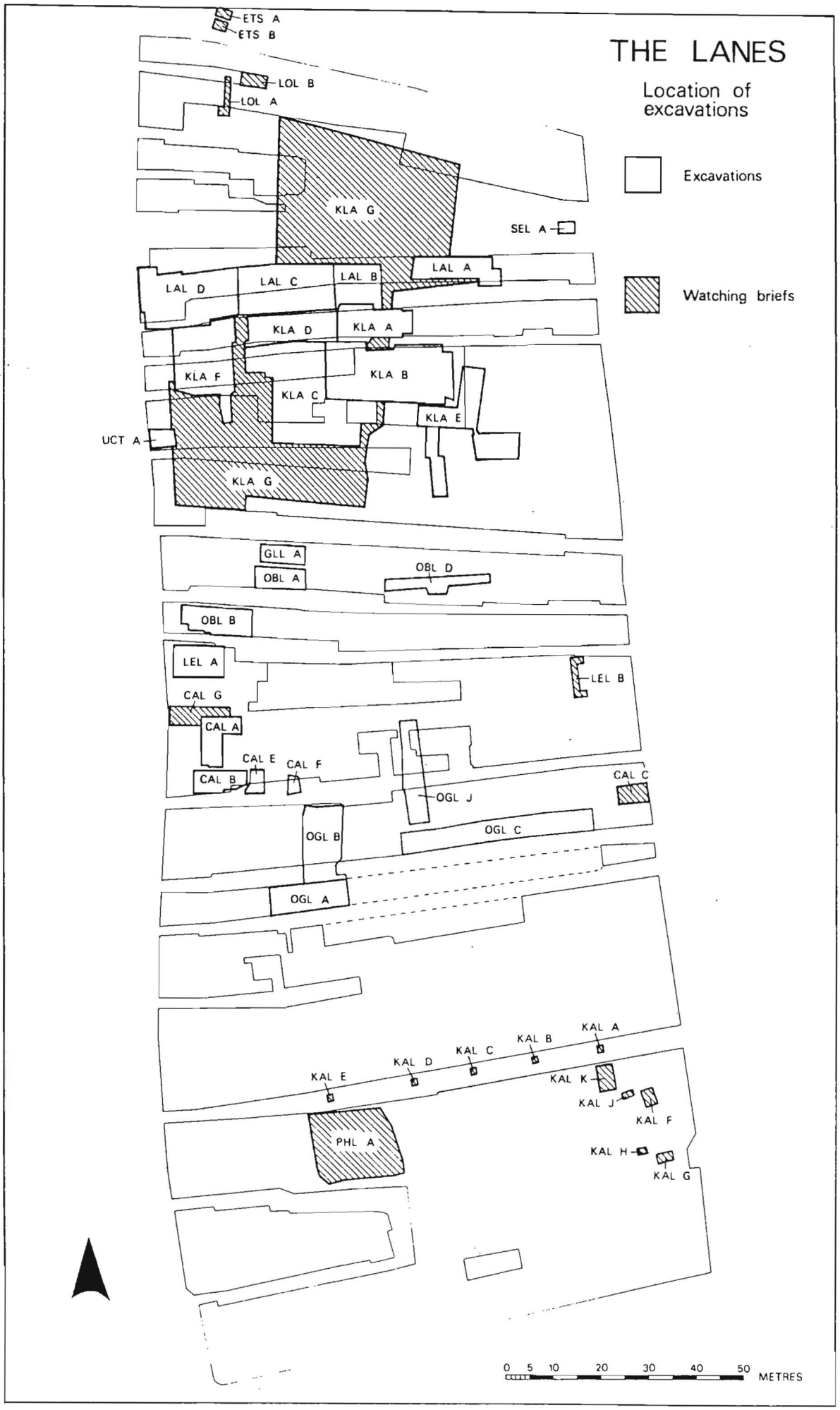


Figure 2: Street plan of The Lanes (reproduced from CAU plan).

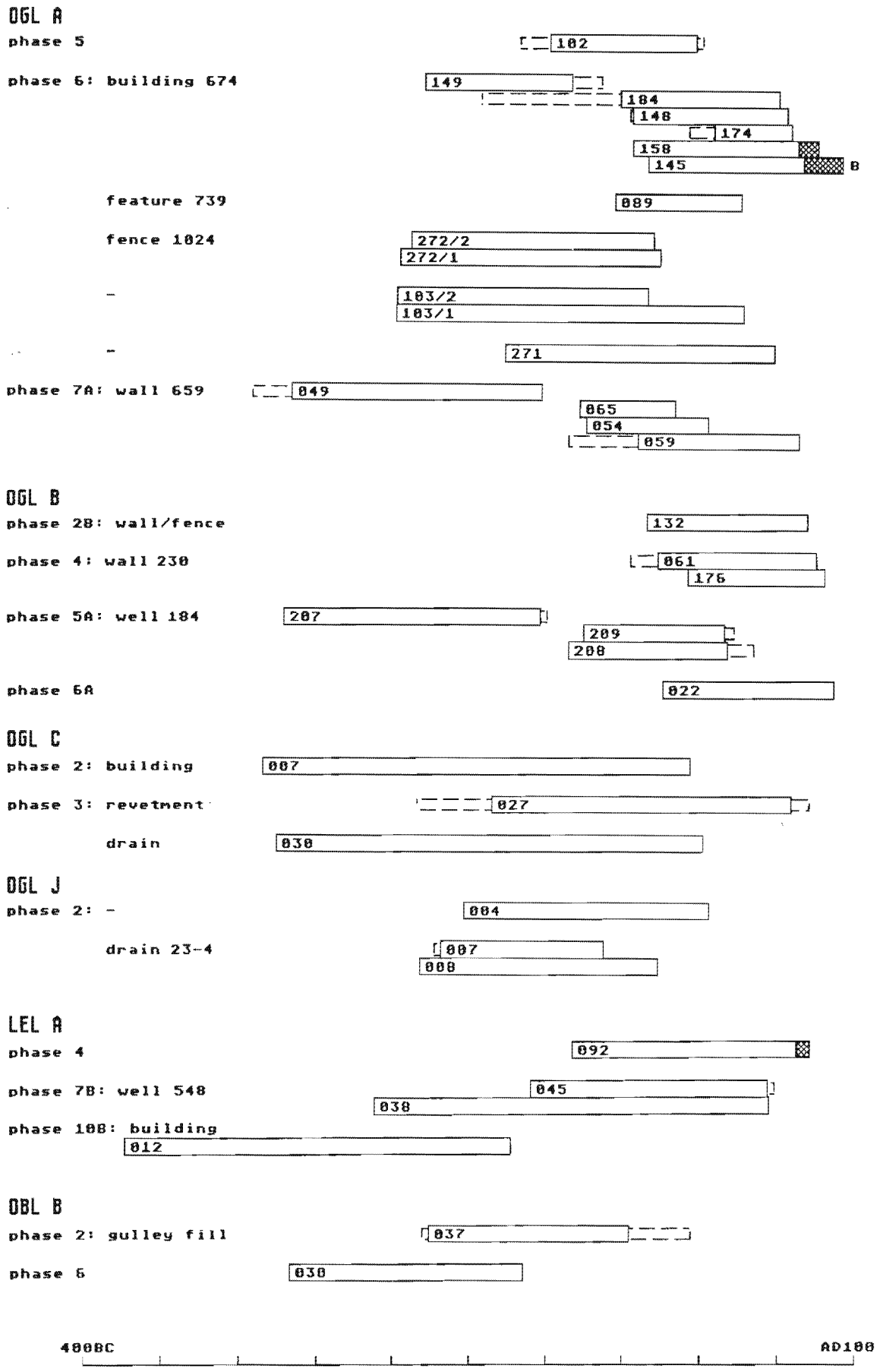


Figure 3: Bar diagram showing the relative positions of the dated samples included in the master curve LANES/ROMI. White bar - heartwood; shaded bar - sapwood; dotted bar - unmeasured rings; B - bark edge.

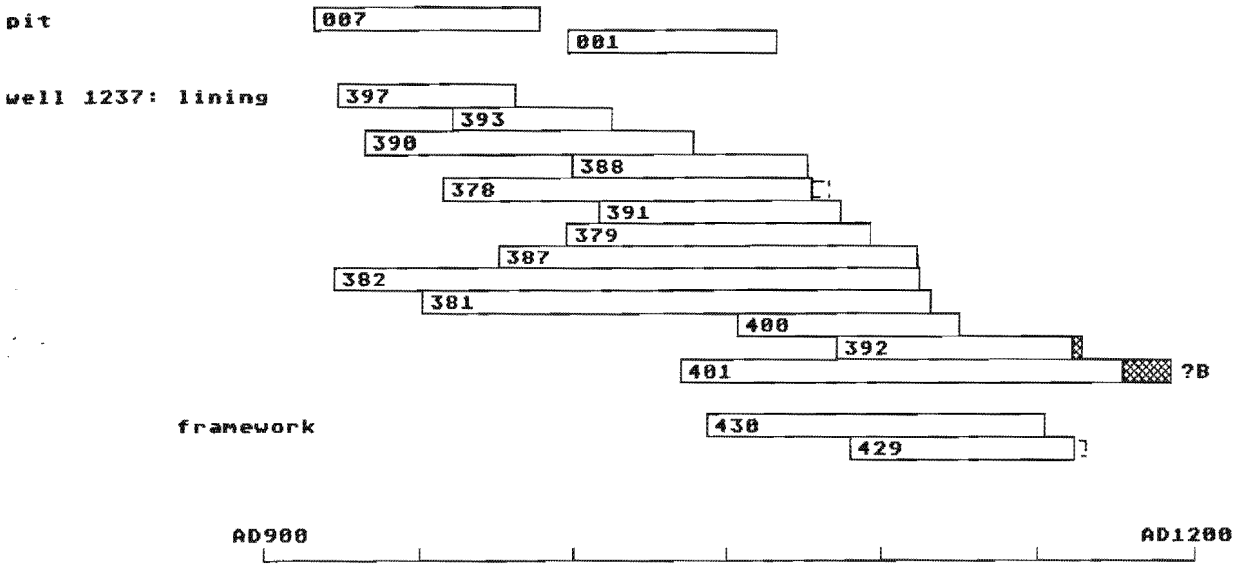


Figure 4: Bar diagram showing the relative positions of the dated samples included in the master curve LANES/MEDI. White bar - heartwood; shaded bar - sapwood; dotted bar - unmeasured rings; B - bark edge.

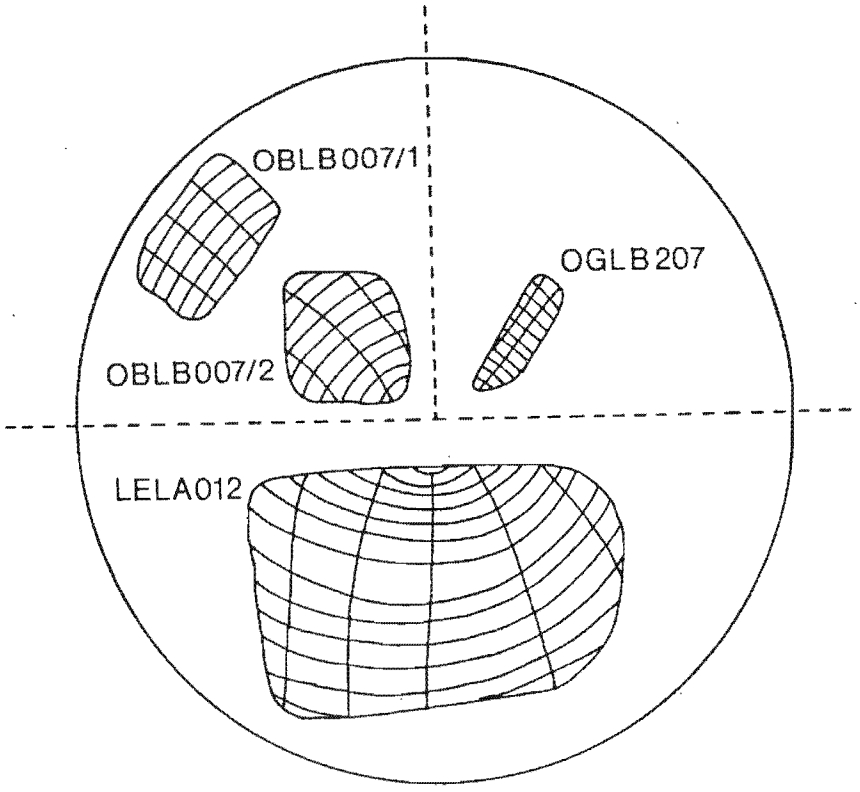


Figure 5: Schematic drawing showing the way in which some of the timbers may have been converted from the parent trunk.

Table 1: Summary of the relationship between the phasing sequences at Old Grapes Lane trenches A, B, C and J, after McCarthy (pers comm). Phases linked by = are the same; phases linked by =/= may be the same.

	OGL A		OGL B		OGL C		OGL J
phase	4						
	5						
	6	=	4A-E	=/=	2		
	7	=	5A				
	8A			=/=	3	=	2
	8B	=	5B				
	9E	=	6D				
	10D	=	6F				
	12-13	=	9				

Table 2: The samples and structures.

Site	Phase	Structure	Function	Samples
CAL A	late/post Roman	pit 66	plank	015
	post-Roman	pit 64	beams	009 011 013
			plank	012
			post	014
	post-Roman	pit 70	post	008
OGL A	3	-	post	306
	4	-	plank	285
	5	-	plank	102
	5-6	-	-	344
	5 or later	-	-	353
	6	building 674	wall posts	146 148 149 168 169 171 174 178 184
			corner posts	145 158
			threshold	151
			door jamb	152
			minor features	189 234
		feature 739	-	085 086 087 089 092
		feature 698	-	136 141
		fence 1024	-	272/1 272/2
		fence	-	332
		revetment	-	139
		-	-	103/1 103/2 104 271
	7A	wall/fence 659	-	048 049 054 057 059 062 065 066 067 068

Table 2: The samples and structures (cont).

Site	Phase	Structure	Function	Samples
	8A-9A	-	-	078
	9A-D	-	-	351
	9E	-	-	018
		fence	post	083
OGL A	13	well 1237	framework	425 426 427 428 429 430 431 432 433
			plank lining	378 379 381 382 383 387 388 389 390 391 392 393 397 398 400 401
	medieval	pit	-	001 007
	unphased	context 430	-	125 336 345 346 347
		-	-	017 019 036
OGL B	2B	wall/fence	post	132
	4	wall 281	-	103 164
		wall 230	-	061 062 176
		fence line	posts	113 114
		isolated	-	059
	5A	well 184	planks	207 208 209 213
	6A	-	post	022
	6B	building	-	028 232 236
	6E	building	-	233
	9	pit 10	plank	008
	unphased	feature 331	-	137
OGL C	2	building	post	007
		-	-	029
	2/3	building	post	001
	3	drain	plank	030
		revetment	post	027
	?medieval	-	plank	034
OGL J	2	alignment	posts	002 003
		drain 23-4	-	005 006 007 008
		-	-	004
LEL A	3	-	post	134/1 134/2
	4	-	-	092
	5	drain 615	plank	100
	7B	well 548	-	038 043 044 045
	10B	building	posts	012 013
OBL B	2	gulley fill	-	037
	6	-	post	030
	2-7	building 117	-	007/1 007/2 009 013 018 031 035

Table 3: Details of the samples; sketches are not to scale; sapwood is shaded.

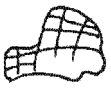
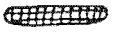
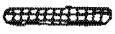
Site	Timber	Context	Phase	Length	Sapwood	Av width	Result	Dimensions mm	Sketch	Comment
CAL A 008		0070	postR	166	0	0.5	undated	0x0	-	?re-used
CAL A 009		0064	postR	82	0	1.4	undated	0x0	-	?re-used
CAL A 011		0064	postR	71	0	2.0	undated	0x0	-	?re-used
CAL A 012		0064	postR	138	0	1.2	dated	0x0	-	+113(1sap) ?re-used
CAL A 013		0064	postR	84	0	1.2	undated	0x0	-	?re-used
CAL A 014		0064	postR	61	0	2.7	undated	0x0	-	
CAL A 015		0066.2	postR	119	0	1.0	undated	0x0	-	?re-used
OGL A 001			med	69	0	0.7	dated	0x0	-	
OGL A 007			med	74	0	0.8	dated	0x0	-	
OGL A 017			Unph	0	0	0.0	rejected	0x0	-	rejected at Belfast
OGL A 018		0417	9E	16	0	6.7	rejected	185x105		
OGL A 019		0471	Unph	286	0	0.3	undated	0x0	-	
OGL A 036		0486	Unph	0	0	0.0	rejected	0x0	-	rejected at Belfast
OGL A 048		0659	7A	80	0	1.9	rejected	150x10		broken
OGL A 049		0659	7A	165	0	0.8	dated	175x15		
OGL A 054		0659	7A	80	0	0.9	dated	75x10		same tree as OGLA059
OGL A 057		0659	7A	105	0	0.8	undated	140x10		
OGL A 059		0659	7A	105	0	1.0	dated	155x15		same tree as OGLA054
OGL A 062		0659	7A	125	0	1.0	rejected	130x10		broken decayed

Table 3: Details of the samples; sketches are not to scale; sapwood is shaded.

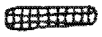
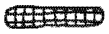
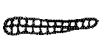
Site	Timber	Context	Phase	Length	Sapwood	Av width	Result	Dimensions mm	Sketch	Comment
OGL A	065	0659	7A	63	0	1.1	dated	70x25		
OGL A	066	0659	7A	28	0	1.4	rejected	40x25		
OGL A	067	0659	7A	68	0	1.0	undated	75x20		
OGL A	068	0659	7A	28	0	2.5	rejected	70x35		
OGL A	078	0600	8A-9A	7	0	9.2	rejected	130x115		alder
OGL A	083	0442	9E	28	8	4.1	rejected	115x110		
OGL A	085	0714	6	55	0	1.2	undated	70x50		
OGL A	086	0715	6	28	0	2.3	rejected	65x45		
OGL A	087	0716	6	7	0	7.1	rejected	50x20		
OGL A	089	0740	6	83	0	1.2	dated	105x40		
OGL A	092	0742	6	23	0	2.0	rejected	70x45		
OGL A	102	0770.1	5	116	0	1.1	dated	150x30		+5
OGL A	103/1	0771	6	227	0	0.7	dated	0x0	-	
OGL A	103/2	0771	6	165	0	1.4	dated	285x15		
OGL A	104	0772	6	75	0	0.9	rejected	70x10		decayed
OGL A	125	0430	Unph	26	0	2.3	rejected	60x10		
OGL A	136	0649	6	122	0	1.0	undated	130x15		
OGL A	139	0782	6	66	0	1.1	undated	90x10		+5
OGL A	141	0824	6	144	0	0.9	undated	135x15		

Table 3: Details of the samples; sketches are not to scale; sapwood is shaded.

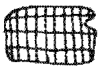
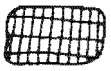
Site	Timber	Context	Phase	Length	Sapwood	Av width	Result	Dimensions mm	Sketch	Comment
OGL A	145	0675	6	126	24	1.1	dated	140x130		same tree as OGLA158
OGL A	146	0846	6	59	0	2.1	undated	125x100		
OGL A	148	0837	6	100	0	1.1	dated	110x100		+2 inner
OGL A	149	0695	6	98	0	1.5	dated	165x60		knots, +c20
OGL A	151	0835.1	6	76	0	1.1	undated	95x25		
OGL A	152	0834	6	132	0	0.9	undated	155x105		
OGL A	158	0854	6	120	12	1.1	dated	140x95		same tree as OGLA145
OGL A	168	0932	6	90	0	0.9	rejected	85x40		narrow bands
OGL A	169	0933	6	22	0	3.4	rejected	75x35		
OGL A	171	0935	6	44	0	2.3	rejected	100x85		?re-used
OGL A	174	0938	6	51	0	1.5	dated	110x25		+16 inner
OGL A	178	0652	6	44	0	2.0	rejected	90x50		
OGL A	184	0951	6	103	0	0.7	dated	130x105		+95 inner
OGL A	189	0960	6	42	0	1.9	rejected	80x20		
OGL A	234	1003	6	30	0	3.8	rejected	115x40		
OGL A	271	0788	6	175	0	0.7	dated	130x35		
OGL A	272/1	1027	6	171	0	0.9	dated	165x30		
OGL A	272/2	1027	6	159	0	1.1	dated	170x75		

Table 3: Details of the samples; sketches are not to scale; sapwood is shaded.

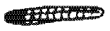
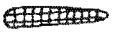
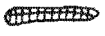
Site	Timber	Context	Phase	Length	Sapwood	Av width	Result	Dimensions mm	Sketch	Comment
OGL	A 285	1042	4	46	5	4.7	undated	215x55		
OGL	A 306	1128	3	95	0	1.0	undated	95x85		
OGL	A 332	1028	6	68	0	1.4	undated	105x10		+8 sapwood
OGL	A 336	0430	Unph	65	0	1.5	undated	100x10		
OGL	A 344	1225	5-6	48	0	2.3	rejected	110x30		
OGL	A 345	0430	Unph	147	0	1.5	undated	230x35		
OGL	A 346	0430	Unph	27	0	3.3	rejected	90x45		elm
OGL	A 347	0430	Unph	65	0	1.5	rejected	95x10		decayed
OGL	A 351	0471.4	9A-D	73	0	1.8	undated	150x10		
OGL	A 353	1238	5+	90	0	1.4	undated	155x125		
OGL	A 378	1237	13	121	0	1.2	dated	160x30		+12 outer
OGL	A 379	1237	13	100	0	1.3	dated	135x35		
OGL	A 381	1237	13	166	0	1.0	dated	170x20		
OGL	A 382	1237	13	191	0	0.8	dated	145x10		
OGL	A 383	1237	13	34	0	3.5	rejected	120x20		
OGL	A 387	1237	13	137	0	0.8	dated	120x15		
OGL	A 388	1237	13	78	0	1.9	dated	150x25		
OGL	A 389	1237	13	82	0	1.4	undated	115x30		
OGL	A 390	1237	13	108	0	1.2	dated	130x25		

Table 3: Details of the samples; sketches are not to scale; sapwood is shaded.

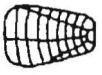
Site	Timber	Context	Phase	Length	Sapwood	Av width	Result	Dimensions mm	Sketch	Comment
OGL	A 391	1237	13	80	0	1.5	dated	125x40		
OGL	A 392	1237	13	80	3	1.8	dated	145x25		
OGL	A 393	1237	13	53	0	2.7	dated	150x15		
OGL	A 397	1237	13	59	0	2.5	dated	155x35		
OGL	A 398	1237	13	42	0	2.4	rejected	100x30		
OGL	A 400	1237	13	73	0	1.5	dated	115x20		
OGL	A 401	1237	13	159	15	1.1	dated	170x65		
OGL	A 425	1239	13	70	0	2.3	undated	170x150		
OGL	A 426	1239	13	90	9	1.6	undated	140x110		
OGL	A 427	1239	13	55	0	2.2	undated	120x100		
OGL	A 428	1239	13	76	0	2.2	undated	175x130		
OGL	A 429	1239	13	73	0	1.5	dated	110x60		+8
OGL	A 430	1239	13	110	0	1.5	dated	165x70		
OGL	A 431	1239	13	121	18	1.3	undated	170x110		
OGL	A 432	1239	13	75	0	1.4	undated	125x95		
OGL	A 433	1239	13	70	0	2.1	undated	155x50		
OGL	B 008	0010	9	82	0	2.0	undated	175x30		+4
OGL	B 022	0124	6A	111	0	1.0	dated	170x160		
OGL	B 028	0086	6B	28	0	3.2	rejected	90x65		

Table 3: Details of the samples; sketches are not to scale; sapwood is shaded.

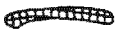
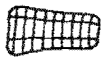
Site	Timber	Context	Phase	Length	Sapwood	Av width	Result	Dimensions mm	Sketch	Comment
OGL B	059	0259B	4D	0	0	0.0	rejected	0x0	-	broken
OGL B	061	0230C	4E-F	103	0	1.0	dated	140x10		+18 inner
OGL B	062	0230E	4E-F	212	0	0.8	undated	180x15		
OGL B	103	0286B	4A-F	80	0	1.8	rejected	145x145		knots
OGL B	113	0300L	4A-F	35	0	2.3	rejected	160x80		
OGL B	114	0300P	4A-F	40	0	3.1	rejected	125x100		
OGL B	132	0316	2B	105	0	1.3	dated	155x150		
OGL B	137	0331	Unph	35	0	3.6	rejected	125x75		
OGL B	164	0286C	4A-F	139	0	0.7	undated	110x55		
OGL B	176	0230D	4E-F	89	0	1.3	dated	120x15		
OGL B	207	0184	5A	169	0	1.0	dated	185x40		+5
OGL B	208	0184	5A	104	0	0.8	dated	95x35		+17
OGL B	209	0184	5A	92	0	0.9	dated	90x40		+7
OGL B	213	0184	5A	40	0	3.0	rejected	180x45		
OGL B	232	0089	6B	110	0	1.7	rejected	190x155		decayed ?re-used
OGL B	233	0029	6E	130	0	1.3	rejected	165x160		decayed
OGL B	236	0146	6B	100	0	1.0	undated	110x20		
OGL C	001	0006	2/3	46	0	4.2	rejected	255x250		

Table 3: Details of the samples; sketches are not to scale; sapwood is shaded.

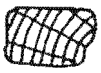
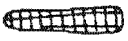
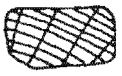
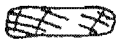
Site	Timber	Context	Phase	Length	Sapwood	Av width	Result	Dimensions mm	Sketch	Comment
OGL	C 007	0021	2	280	0	1.1	dated	320x195		
OGL	C 027	0054	3	195	0	1.0	dated	265x180		+12
OGL	C 029	0056	2	30	0		rejected	0x0	-	
OGL	C 030	0069	3	279	0	0.8	dated	240x40		
OGL	C 034	0050	Unph	130	0	1.2	undated	155x40		
OGL	J 002	0018	2	195	0	0.8	undated	295x115		
OGL	J 003	0019	2	33	0	3.7	rejected	155x155		knots
OGL	J 004	0020	2	160	0	1.1	dated	180x170		
OGL	J 005	0021	2	45	0	3.5	rejected	270x90		
OGL	J 006	0022	2	54	0	2.7	undated	215x90		
OGL	J 007	0023	2	107	0	1.2	dated	205x50		knots +5 inner
OGL	J 008	0024	2	157	0	1.2	dated	205x55		
LEL	A 012	0486	10B	252	0	0.7	dated	280x160		
LEL	A 013	0497	10B	135	0	1.7	undated	290x235		
LEL	A 038	0548A	7B	257	0	0.9	dated	225x40		
LEL	A 043	0548F	7B	67	0	1.8	undated	125x30		hs boundary?
LEL	A 044	0548G	7B	59	10	1.9	undated	125x30		+4
LEL	A 045	0548H	7B	154	0	1.9	dated	305x55		knots, +5
LEL	A 092	0616	4	154	8	1.0	dated	170x30		

Table 3: Details of the samples; sketches are not to scale; sapwood is shaded.

Site	Timber	Context	Phase	Length	Sapwood	Av width	Result	Dimensions mm	Sketch	Comment
LEL A	100	0615F	5	65	0	2.1	undated	175x65		+11 inner
LEL A	134/1	0624	3	114	0	0.9	undated	125x80		+20
LEL A	134/2	0624	3	103	0	0.9	undated	130x35		+40
OBL B	007/1	0022	2-7	145	0	1.0	undated	220x140		+15
OBL B	007/2	0022	2-7	75	0	1.6	undated	110x110		
OBL B	009	0024	2-7	54	12	1.6	rejected	115x95		knots
OBL B	013	0027	2-7	40	23	1.3	undated	105x95		felled winter
OBL B	018	0033	2-7	74	13	1.5	undated	120x75		felled summer
OBL B	030	0092	6	154	0	1.5	dated	285x185		
OBL B	031	0038	2-7	43	6	2.2	undated	110x45		
OBL B	035	0025	2-7	85	0	1.4	undated	110x105		
OBL B	037	0113	2	132	0	1.3	dated	185x115		+5 inner, +40

Table 4: Details of the tree-ring dates. Where applicable the date of the first sapwood ring is given in brackets.

Timber	Phase	Date span of measured rings	Unmeasured outer rings	Date of last ring	Felling date
CAL A					
012	post Roman	AD512-649	113(1 sap)	AD762	AD771-816
OGL A					
102	5	116-1BC	5	AD5	after AD15
089	6	54BC-AD29	-	AD29	after AD39
103/1	6	197BC-AD30	-	AD30	after AD40
103/2	6	196-32BC	-	32BC	after AD40
145	6	33BC-AD93 (AD70)	-	AD93	AD93/94
148	6	42BC-AD58	-	AD58	after AD68
149	6	178-81BC	20	61BC	after 51BC
158	6	42BC-AD78 (AD67)	-	AD78	AD78-121
174	6	AD11-61	-	AD61	after AD71
184	6	50BC-AD53	-	AD53	after AD63
271	6	125BC-AD50	-	AD50	after AD60
272/1	6	194-24BC	-	24BC	after 14BC
272/2	6	187-29BC	-	29BC	after 14BC
049	7A	265-101BC	-	101BC	after 91BC
054	7A	72BC-AD8	-	AD8	after AD18
059	7A	39BC-AD66	-	AD76	after AD76
065	7A	77-15BC	-	15BC	after 5BC
378	13	AD958-1078	12	AD1090	after AD1100
379	13	AD998-1097	-	AD1097	after AD1107
381	13	AD951-1116	-	AD1116	after AD1126
382	13	AD923-1113	-	AD1113	after AD1123
387	13	AD976-1112	-	AD1112	after AD1122
388	13	AD1000-1077	-	AD1077	after AD1087
390	13	AD933-1040	-	AD1040	after AD1050
391	13	AD1009-1088	-	AD1088	after AD1098
392	13	AD1086-1165 (1163)	-	AD1165	AD1172-1217
393	13	AD961-1013	-	AD1013	after AD1023
397	13	AD942-982	-	AD982	after AD992
400	13	AD1054-1126	-	AD1126	after AD1136
401	13	AD1035-1193 (1179)	-	AD1193	AD1193-96
429	13	AD1090-1162	8	AD1170	after AD1180
430	13	AD1044-1153	-	AD1153	after AD1163
001	med	AD999-1067	-	AD1067	after AD1077
007	med	AD917-990	-	AD990	after AD1000

Table 4: Details of the tree-ring dates. Where applicable the date of the first sapwood ring is given in brackets (cont).

Timber	Phase	Date span of measured rings	Unmeasured outer rings	Date of last ring	Felling date
OGL B					
132	2B	32BC-AD73	-	AD73	after AD83
061	4E-F	25BC-AD78	-	AD78	after AD88
176	4E-F	5BC-AD84	-	AD84	after AD94
207	5A	269-101BC	5	96BC	after 86BC
208	5A	83BC-AD21	17	AD38	after AD48
209	5A	73BC-AD19	7	AD26	after AD36
022	6A	22BC-AD89	-	AD89	after AD99
OGL C					
007	2	283-4BC	-	4BC	after AD6
027	3	133BC-AD62	12	AD74	after AD84
030	3	274BC-AD5	-	AD5	after AD15
OGL J					
004	2	152BC-AD8	-	AD8	after AD18
007	2	167-61BC	-	61BC	after 51BC
008	2	181-25BC	-	25BC	after 15BC
LEL A					
092	4	81BC-AD73 (66)	-	AD73	AD75-120
038	7B	211BC-AD46	-	AD46	after AD56
045	7B	109BC-AD45	5	AD50	after AD60
012	10B	372-121BC	-	121BC	after 111BC
OBL B					
037	2	176-45BC	40	5BC	after AD6
030	6	266-113BC	-	113BC	after 103BC

Table 5: Ring width data, in units of 0.01mm, of The Lanes Roman master curve, LANES/ROMI, 372BC-AD93.

years	ring widths										number of samples per year									
372BC									123	104									1	1
	105	103	93	108	101	151	166	163	155	170	1	1	1	1	1	1	1	1	1	1
	112	137	88	89	77	81	78	83	71	64	1	1	1	1	1	1	1	1	1	1
350BC	66	74	72	75	63	66	64	84	67	91	1	1	1	1	1	1	1	1	1	1
	78	81	85	69	67	68	65	73	86	53	1	1	1	1	1	1	1	1	1	1
	43	49	57	71	69	79	73	60	57	59	1	1	1	1	1	1	1	1	1	1
	68	56	50	62	70	73	84	74	61	46	1	1	1	1	1	1	1	1	1	1
	48	41	46	70	56	64	64	64	64	73	1	1	1	1	1	1	1	1	1	1
300BC	51	67	64	53	51	67	67	72	74	62	1	1	1	1	1	1	1	1	1	1
	62	44	57	57	54	64	74	93	116	114	1	1	1	1	1	1	1	2	2	2
	93	105	90	75	104	91	100	92	108	116	2	2	2	2	2	2	3	3	3	3
	92	109	101	82	105	89	62	81	76	123	3	4	4	4	5	6	6	6	6	6
	164	132	116	118	87	80	85	118	97	128	6	6	6	6	6	6	6	6	6	6
250BC	125	110	99	103	104	134	129	130	105	131	6	6	6	6	6	6	6	6	6	6
	112	158	135	134	144	122	89	76	105	111	6	6	6	6	6	6	6	6	6	6
	115	108	104	120	104	122	105	89	82	76	6	6	6	6	6	6	6	6	6	6
	82	83	102	110	106	129	117	102	80	79	6	6	6	6	6	6	6	6	6	7
	104	122	90	79	98	94	94	109	107	100	7	7	7	7	7	7	7	7	7	7
200BC	128	114	108	111	109	137	101	119	135	136	7	7	7	8	8	8	9	9	9	9
	90	87	101	96	90	102	95	101	86	117	9	9	9	9	9	9	9	9	9	10
	91	96	110	81	95	126	121	101	104	109	10	10	11	11	12	12	12	12	12	12
	105	115	83	92	104	145	124	120	111	128	12	12	12	12	12	12	12	12	12	12
	148	145	114	91	86	82	83	103	117	115	12	12	12	12	12	12	12	12	13	13
150BC	111	134	144	142	125	99	89	100	87	107	13	13	13	13	13	13	13	13	13	13
	122	128	121	116	111	130	103	111	123	127	13	13	13	13	13	13	13	14	14	14
	123	128	100	108	138	105	94	70	109	108	14	14	14	14	14	15	15	15	15	15
	121	140	121	117	109	94	86	96	107	131	14	14	14	14	14	14	14	14	13	13
	119	106	106	101	94	99	104	104	117	105	13	14	14	14	14	14	14	14	14	14
100BC	128	140	138	128	117	112	89	92	116	116	12	12	12	12	13	13	13	13	13	13
	140	124	153	112	124	119	97	120	115	151	13	13	13	13	13	13	13	14	14	15
	127	144	124	125	127	124	141	116	111	104	14	14	14	15	15	15	15	16	17	17
	112	124	124	119	130	119	130	122	102	104	17	17	17	17	17	17	17	17	17	17
	104	88	95	103	115	117	92	91	108	110	17	17	17	17	17	17	18	18	18	18
50BC	87	75	66	100	87	96	107	107	115	115	19	19	19	19	19	19	18	18	20	20
	85	74	89	101	116	117	115	130	130	116	20	20	20	20	20	20	20	20	21	21
	104	96	88	115	107	110	107	120	135	107	21	21	21	21	21	22	21	20	21	21
	109	105	91	92	99	93	95	107	83	78	21	21	21	21	21	21	20	20	20	20
	80	100	83	86	100	97	106	89	83	82	20	20	20	20	20	21	21	20	20	20
AD1	94	92	83	87	88	96	95	86	87	102	19	19	19	19	19	18	18	18	17	17
	96	93	76	100	97	99	94	111	103	104	18	18	18	18	18	18	18	18	18	17
	100	101	79	85	101	90	96	106	108	91	17	16	16	16	16	16	16	16	16	15
	115	120	123	94	103	89	107	112	123	97	14	14	14	14	14	14	14	14	14	14
	106	107	101	122	100	101	95	90	83	99	14	14	14	14	14	13	12	12	12	12

Table 5: Ring width data, in units of 0.01mm, of The Lanes Roman master curve, LANES/ROMI, 372BC-AD93 (cont).

years	ring widths										number of samples per year									
AD51	111	81	82	103	115	104	97	86	91	104	11	11	11	10	10	10	10	10	9	9
	106	105	116	107	96	105	102	127	111	100	9	8	7	7	7	7	6	6	6	6
	108	94	103	134	103	140	86	89	97	136	6	6	6	4	4	4	4	4	3	3
	108	150	173	134	88	138	93	98	62	55	3	3	3	3	2	2	2	2	2	1
	78	86	122								1	1	1							

Table 6: Ring width data, in units of 0.01mm, of The Lanes medieval master curve, LANES/MEDI, AD917-1193.

years	ring widths										number of samples per year									
AD917							26	21	19	20							1	1	1	1
	22	24	81	198	171	141	196	184	185	145	1	1	2	3	3	3	3	3	3	3
	165	173	128	157	151	144	209	180	151	204	3	3	4	4	4	4	4	4	4	4
	219	167	161	150	178	170	157	201	156	138	4	4	4	4	4	4	4	4	4	4
AD951	125	127	110	143	187	120	152	133	150	155	5	5	5	5	5	5	5	6	6	6
	196	186	197	158	122	164	154	125	128	148	7	7	7	7	7	7	7	7	7	7
	169	184	113	115	128	119	144	90	126	164	7	7	7	7	7	8	8	8	8	8
	134	144	132	135	161	127	108	111	115	142	8	8	7	7	7	7	7	7	7	7
	131	132	159	146	179	183	162	165	170	170	6	6	6	6	6	6	6	7	8	9
AD1001	172	171	189	128	102	108	133	160	149	143	9	9	9	9	9	9	9	9	10	10
	115	154	178	114	142	115	147	135	132	127	10	10	10	9	9	9	9	9	9	9
	121	123	158	111	76	113	128	139	124	125	9	9	9	9	9	9	9	9	9	9
	129	107	109	90	110	97	132	120	123	113	9	9	9	9	10	10	10	10	10	10
	142	96	84	83	87	127	137	131	133	146	9	9	9	10	10	10	10	10	10	10
AD1051	96	109	104	68	90	97	122	134	144	140	10	10	10	11	11	11	11	11	11	11
	118	111	96	105	85	111	129	120	129	128	11	11	11	11	11	11	11	10	10	10
	100	87	77	114	116	101	113	120	102	93	10	10	10	10	10	10	10	9	8	8
	98	115	125	113	130	156	129	125	122	102	8	8	8	8	8	9	9	9	8	9
	129	103	101	104	135	117	133	134	135	108	9	9	9	9	9	9	9	8	8	8
AD1101	78	89	116	108	120	132	123	134	109	72	8	8	8	8	8	8	8	8	8	8
	72	72	91	107	123	128	128	150	112	87	8	8	7	6	6	6	5	5	5	5
	79	109	136	110	120	111	114	126	70	72	5	5	5	5	5	5	4	4	4	4
	113	136	137	156	186	174	143	124	154	106	4	4	4	4	4	4	4	4	4	4
	80	141	156	108	106	115	139	174	224	174	4	4	4	4	4	4	4	4	4	4
AD1151	155	173	218	240	209	241	205	139	175	190	4	4	4	3	3	3	3	3	3	3
	165	162	167	158	177	143	152	106	139	113	3	3	2	2	2	1	1	1	1	1
	77	102	102	74	126	146	104	143	142	121	1	1	1	1	1	1	1	1	1	1
	114	152	104	72	87	93	112	110	140	158	1	1	1	1	1	1	1	1	1	1
	132	125	133								1	1	1							

Table 7: Ring width data, in units of 0.01mm, of the dated Anglo-Scandinavian timber, CALA012 (AD512-649).

years	ring widths									
AD512		174	100	136	156	96	92	96	110	100
	108	100	78	96	82	84	98	104	94	98
	106	96	90	88	82	74	86	74	68	46
	80	138	122	116	114	152	126	132	124	96
AD551	82	80	86	86	96	70	110	118	110	126
	116	104	122	130	124	132	112	118	142	170
	182	206	212	220	226	108	90	124	224	234
	250	226	208	180	184	174	222	202	202	184
	146	130	118	142	114	100	150	238	184	240
AD601	196	232	160	134	110	120	102	114	100	126
	108	116	110	152	134	126	160	184	106	106
	98	98	68	94	84	88	64	102	82	76
	68	106	136	100	126	104	112	102	86	60
	80	94	80	84	70	76	124	84	64	

Table 8: Results of comparisons between timber CALA012 (AD512-649) and firstly reference chronologies spanning the Saxon period and secondly dated individual sequences included in the Castle Street and Tullie House Saxon master curves.

reference sequence		t value
Carlisle: Castle Street (Groves unpubl)		7.27
Tullie House (Hillam unpubl)		5.47
London: Barking Abbey (Tyers 1988)		3.85
York buildings (Tyers 1989)		3.25
Portchester (Fletcher pers comm)		3.66
Carlisle: Castle Street	0026	6.04
	0028	5.59
	0029	4.09
	0033	5.48
	0035	4.88
	0040	3.21
	0041	4.03
	0045	7.14
	0046	5.69
Tullie House	1008D	4.19
	1064D	3.91
	1065D	3.29
	1066D	4.92

Table 9: Ring width data, in units of 0.01mm, of the 90 year undated medieval master curve, FRAME/T3.

years	ring widths										number of samples per year									
1	159	172	216	200	178	151	183	197	215	184	1	1	1	1	1	1	1	2	2	2
	204	164	161	173	142	118	107	172	205	273	2	2	2	2	2	2	2	2	2	2
	204	130	167	236	259	250	198	217	187	249	2	2	2	3	3	3	3	3	3	3
	278	309	260	251	222	283	212	244	248	248	3	3	3	3	3	3	3	3	3	3
	265	224	217	228	216	142	196	284	186	215	3	3	3	3	3	3	3	3	3	3
51	206	149	197	268	205	222	230	239	235	182	3	3	3	3	3	3	3	3	3	3
	207	188	207	277	223	226	161	139	158	130	3	3	3	3	3	3	3	3	3	3
	105	155	125	82	98	172	135	123	134	139	3	3	3	3	3	3	3	2	1	1
	122	134	129	174	124	124	107	128	158	98	1	1	1	1	1	1	1	1	1	1

Table 10: Results of comparisons between The Lanes medieval master curve, LANES/MEDI (AD917-1193) and reference chronologies spanning the medieval period.

reference chronology	t value
Beverley: Eastgate (Groves 1990a)	6.84
Hall Garth (Hillam 1981)	3.80
Bristol: Dundas Wharf (Nicholson & Hillam 1987)	7.30
Carlisle: Annetwell Street (Groves forthcoming)	12.31
medieval (Baillie pers comm)	14.86
Hartlepool (Hillam 1983)	5.11
London: Southwark Boats 1 (Tyers 1990)	4.19
Swan Lane (Groves & Hillam 1987)	5.35
Nantwich: Willaston (Groves 1990b)	6.17
Scotland (Baillie 1977a)	7.10
Stafford (Groves unpubl)	6.03
York: Coppergate (Hillam 1989)	4.31
Queen's Hotel (Groves 1990c)	3.57
Germany West (Hollstein 1980)	3.31
Ireland: Dublin (Baillie 1977b)	4.74

Table 11: Summary of the dating framework implied by the tree-ring results.

Site	Phase	Structure	Estimated felling date range and construction date
CAL A	-	64 (pit)	AD771-816 (timber probably reused)
OGL A	3	-	before AD94
	4	-	before AD94
	5	-	AD10-93
	6	building 674	AD93/94
		feature 739	after AD39
		fence 1024	after 14BC
		others	after AD60
	7A	wall/fence 659	after AD94
	12-13	well 1237	AD1193-96
	med	pit	after AD1077
OGL B	2B	wall/fence	after AD83
	4E-F	wall 230	after AD94
	5A	well 184	after AD94
	6	-	after AD99
OGL C	2	building	after AD6
	3	revetment	after AD84
	3	drain	after AD84
OGL J	2	drain 23-4	after 15BC
		other	after AD18
LEL A	4	-	AD75-120 (?sample labelled wrongly)
	7B	well 548	after AD60
	10B	building	after AD60
OBL B	2	gulley fill	after AD6
	6	092	after AD6

Table 12: Results of comparisons between The Lanes Roman master curve, LANES/ROMI (372BC-AD93) and reference chronologies spanning the Roman period.

reference chronology	t value
Alcester, Warwickshire (Baillie pers comm)	5.09
Carlisle: Annetwell Street (Groves forthcoming)	16.01
Castle Street (Groves 1991)	14.17
Caerleon, Wales (Hillam 1987b)	4.79
Castleford, Yorkshire (Hillam unpubl)	4.97
Droitwich Upwich (Groves & Hillam 1992)	6.23
London: Bridgehead (Hillam 1986)	4.49
Southwark (Tyers pers comm)	4.67
Papcastle, Cumbria (Hillam 1988)	8.67
Ribchester, Lancashire (Hillam unpubl)	6.01
Vindolanda, Northumberland (Hillam 1991)	11.93
Walton-le-dale, Preston (Groves 1987)	7.18
Ireland: Dorsey/Navan (Belfast data)	5.49
Keenagh 8 (Belfast data)	5.82
Germany South (Becker 1981)	3.02