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TREE-RING DATING IN THE CITY OF LONDON: THE BRIDGEHEAD SITES AND THE DATING OF THE ROMAN HARBOUR

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Abstract

Over 300 oak timbers from structures associated with the construction and development of the Roman harbour were examined from three sites in the City of London: Miles Lane to the west of London Bridge, and Peninsular House and Pudding lane to the east. The dendrochronological study provided a firm dating framework which linked the chronology of the three sites as well as giving dates for many of the structures, such as the 1st century quays and associated buildings, and the remains of what was probably the first Roman bridge across the Thames.

CONTENTS

List of figures

List of tables

Tree-ring dating of the Roman harbour

INTRODUCTION

The 1970's saw intensive redevelopment in the City of London, and this offered archaeologists a unique opportunity to investigate waterfront activity from Roman times to the present day (Milne 1985). During 1979-1981, three sites were excavated which revealed the oak timbers of the waterfront structures belonging to the Roman harbour. The sites lie just north of Lower Thames Street, about 100 yards north of the present river frontage: Miles Lane, to the west of London Bridge, and Pudding Lane and Peninsular House to the east (Fig 1).

Miles Lane (site code ILA'79) was excavated by Louise Miller of the Department of Urban Archaeology during 1979, and 40 oak timbers removed for dendrochronology. A further 60 samples were taken during the watching brief at the site in 1981. Peninsular House (PEN'79) was excavated in the winter of 1979/80 by Gustav Milne, and produced 46 timbers for tree-ring analysis. The success of this excavation, plus the subsequent watching brief, led to the larger scale excavation at Pudding Lane (PUD'81), which is immediately to the west of Peninsular House. Pudding Lane was excavated by Milne and Nic Bateman during 1981, and was monitored during further development on the site in 1982. The controlled excavation produced over 180 timbers for dendrochronology. Details of the three excavations, and the structures found, are described by Milne (1985). Further details can also be found in the site archive reports which are stored in the Museum of London library.

Unlike Seal House and New Fresh wharf to the south of Lower Thames Street which had provided timbers from the third century quay (Fig 1), this complex of three sites yielded timbers from the first century quay and associated structures, including what may be the pier base of the first Roman timber bridge across the Thames. The excellent preservation of the large quantities of oak timbers (Quercus spp) provided material for a detailed chronological sequence based on tree-ring dating. The aims of the dendrochronological study were to provide dates for the structures, and the various phases of waterfront activity; and to provide relative dating between the three sites. It was hoped that the tree-ring dates, along with other dating evidence from coins, pottery and stratigraphy, would provide a firm and precise dating framework for the Roman harbour

structures found at the three sites (henceforth called the Bridgehead complex). The tree-ring analysis was carried out during the period 1981 to 1985.

THE SITES

The west quay: Miles Lane (grid ref TQ 3284 8075)

Roman structures, interpreted as a first century quay and associated building, were first observed on this site in 1920, but it was not until 1979 that an opportunity to excavate occurred. The controlled excavation on a small section of the site uncovered a timber structure which was unlike that found in 1920. During the watching brief over the whole site (Miller 1982, fig 1), the true position of the Roman waterfront was established, and could be related to the structures seen in 1920 and during the controlled excavation. A 62m stretch of the east-west quay front was excavated and recorded (about 200 timbers in total, although not all were sampled for dendrochronology). The remains of several buildings were also found, plus several phases of an open timber-lined drain (Miller 1982, fig 2; Milne 1985).

The controlled excavation produced timbers from two phases of the drain (drain 1 and 2), and from structures referred to as revetments 1 and 2. These were re-identified later as the first century quay (west quay) and a later extension to it. The watching brief produced more timbers from the quay and extension, as well as timbers from the buildings to the north of the quay (buildings A-F) and from a terrace wall which stratigraphically pre-dates the quay (Table 1a). A timber from a post-medieval well was also recovered. There was no sign of re-use on any of the timbers.

The east quay: Peninsular House and Pudding Lane

a) Peninsular House (TQ 3295 3340)

Further evidence of a first century quay was found to the east of London Bridge at Peninsular House (Bateman & Milne 1983), but its style of construction was different to the Miles Lane quay and the relationship between the two structures could not be determined at the time of excavation. The remains of buildings, drains and other features were also found. A relative chronology for the different phases was established from stratigraphic evidence, the groups being labelled A to E, where A is the oldest and E the most recent. This relative framework was later extended to cover the features found at Pudding Lane. The majority of the Peninsular House timbers were Roman,

although two mid-late Saxon timbers were sampled, plus five timbers thought to be post-Roman.

b) Pudding Lane (TQ 3294 8072)

This site is between Fish Street Hill and Pudding Lane, ie on the opposite side of Pudding Lane to the Peninsular House site (Fig 1). Its excavation was undertaken to explore further the development of the Roman waterfront, and to help clarify the information gathered from the Peninsular House excavation.

The north bank of the pre-urban river was located, and evidence of the first Roman activity was given by a double row of piles and other strucutres found on the river bank. Later in the first century, a timber structure (originally called Quay 1, now known as a landing stage) was built into the open river, and was later replaced by an infilled timber front quay (Quay 2 or east quay) which survived to its full height of 2m. Contemporary warehouses and other buildings (buildings 1-9) were also excavated, plus a substantial timber structure, thought to be mid-first century in date, which was erected in the open river. The latter was found at the south-west corner of the site, and was thought to represent a pier base of an early Roman timber bridge (Milne 1982).

At the start of the tree-ring analysis, the exact nature and function of many of the structures on the three sites were unknown, and the analysis was further complicated by the fact that many of the Pudding Lane timbers were re-used. Only when the stratigraphy was examined in detail, and results from dendrochronology and other studies were collected, was it possible to interpret the findings in a meaningful way.

TREE-RING DATING

1. Background

The annual growth rings in oak timbers represent a unique pattern of wide and narrow rings which is peculiar to the period over which the tree was growing, the actual widths of the rings being controlled largely by climate. Timbers of the same date therefore will show similar ring patterns, and this is readily visible if the ring widths are plotted as graphs (width against time), and one graph superimposed over the other. By overlapping ring patterns of successively older timbers, starting with those from living trees so that each ring can be assigned a calenar date, a continuous sequence can be produced. Such a sequence, known as a

providing absolute dates for all the London timbers. In 1982, the timbers from Miles Lane were examined, first from the controlled excavation and then from the watching brief. This produced two almost identical chronologies which also crossmatch the London and German curves. Finally the Pudding Lane timbers were tackled in 1983, producing another independent chronology which could be dated against Germany. When the chronlogies from the three sites were combined to produce the Bridgehead chronology, it crossdated well with all the available chronologies from England, Ireland and Germany (eg Fig 2). There can therefore be no doubt about the absolute dating of the chronologies from the three sites.

Because the tree-ring work under discussion is tied up with the progress of English dendrochronology in general, and also relates to a large number of samples, it cannot be described as a simple step-by-step process. Normally the ring widths of timbers from one site are measured, matching sequences are combined into a site master curve, and this is dated by comparison with several independent reference chronologies. Although the work on the Bridgehead timbers broadly followed this pattern, it was far more complicated, involving many checks and cross-checks to ensure that all the ring patterns crossmatched with at least two others in consistent positions, and that each site chronology was reliably dated.

3. Methods

Duplicate slices, each of 50-500mm thickness, were cut from the timbers. One slice is stored at the Museum of London, whilst the other was sent to the Sheffield Dendrochronology Laboratory if it appeared to have sufficient rings. (At the start of the study, the minimum number of rings acceptable for dating purposes was set at 50, although some with less than this were examined if they had bark.) For ease of handling the larger timbers, many of which had cross-sections of at least 300 by 400mm, were split into smaller wedges still retaining the full sequence of growth rings. The samples were deep-frozen for at least 48 hours to harden the wood and make it easier to clean. The surface was prepared, whilst the wood was still frozen, with a Surform plane. Usually this left a surface on which the ring boundaries were clearly defined, but occasionally further cleaning with a sharp knife was also needed. The samples were then left to thaw out before they were measured.

The measuring equipment at Sheffield consists of a travelling stage which is connected to a display panel. The sample is placed on the stage, and the rings observed

tree-ring chronology, can then be used to date the ring pattern from a timber of unknown date by locating the period over which the two sequences are synchronous. The study is not confined to oak: the pioneering work in America, for example, was carried out on coniferous species (Baillie 1982), and in some areas of Europe other species are used (Eckstein et al 1984). However in the British Isles, only oak is found in sufficient quantities to enable long chronologies to be constructed. Its role as the major building timber, because of its strength and durability, have ensured its survival in standing buildings and waterlogged archaeological sites. In the prehistoric period its occurrence in archaeological sites is augmented by many sub-fossil oaks found in peat bogs or river gravels.

Although simple in theory, tree-ring dating is a time-consuming study requiring skill and experience, and for this reason progress in chronology building in Europe has been slow. Two long chronologies, each of about 7,000 years, have recently been completed using material from Ireland and Germany (Pilcher et al 1984). In England, where work has concentrated on dating timbers from archaeological sites or art-historical objects rather than on chronology building, there is a continuous chronology back to AD 404, made up from smaller site chronologies from different regions which vary in length from 150 to 600 years approximately. There is also a chronology, 252BC-AD294, for the Roman period which is dated by comparison with the independent chronologies from Germany and Ireland. Known as the City/Southwark chronology, it is composed of tree-ring data from Southwark and the City of London, and includes tree-ring sequences from one of the sites included in this report. (Data for the City/Southwark chronology was provided by Fletcher, Hillam, Morgan and Tyers - see Sheldon & Tyers 1983.)

2. Dendrochronology and Roman London

When the tree-ring work commenced on the timbers from Peninsular House in 1981, none of the Roman chronologies from London or elsewhere in England had been absolutely dated, although there were two chronologies made up of sequences from various sites in the City of London, all of which had been dated relative to each other. One of these included timbers from Seal House, New Fresh Wharf and Custom House (Morgan & Schofield 1978); the other, Roman London, was made up of sequences from New Fresh Wharf, Thames Street Tunnel and Watling Court (Hillam & Morgan 1981a). The analysis of timbers from Peninsular House resulted in an independent chronology of 252 years which crossmatched with the two floating chronologies from London, and with the dated German chronology (Hillam & Morgan 1981b), thus

through a x10 binocular microscope. As each ring is traversed, the movement of the stage is measured and recorded on the display. The Miles Lane and Peninsular House ring widths were recorded by hand from the display panel, and were later punched into the mainframe computer in units of 0.1mm. This system has now been updated so that an Apple microcomputer automatically records the ring widths in units of 0.02mm (Hillam 1985, fig 4). This has speeded up the measurement process, as well as reducing potential operator error during the recording of the data and its transfer to the mainframe. Most of the Pudding Lane samples were measured using the latter system.

The ring widths are plotted as graphs, known as tree-ring curves, on transparent semi-logarithmic paper. Curves from a particular context or structure are compared together by sliding one graph over another so that the ring patterns are superimposed. Two curves are said to crossmatch where their ring patterns are synchronous. As well as the visual matching, a computer program (Baillie & Pilcher 1973) is also used for crossmatching. It calculates the degree of correlation between two sets of data at each position of overlap, and converts this value into Student's t-value to take into account the length of overlap. Values greater than 3.5 represent a match provided that the visual match is acceptable. It is also imperative that replication is obtained (Baillie 1983), so that curve A matches curves B,C,D and curve B matches C and D and so on. In fact, given ten timbers from any site or structure, for example, it is unlikely that they will all match each other equally well: some curves will appear very similar, many will match moderately well and a few will appear not to match. However each curve should match at least two others.

The Bridgehead complex therefore was tackled site by site, and structure by structure, although some attempt was made to divide the 185 Pudding Lane samples into different priorities so as to minimize the work. When sufficient curves crossmatched, a site master curve was produced by averaging the matching ring widths, and unmatched curves were then tested against this. In this way more and more sequences were fitted into the relative dating framework. By the time the Pudding Lane timbers were examined, a dated London chronology covering the period 252BC-AD255 was available (Sheldon & Tyers 1983). Many of the Pudding Lane curves were compared by computer directly with this in an effort to speed up the crossmatching process. Any high t-values were checked visually, and it was also necessary to check the curves from individual timbers against each other as before. Failure to do this, could lead to spurious matches being accepted.

When as many curves as possible were dated, the results were set out as a bar diagram (eg Fig 3) so that the temporal relationship between the matching ring sequences could be examined. Up to this point, dendrochronology is an independent dating method, the results from which are totally reliable and precise to a year. However the results only date the rings present in the timber; they do not necessarily represent the felling date of the timber, less still when the structure was built.

4. Interpretation

Before tree-ring dates can be related to the date of felling, it is necessary to assess how much wood,if any, was removed when the timber was converted into plank, beam, pile etc. Determination of construction dates means that other factors such as re-use and seasoning also have to be taken into account. At this stage the dendrochronologist needs feedback from the archaeologist so that evidence from other dating methods can be included to produce more precise felling and construction dates.

The estimation of felling dates for oak timbers is made easier by the presence of sapwood. This is the outer part of a tree which in oak is usually distinguishable from the heartwood by a difference in colour and structure. The number of oak sapwood rings is relatively constant: 95% confidence limits for British trees older than 30 years are 10-55 rings (Hillam et al forthcoming). If a timber retains one sapwood ring therefore, its felling date estimate is accurate to within 45 years, but if it has 40 sapwood rings, the felling is accurate to within 15 years (although obviously if the timber has bark or bark edge, the felling date is exact to a single year). Where sapwood has been removed completely, which often occurs because of its lower density and susceptibility to insect and fungal attack, the felling date is expressed as a terminus post quem by adding the minimum sapwood allowance of 10 years to the date of the last measured ring.

The estimation of felling dates can often be enhanced by grouping together timbers from the same structure (eg Baillie 1982 56). before this can be done, information is needed from the excavator as to the context of a timber, and any timbers with which it might be associated. Whether the timber is primary or re-used is also important, although the latter can sometimes also be determined from the tree-ring results themselves. By grouping together the dated sequences from the Pudding Lane landing stage, for example, the felling date becomes AD 69-96, whereas if PDN3360, a timber from the structure without sapwood, is considered in

isolation, its felling date would be some time after AD 44 (Fig 7). The sampling of as many timbers as possible from any one structure therefore is important in obtaining the best felling date, and also increases the chances of finding timbers with bark edge.

Seasoning is not likely to be important where waterfront structures are concerned, nor was it a common practice until recently. Work on Roman timbers in Germany, for example, indicates that oak timbers were felled as required and used almost immediately (Hollstein 1965, 1980). Hence the construction date is likely to be very similar to the felling date.

RESULTS

Miles Lane

Of the 100 timbers sampled, 14 were rejected prior to measurement, either because they had insufficient rings (less than 40 for this site) or their rings were unmeasurable due to knots, narrow rings or attacks of modern fungus. The fungus had also attacked the inside (eg 2279) or outside (eg 2271) of other timbers, but it was possible to measure a large portion of the ring sequence. (Unmeasured sections are indicated by '+' in figures or tables.)

The timbers were very variable in size, shape and the number of rings (Table 2a): those from the west quay itself tended to be large in cross-section (eg 2265 measured 400 by 440mm). The trees had been relatively fast-grown so none of the samples had more than 200 rings, and only a few had more than 150. The timbers used for the drain were usually small, and contained less than 100 rings.

The timbers were sent to Sheffield in two batches: one from the excavation and the other from the watching brief. The initial analyses therefore were carried out in two stages, each producing a master curve (ML1 and ML2). The two master curves were very similar ($\underline{t}$ = 13.4), and were later combined to give a single site master (Table 3). The masters were dated by reference chronologies from London and Germany, and the individual ring sequences were also checked against other London curves: first against Peninsular House, and later against the City/Southwark chronology. A total of 66 timbers were dated, and a further five have been dated during the preparation of this report.

Most of the curves correlated well with City/Southwark (Table 4). The piles from the terrace wall were the only group with ring patterns which had low correlations. However

when these were combined to give a 'piles' master curve, the master gave a t-value of 6.7 with City/Southwark. All the matches therefore have been checked and cross-checked to ensure complete reliability of the tree-ring dates.

The two masters span the periods 169BC-AD61 (ML1) and 164BC-AD43 (ML2). They crossmatch chronologies from Germany, Droitwich and other sites in London, although they show poor agreement with sequences from Ireland and Carlisle (Table 5).

Although the dating success rate was good (15 remain undated, four of which have less than 50 rings), the interpretation of the tree-ring dates has proved difficult because only seven of the dated timbers have sapwood.

1. Terrace wall

The terrace wall, known to pre-date the west quay, produced seven matching ring patterns. The dates of their outer rings vary from 38BC to AD13 (Fig 3), but their date of felling is uncertain because none of the piles had sapwood. Allowing ten years for the minimum amount of missing sapwood, the timber cannot have been felled before AD 23. If only the sapwood was removed from the piles so that the outer rings are roughly equivalent to the heartwood-sapwood transition (see Baillie 1982 54-57), then they were probably felled before AD 55.

2. West quay

Twenty three timbers from the quay were dated, but only 1271 had sapwood. The date of its heartwood-sapwood transition is 7BC, and the date of the last measured sapwood ring is AD 18. Using the sapwood allowance of 10-55 rings (Hillam et al forthcoming), there is a 95% probability that the timber was felled during the period AD 18-49. However, with the exception of 1236 and 1905, the outer rings of the other matched sequences date to between AD 6 and 45, which would give a terminus post quem for felling of AD 55. The ring pattern of 1236 is almost identical to that of 1271, indicating that they probably derive from the same tree. 1905 covers the period 151-95 BC, which suggests that it came from the inner part of a tree trunk (see the results for drain 1 below). If it is assumed therefore that most of the timbers had only the sapwood removed, and that 1271/1236 has a number of sapwood rings outside the 95% limits, then the estimated felling date for the west quay timbers becomes AD 55-72. This would necessitate 1271 having 61-78 sapwood rings which, although unusual, is not impossible. (The sapwood statistics indicate that five of the 100 Miles Lane

timbers could have either more or less than the quoted sapwood range of 10-55 rings.)

3. Buildings A-F

Eight timbers were dated from the buildings, which seem from archaeological evidence to have been constructed at the same time. One of the timbers (1235) retained all its sapwood, but the outer ten or so rings were badly compressed making the exact date of felling uncertain. However it must have been felled during the period AD 66-68. Stratigraphical and archaeological evidence suggests that the buildings were constructed at the same time as the quay. The felling dates of AD 66-68 for the buildings and AD 55-72 for the quay tend to confirm this suggestion.

4. Drain 1

Stratigraphically this drain post-dates the construction of the quay and buildings, but this is not obvious from the tree-ring dates because of the almost complete lack of sapwood. Only two samples (1176, 1179), probably from the same tree, have sapwood. The remainder have end dates that are spaced at fairly regular intervals between 67BC and AD 32. Such a pattern (Fig 3: drain 1) is common in studies of timbers from the Somerset Levels trackways (eg Morgan 1984, fig 59), and represents the way in which the timber was split to produce planks. Timbers such as 1046 and 1263 were cut from the outside of the trunk, whilst 1130 and 1226 came from the inside (Fig 4). 1176 or 1262, on the other hand, are radially split planks, and their ring patterns run almost from pith to heartwood-sapwood transition. Because the end dates are so spaced in time, the estimated felling date is based only on 1176 and 1179, which have a sapwood transition of AD 39. This gives a felling date in the range AD 49-94.

5. Drain 2

Three out of four timbers from Drain 2 were dated. Again none had sapwood, and their end dates were staggered in time. The most recent end date is AD 51 (668), which means the timbers were not felled before AD 61.

6. Revetment extension

When the initial tree-ring analysis was completed, only one timber could be dated. This was 1054 which ended in AD 61 with no sapwood, thus giving a terminus post quem for felling of AD 71. During the preparation of this report in 1985 however, four more timbers were dated, three of which

had sapwood (Fig 3; Table 3). The timbers cannot have been felled before AD 114, the date of the last measured sapwood ring on 1038. The heartwood-sapwood transition dates of 1040 and 1136 indicate that the timbers were probably felled before AD 142, giving a felling date range of AD 114-142.

7. Other Roman timbers

Four other timbers have been dated: two (1461, 1462) from uncertain context, but probably the same tree, were felled after AD 53. A timber possibly from a jetty south of the waterfront was felled after AD 26, and a possible revetment timber was felled after AD 13.

8. Post-Roman timbers

A single timber was excavated from a post-medieval well. Comparison with some reference chronologies suggests that its ring sequence covers the period AD 1553-1631, but further confirmation is needed before this date can be accepted with confidence.

Peninsular House

Six timbers were rejected prior to measurement because they had under 40 rings (Table 2b). The measured ring patterns were compared together, and with Roman London, the chronology made up of sequences from New Fresh Wharf, Thames Street Tunnel and Watling Court. Many of the curves matched well with each other and with Roman London (Fig 5; Table 6). A Peninsular House site master curve was produced for the period 252BC - AD70 (Table 7), and this was incorporated in the City/Southwark chronology. Any undated curves were tested against the site master, and later against City/Southwark. Thirty three timbers were eventually dated from the Roman period, including the five originally thought to be post-Roman. In addition one of the Saxon timbers was also dated.

The dated Roman sequences are illustrated in Fig 5. They are arranged according to the original relative dating framework which was based on evidence obtained during the excavation. Interpretation of the tree-ring dates is difficult because there are no obvious groups of timbers, and sapwood is present on only four timbers. However with the evidence about the main structures obtained from post-excavation work, it has been possible to extract more information about the tree-ring dates and their relationship to the various structures (Fig 6).

1. Water-tank/building raft

The five dated sequences from this structure, which was originally thought to be post-Roman, fall into two groups each probably representing a single tree: 1368, 1381, 1390; 2020, 2023. The ring patterns in each group were almost identical and, for this reason, it was possible to date the two short ring sequences, 1390 and 2020, which had 47 and 49 rings respectively.

The five ring sequences span the years 252BC - AD31, which suggests that trees of 300 years or older were being exploited for this structure. 2023 had 11 sapwood rings, which gives a felling date of AD 31-76 for at least one tree used in the construction.

2. Revetment

Eight sequences from this post and plank revetment which pre-dates the east quay, were dated by dendrochronology, although none of them had sapwood. Four of the timbers had almost identical ring patterns suggesting that they came from the same tree (1184, 1186, 1192, 1193). This enabled the 36-year sequence from 1186 to be dated with some confidence.

The most recent ring from this structure dates to AD 39, giving a terminus post quem for construction of AD 49.

3. East quay, Peninsular House

Of the seven timbers dated from the quay, only 2119 had any sapwood. Its heartwood-sapwood transition dates to AD 43 which indicates a felling date of AD 53-98.

4. Drain

Neither of the two dated drain sequences had sapwood but as the outer ring of 1532 is AD 70, the drain cannot have been constructed before AD 80.

5. Other Roman timbers

A further 11 timbers have been dated but these have not been assigned to particular structures (Milne 1985). Two of the timbers (1508, 1735) had sapwood. These were felled in AD 33-78 and AD 47-92 respectively.

6. Saxon timbers

Two Saxon timbers (1493, 1665) were sent for analysis, but only 1665 had sufficient rings to warrant measurement. The 76-year ring sequence was compared with dated chronologies from medieval London. It synchronised with these over the period AD 827-902 (see Hillam 1985b for further details). In the absence of sapwood, a terminus post quem for felling of AD 912 is assumed.

Pudding Lane

Although the timbers had been grouped by the excavators according to priority A, B or C (Table 1b), it was found necessary to examine and measure all suitable samples in order to obtain and interpret the tree-ring dates. Many of the samples had insufficient rings and were discarded. Samples with less than 50 rings were rejected unless they included bark edge. There were about 15 samples in this category, such as the piles from revetment 2317 (1884, 1886-9). It was hoped that their ring patterns might be crossmatched within the group, and a short master be produced which could be fitted into the relative dating framework for the site. No crossmatching was found within the groups however, and the samples remain undated along with 37 other ring sequences.

The 125 measured curves were tested against the City/Southwark chronology, and 73 were found to date. The agreement between the reference chronology and the Pudding Lane curves was generally very high (Table 8). A site master was not constructed for Pudding Lane, but instead 14 of the ring sequences were combined with those from Miles Lane and Peninsular House to produce the Bridgehead chronology which covers the period 252BC - AD86 (Table 9).

1. Bridge pier

Four timbers (3307, 3369-70, 3372) from the north wall of this structure crossmatched both with each other and with the City/Southwark chronology. Their rings spanned the period 59BC - AD49 (Fig 7), giving a felling date of after AD 59. The final bridge sample (3371) did not match very well with the others, but it gave a t-value of 5.8 with City/Southwark for the period 28BC - AD78, its heartwood-sapwood transition dating to AD68. When all the bridge sequences were combined to make a master curve, that curve matched very well with the reference chronology (t = 6.8). There is therefore no doubt about the dating of this structure, although the new felling date of AD 78-123 was

later than that originally expected from the archaeological evidence.

2. Landing stage

Four of the 15 matching timbers from the landing stage (originally known as Quay 1) had sapwood. The date of their heartwood-sapwood transition ranges from AD 41-58, which gives a date of felling between AD 69 and AD 96.

3. East quay, Pudding Lane

Although 30 ring sequences were dated from the east quay (formerly Quay 2), interpretation was made complicated by the inclusion in the quay of timbers which had been robbed from the landing stage. However information was included about possible re-use of timbers when the samples were sent to Sheffield (Table 1b), so that the re-used timbers could often be separated from the primary timbers (Fig 7). Without this information, an alternative interpretation would have been deduced from the results, since all the matching sequences would have been grouped together.

Instead the estimated felling date for the primary quay timbers is AD 86-111, whilst that for the timbers robbed from the landing stage is AD 64-93. The latter agrees well with the felling date calculated for the in situ landing stage timbers given above.

4. Building 2

There were relatively few timbers from this structure (originally called Quay 2 warehouse) which were suitable for dendrochronological sampling, and even less that could be used for dating purposes. Despite these difficulties, six ring sequences from timbers associated with the building were dated (Fig 7). The estimated felling date of AD 94-129 is based on two timbers: 1875, which dates to AD 11-84, and 1857, which has a heartwood-sapwood transition dating to AD 74.

5. Drain 1045

None of the three dated timbers from the drain (1383, 1532, 1543), nor the two samples from wedges found beside the drain (2157, 2185) had sapwood. The drain therefore was constructed some time after AD 69, whilst the terminus post quem for the felling of the wedge timbers is AD 3. A timber (2325) from the west side of the drain, which may represent part of an earlier drain, has a terminus post quem for felling of AD 27.

6. Revetment 2317

Four timbers were dated from this revetment, which was known to predate the east quay and possibly the landing stage. Three had sapwood, and one of these (2321) appears to retain its bark edge. The outer ring is complete indicating that the tree was felled in winter or early spring, which in this case is AD 59/60. (If bark edge had not been present, the estimated time of felling for the revetment timbers would be AD 59-79.)

7. Other Roman timbers

Many of the remaining samples came from individual timbers rather than structures, and were therefore difficult to date. Those that were dated (Fig 7) were generally in prioity class C, ie they were given low priority by the excavator. The only sample with any sapwood was from a post (2154) found in an un-identified feature. Bark edge was present, and the outer ring was complete, indicating that the timber was felled in the winter/early spring of AD 86/87.

8. Post-Roman timbers

Only one post-Roman sample (276) was sent for analysis. This was a 9th-10th century timber from a pit fill. Although the sample had 104 rings, no firm dating was obtained when it was compared with reference chronologies of this date.

The original ring width data from all the samples suitable for measurement are stored in the Sheffield Dendrochronology Laboratory where they can be consulted.

DATING THE WATERFRONT STRUCTURES

Because of the relatively few timbers retaining sapwood, the estimated felling dates are usually not precise (Table 10). However when the stratigraphic evidence is taken into account, the chronology of the three sites in the earlier phases of their development becomes clearer.

The east quay sites

The first major structure to be built at the east of the bridge was the Pudding Lane landing stage, but this post-dates other features which contained timbers. The timbers for revetment 2317 at Pudding Lane were felled in the winter of AD 59/60, whilst those for the Peninsular House building raft/water-tank and the post and plank revetment were felled in AD 31-76 and after AD 49 respectively. The three features could be contempoary, but this cannot be ascertained from the tree-ring evidence.

There are two estimated felling dates for the landing stage: AD 69-96 for the in situ timbers, and AD 64-93 for those re-used in the east quay. This gives a combined felling date for the landing stage timbers of AD 69-93. Both the landing stage and the bridge pier are stratigraphically earlier than the east quay. The felling date for the quay is AD 53-98 for the Peninsular House section and AD 86-111 for Pudding Lane. Provided the two sections were built at the same time, the felling date becomes AD 86-98. The bridge pier, which has a felling date of AD 78-123, must therefore have been built shortly after the landing stage, but shortly before the quay. The construction of buildings 1 and 2 seems from archaeological evidence to be broadly contemporary with that of the east quay. The felling date for the timbers from building 2 at Pudding Lane is AD 94-129, which suggests that the buildings and quay were constructed in the last decade of the first century AD.

Other features with dated timbers at the east side of the bridge are two drains which appear from stratigraphical evidence to post-date the quay. The tree-ring dates do not help with the exact dating since none of the timbers had sapwood. The timbers for drain 1045 at Pudding Lane cannot have been felled before AD 69, whilst those for the Peninsular House drain were felled after AD 80.

Timber 2154 from an un-identified feature at Pudding Lane was felled in the winter of AD 86/87. Whilst this does not clarify the function of the timber or the structure from

which it came, it does indicate that some building work was being carried out at this time.

The west quay

The sequence of events at the west side of the bridge differs from those to the east. The earliest structure to be dated dendrochronologically is the terrace wall. The foundation piles for this structure were felled after AD 23 and, if only the sapwood was removed from the logs when they were converted into piles, before about AD 55. They could be contemporary with revetment 2317 at Pudding Lane which was constructed in AD 59/60 or shortly afterwards.

The timbers for the west quay have a felling date after AD 55 and possibly before about AD 72. The construction of buildings A-F and the quay seem from archaeological evidence to be contemporary (Milne 1985). The timbers for one of the buildings were felled in AD 66-68, thus giving a fairly precise construction date for the buildings and the quay. The construction of the west quay and associated buildings therefore pre-dates those at the east of London Bridge, and is instead more contemporary with the construction of the landing stage.

The tree-ring dates indicate that the timbers from drain 1 were felled between AD 49 and 94. However, as the structure post-dates the quay and buildings, they must have been felled between about AD 70 and 94. This drain was infilled and replaced by a second drain, drain 2. None of the drain 2 timbers had sapwood, so the tree-ring dates do not help with the dating of the structure, indicating only that the timbers were felled after AD 61.

The results for the revetment extension, which is thought to be contemporary with drain 2, are more informative. The timbers were felled in the period AD 114-142. Evidence from the pottery is roughly in agreement with this since it suggests a date of AD 100-120 for both the extension and drain 2 (Milne 1985).

Thus it seems that work on the Roman harbour did not start until about AD 60, but that by AD 100 all the main quays, associated buildings and probably at least one bridge had been constructed. Development of the harbour continued after this date with, for example, the construction of a revetment extension at Miles Lane in AD 114-142, but generally the number of dated timbers for the later phases are fewer.

THE TIMBERS

The size of the timbers used at the three sites varied according to function with wood from larger trees, for example, being used for the main structural members of the quays and landing stage, and smaller ones for foundation piles or drains. There was no particular difference, other than style of construction, between the quays to the east and west of the bridge. However the timbers for the Pudding Lane landing stage were of a uniform size whilst those for the quays were more irregular in size (Milne 1985). The diameter of tree varied from about 130mm (eg 1884, a pile from revetment 2317 at Pudding Lane) to well over a metre (eg 3374, a south wall timber from the Pudding Lane east quay).

The exact age of the trees used is often difficult to determine because of the way the timber was worked, but age was also variable. PDN 1884, for example, was 32 years old when felled, but PDN 3374 was probably aged over 200 years, and some of the Peninsular House trees may have been older than 300 years. The Miles Lane trees may have been slightly younger than those at the other two sites. However examination of their ring patterns did not reflect this difference, so the apparent age difference may be a feature of the sampling strategy. The ring patterns from the dated timbers at the three sites are very similar (Table 5), suggesting a common origin. Ring patterns from other Roman sites in London are also similar so it seems likely that the woodland surrounding London was being exploited on a large scale. The Roman waterfront structures were not economically built, either in terms of timber or the labour and cost involved in felling, working and transporting it. The Roman structures used much larger timbers than their medieval counterparts, often just one timber being extracted from a tree over a metre in diameter. Such a building technique is very wasteful and costly. It indicates that the Romans were exploiting the surrounding woodland on a huge scale, and suggests official involvement, perhaps by the army, in the construction of the harbour. The use of timber also suggests that the Romans were merely felling and clearing the trees, rather than developing and managing their source of timber.

CONCLUSION

Analysis of over 300 samples from the sites of Miles Lane, Peninsular House and Pudding Lane provided tree-ring dates for many of the Roman timbers. The resulting felling dates were often not precise because of the absence of sapwood from most of the timbers, but when the dendrochronological results were used with other evidence, such as stratigraphy

and pottery, the precision was often improved. The study therefore demonstrates the need for the exchange of information between dendrochronologist and excavator during post-excavation work as well as during the excavation itself. It also demonstrates the need for total sampling where possible since it is noticable that dendrochronology was more successful for the earlier phases where timbers were plentiful, such as the east quay, than for the later phases. It also became apparent that the division of samples into prioity classes does not reduce the amount of work, even if large numbers of samples are involved. Although the Pudding Lane samples were examined in order of priority, it was found necessary to include all the samples so as to improve both the dating success rate and the precision of the felling dates.

The tree-ring dates indicate that none of the main structures of the Roman harbour were built before AD 60, and that they were all in place by AD 100. The dates have also resolved several problems of chronology, such as showing that the bridge pier was built shortly after the construction of the landing stage but before that of the east quay, as well as linking the chronologies from the east and west sides of London Bridge. For example, it is now known that the east and west quays were not constructed at the same time, but that the west quay was built at about the same time as the landing stage, and is therefore earlier in date than the east quay. The tree-ring dates for these earlier phases of harbour development are particularly important since there is little evidence from pottery or coins.

ACKNOWLEDGEMENTS

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REFERENCES

Baillie MGL 1982 Tree-Ring Dating and Archaeology. Croom Helm, London

---------- 1983 Development of tree-ring chronologies. In D Eckstein, S Wrobel & RW Aniol (eds), Dendrochronology and Archaeology in Europe, Wiedebusch, Hamburg 33-48

Baillie MGL & Pilcher JR 1973 A simple crossdating technique for tree-ring research. Tree Ring Bulletin 33 7-14

Bateman N & Milne G 1983 A Roman harbour in London; excavations and observations near Pudding Lane, City of London 1979-82. Britannia 14 207-26

Becker B 1981 Fallungsdaten Romischer Bauholzer. Fundberichte aus Baden-Wurttemburg 6 369-86

Eckstein D, Baillie MGL & Egger H 1984 (eds), Handbooks for Archaeologists. No 2 Dendrochronological Dating. European Science Foundation, Strasbourg

Hillam J 1985a Theoretical and applied dendrochronology: how to make a date with a tree. In P Phillips (ed), The Archaeologist and the Laboratory, CBA Research Report No 58 17-23

-------- 1985b Tree-ring dating of saxon timbers from the City of London. Ancient Monuments Report series

Hillam J & Morgan RA 1981a What value is dendrochronology to waterfront archaeology? In G Milne & B Hobley (eds), Waterfront Archaeology in Britain and Northern Europe, CBA Research Report No 41 39-46

---------- 1981b Dendro dates from Sheffield. Current Archaeology 7(9) 286-87

Hillam J, Morgan R & Tyers I (1986) Sapwood estimates and the dating of short ring sequences. In RGW Ward (ed), Tree-ring studies in Britain, BAR, Oxford (in press)

Hollstein E 1965 Jahrringchronologische Datierung von Eichenholzern ohne Waldkante. Bonner Jahrbuch 165 12-27

---------- 1980 Mitteleuropaische Eichenchronologie. Zabern, Mainz-am-Rhein, 273pp

Miller L 1982 Miles Lane: the early Roman waterfront. London Archaeologist 4(6) 143-47

Milne G 1982 Further evidence for Roman London Bridge. Britannia 13 271-76

Milne G 1985 The Port of Roman London. Batsford, London, 160pp

Morgan RA 1984 Tree-ring studies in the Somerset Levels: the Sweet Track 1979-1982. Somerset Levels Papers 10 46-64

Morgan RA & Schofield J 1978 Tree-rings and the archaeology of the Thames waterfront in the City of London. In JM Fletcher (ed), Dendrochronology in Europe, BAR Int Series 51 223-38

Pilcher JR, Baillie MGL, Schmidt B & Becker B 1984 A 7,272-year tree-ring chronology for western Europe. Nature 312 150-52

Sheldon HL & Tyers 1983 Recent dendrochronological work in Southwark and its implications. London Archaeologist 4(13) 355-61

LEGENDS TO FIGURES

Fig 1: Location of Roman waterfront sites in the City of London. The position of the 3rd century quay, and the 1st century quays and their associated structures are also shown. ML - Miles Lane; PEN - Peninsular House; PUD - Pudding Lane; SH - Seal House; NFW - New Fresh Wharf/St Magnus; BILL - Billingsgate (after Bateman & Milne 1983 208).

Fig 2: Matching tree-ring curves. Agreement between the Bridgehead chronology (solid circles) and Germany (open circles) over the period 100-1 BC. The German data (Hollstein 1980) was modified by Haddon-Reece & Tyers (pers comm).

Fig 3: Miles Lane bar diagram showing the temporal relationship between the dated ring sequences, plus their estimated felling dates. White bar - heartwood rings; hatching - sapwood; + - presence of unmeasured rings; HS - heartwood-sapwood transition.

Fig 4: Schematic drawing showing how some of the planks lining drain 1 at Miles Lane might have been produced (although those illustrated do not necessarily come from the same tree). Such a tree probably exceeded 600mm in diameter without sapwood and bark.

Fig 5: Peninsular House bar diagram with ring sequences arranged according to their original groupings. Felling dates are almost impossible to estimate from this information.

Fig 6: Bar diagram showing the relationship between the ring sequences from the main structures at Peninsular House and their estimated felling dates.

Fig 7: Pudding Lane bar diagram.

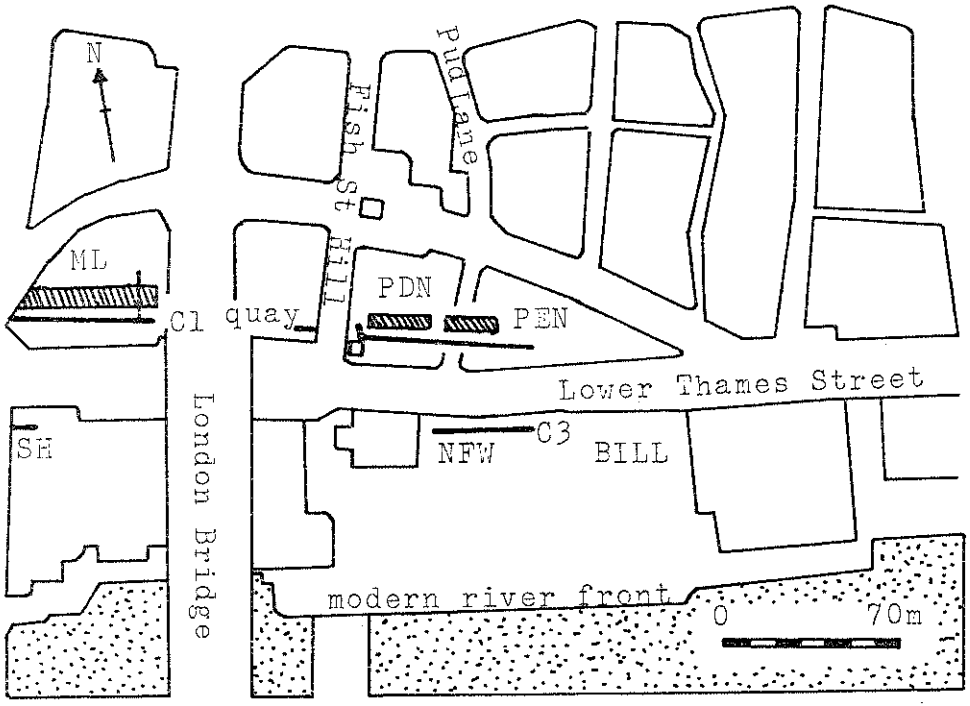

N
Fish St Hill
Pud Lane
ML
C1 quay
PDN
PEN
Lower Thames Street
London Bridge
SH
NFW
C3
BILL
modern river front
0
70m

Fig 1

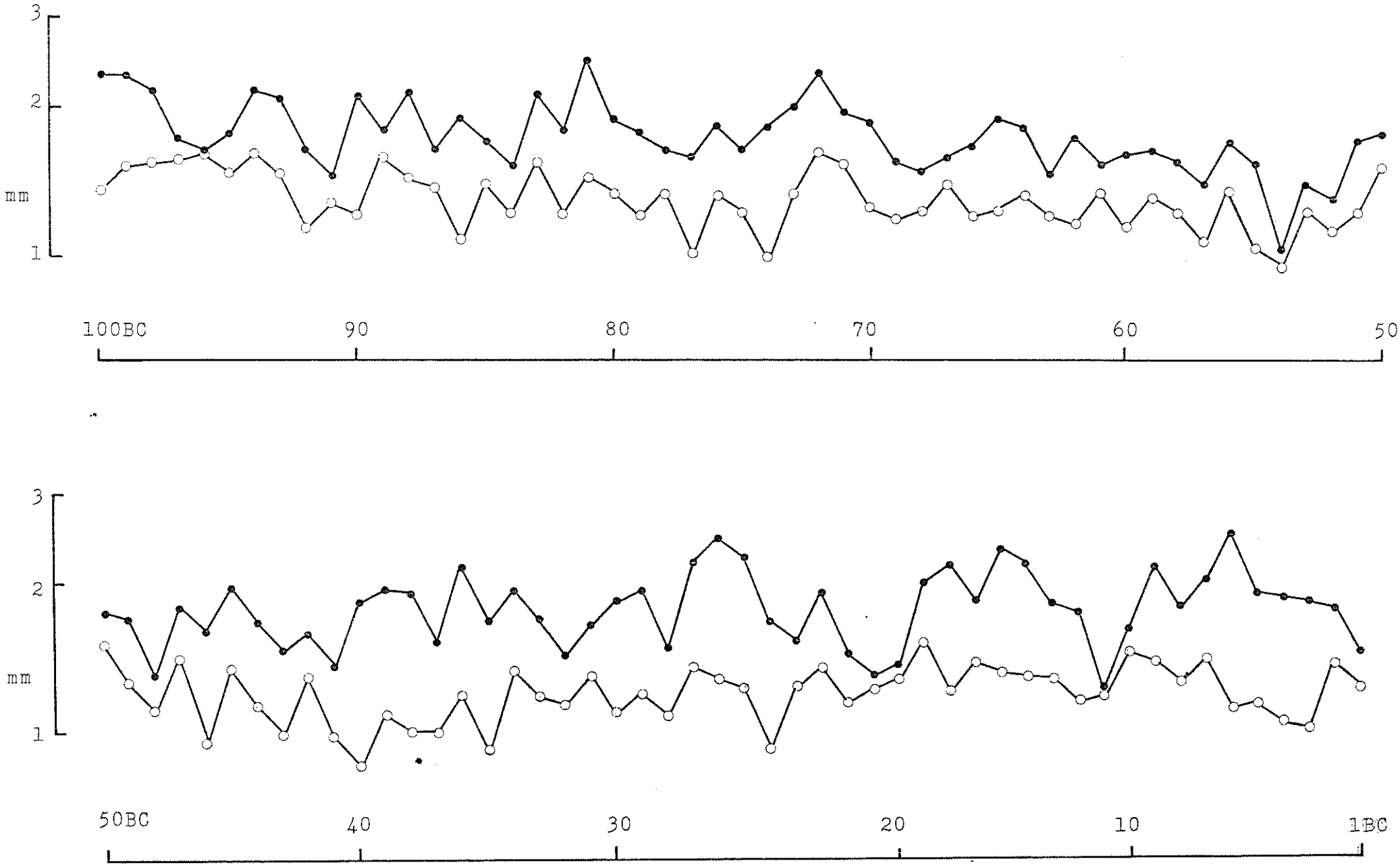
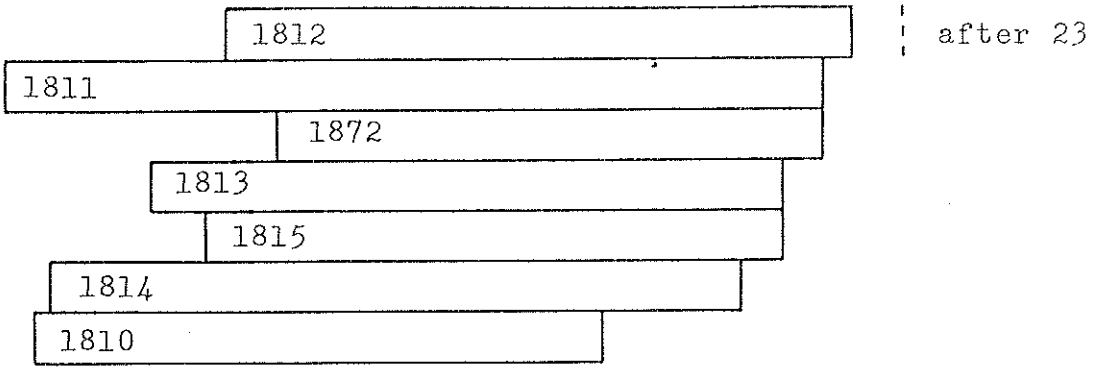


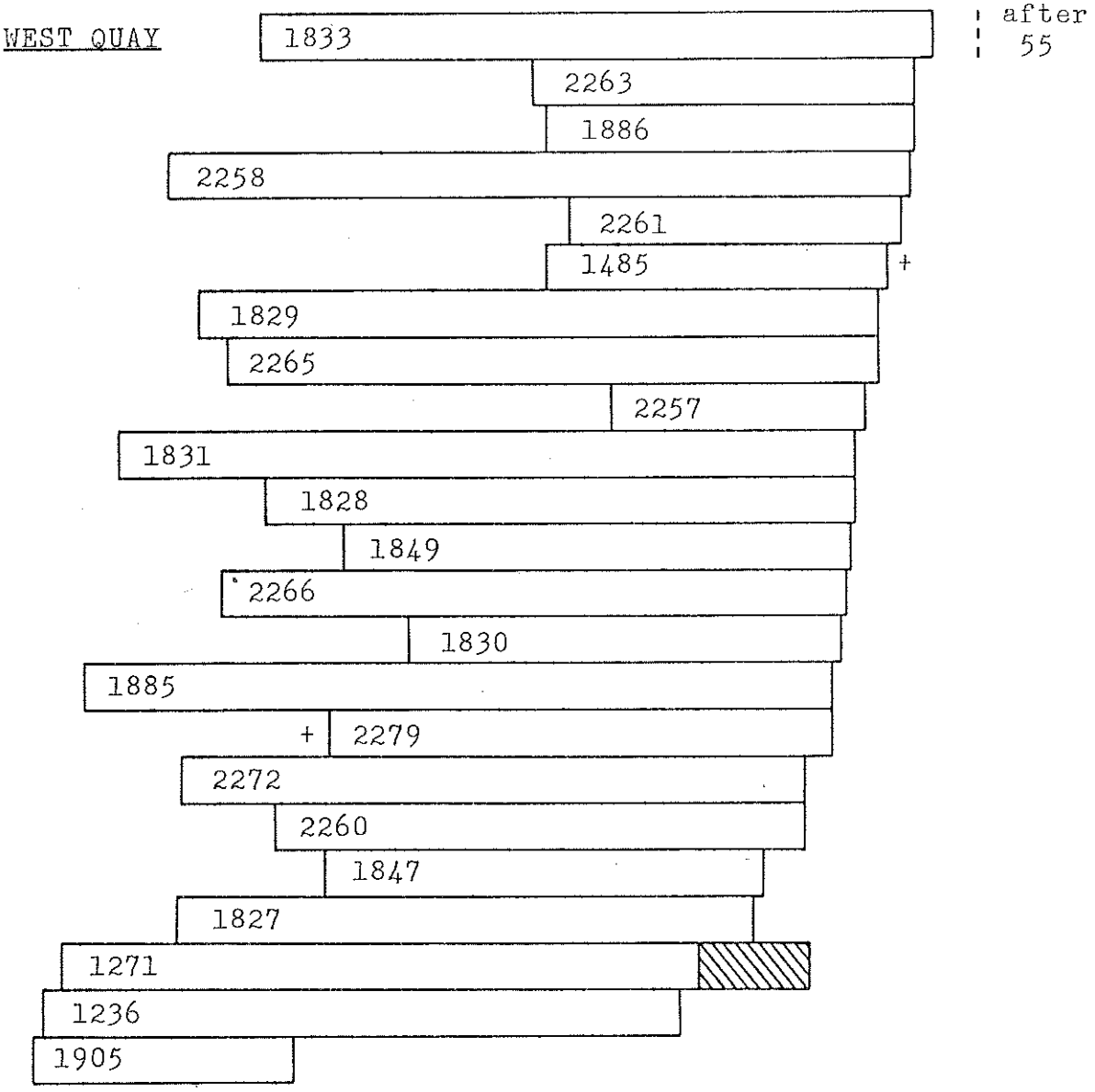
Fig 2

MILES LANE

TERRACE WALL



WEST QUAY



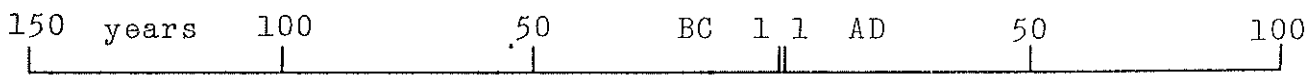


Fig 3.1

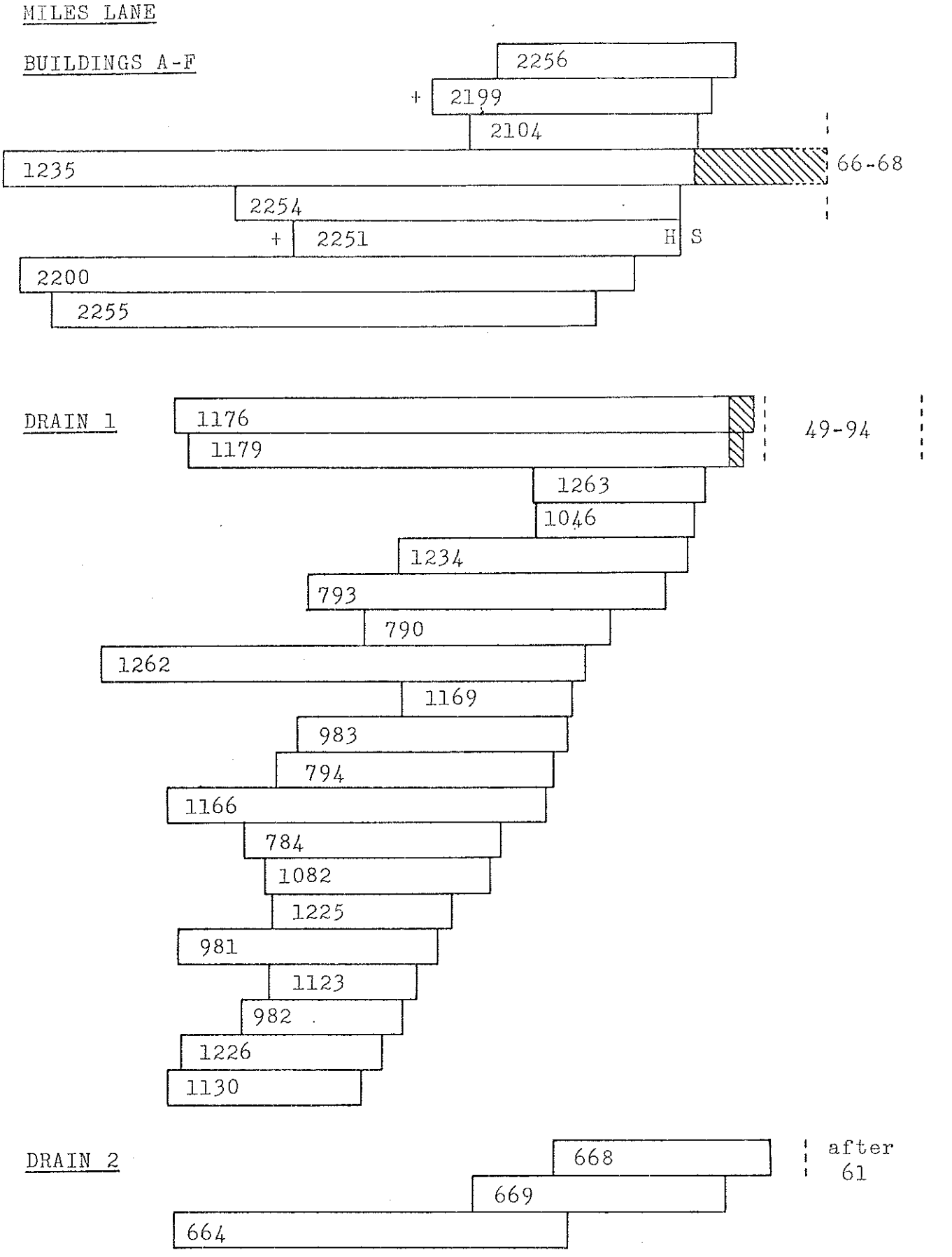

MILES LANE
BUILDINGS A-F
2256
+ 2199
2104
1235
66-68
2254
+ 2251
H
S
2200
2255
DRAIN 1
1176
49-94
1179
1263
1046
1234
793
790
1262
1169
983
794
1166
784
1082
1225
981
1123
982
1226
1130
DRAIN 2
668
after 61
669
664
150
100
50
BC
11
AD
50
100

Fig 3.2

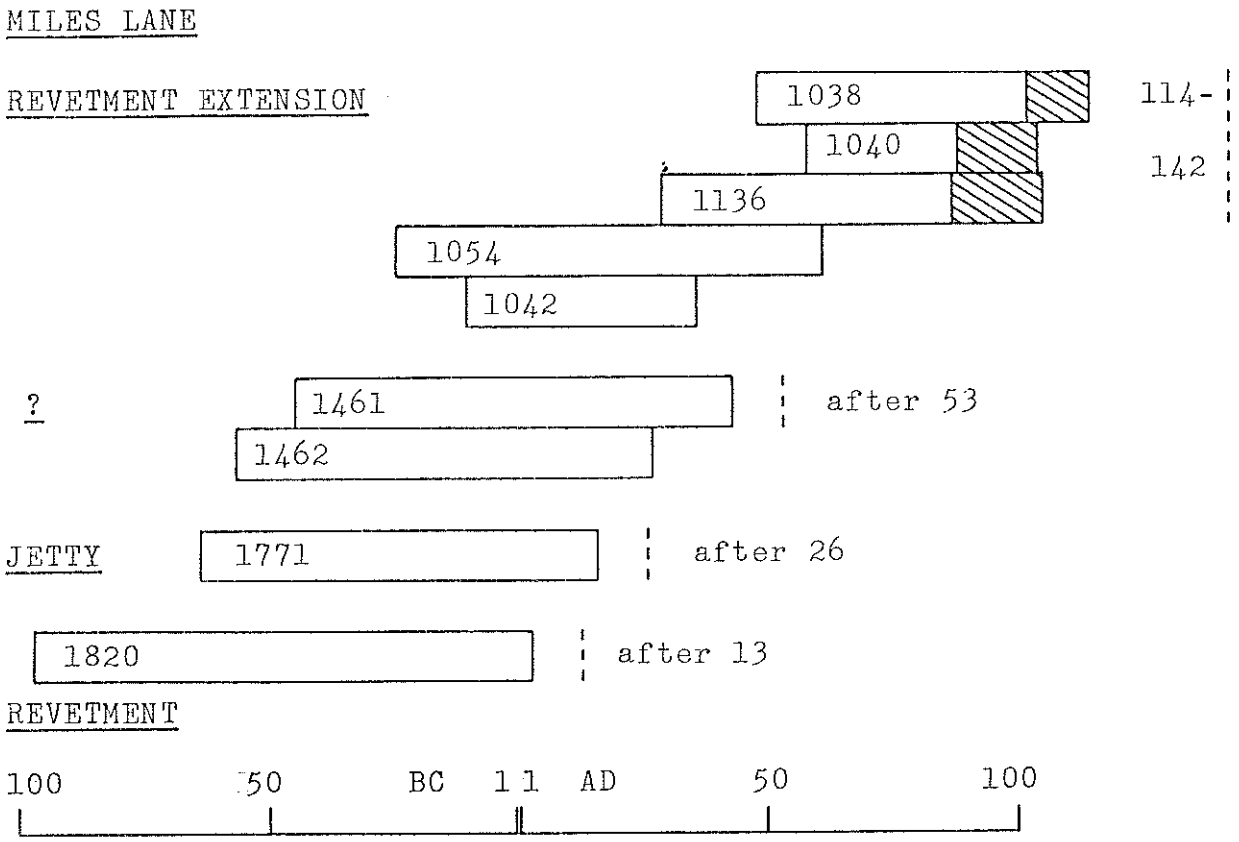

MILES LANE
REVETMENT EXTENSION
1038
1040
1136
1054
1042
114-
142
?
1461
1462
after 53
JETTY
1771
after 26
1820
after 13
REVETMENT
100
50
BC
1 1
AD
50
100

Fig 3.3

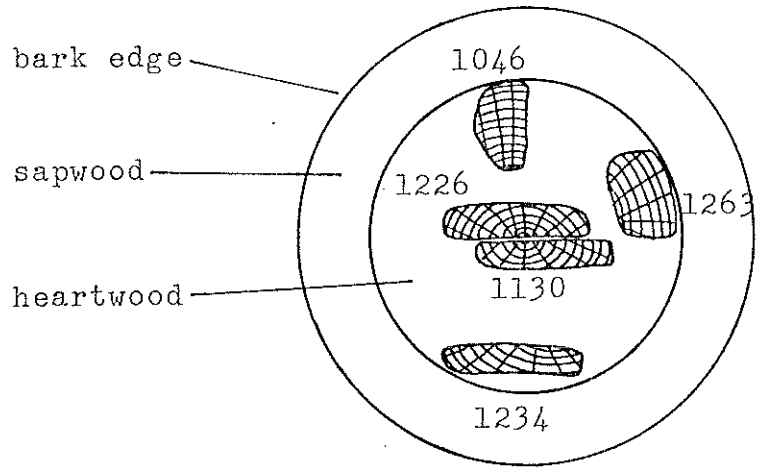

bark edge
sapwood
heartwood
1046
1226
1263
1130
1234

Fig 4

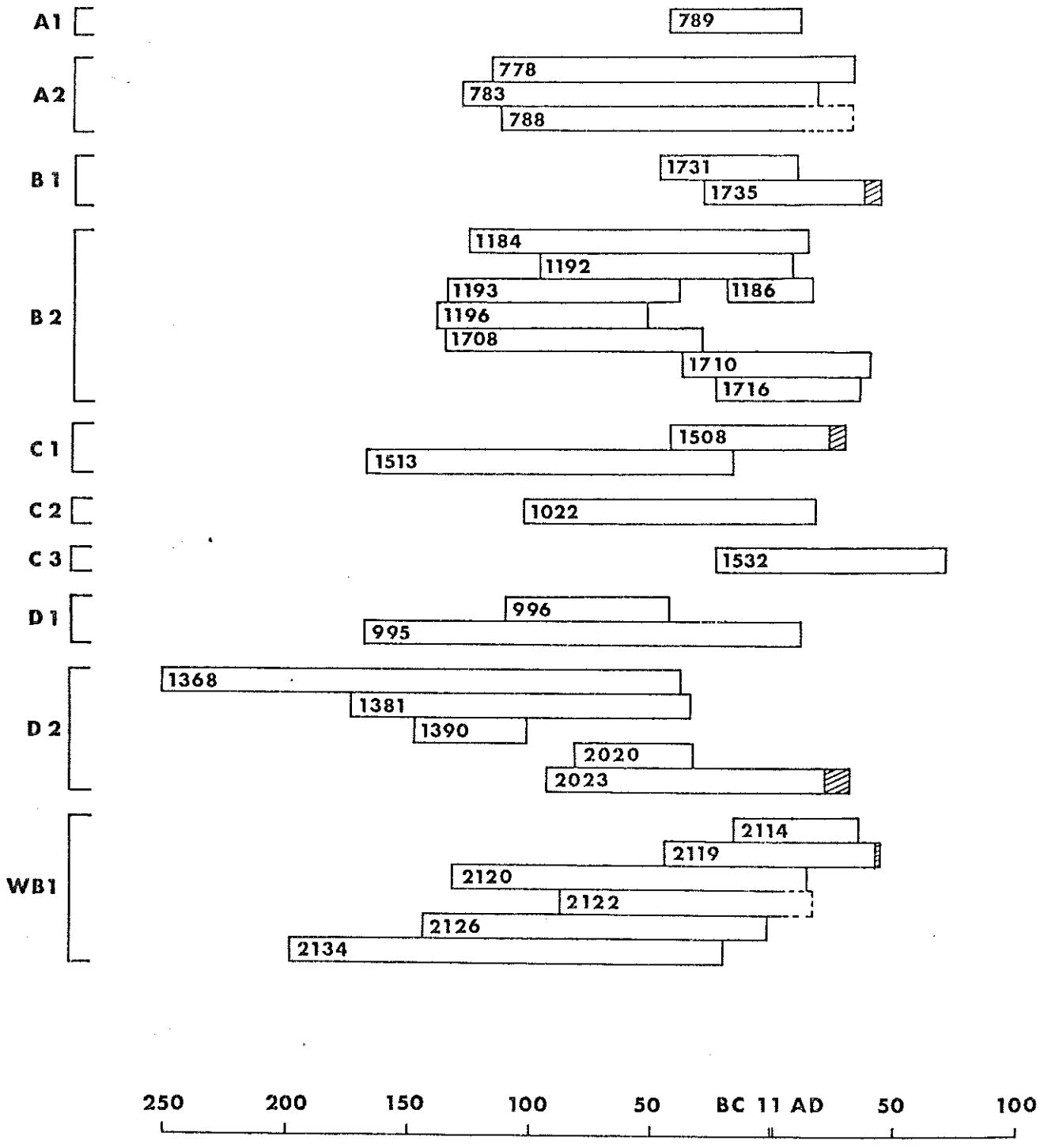

A1
789
A2
778
783
788
B1
1731
1735
B2
1184
1192
1193
1186
1196
1708
1710
1716
C1
1508
1513
C2
1022
C3
1532
D1
996
995
D2
1368
1381
1390
2020
2023
WB1
2114
2119
2120
2122
2126
2134
250
200
150
100
50
BC 11 AD
50
100

Fig 5

PENINSULAR HOUSE

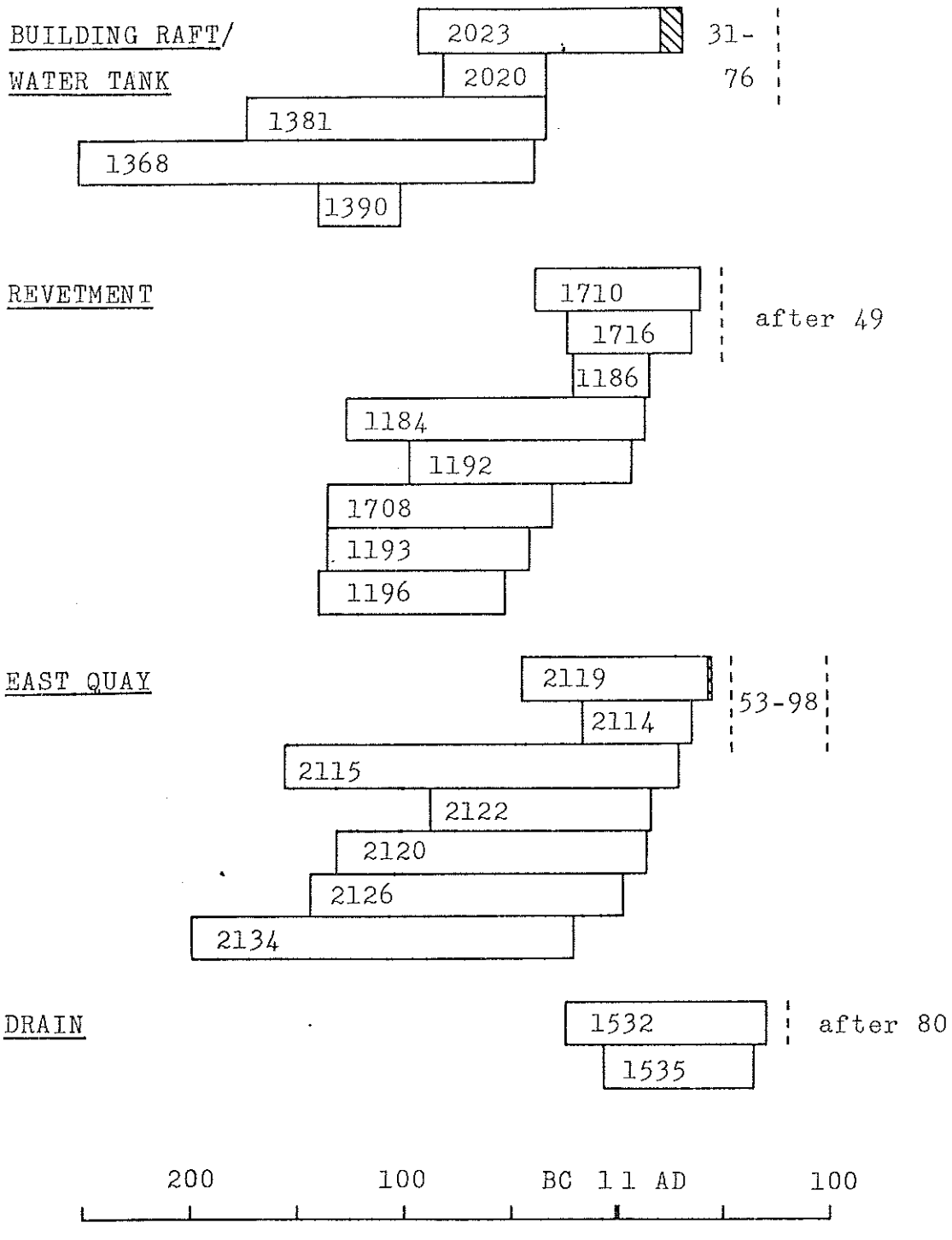
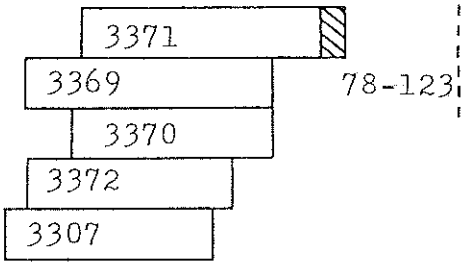


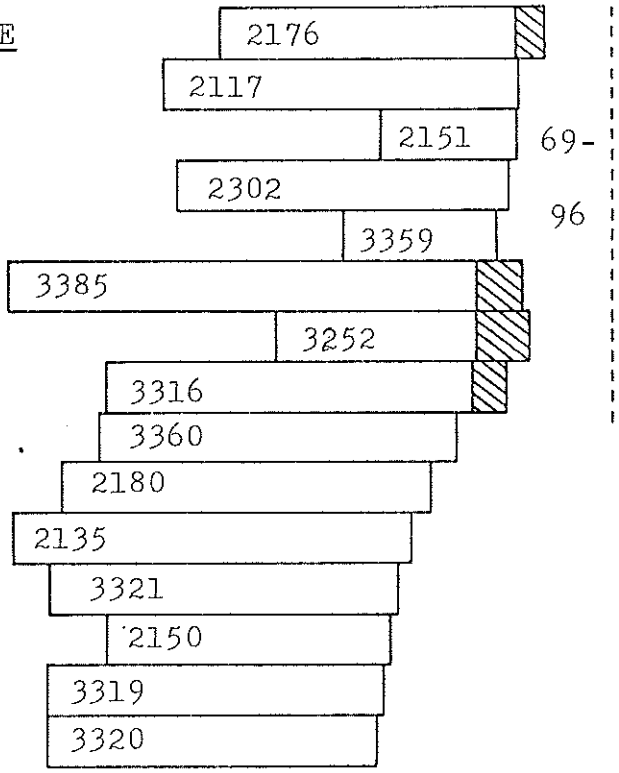
Fig 6

PUDDING LANE

?BRIDGE PIER



LANDING STAGE



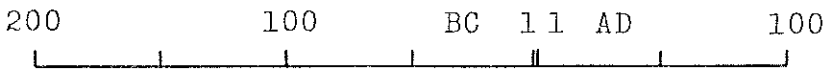
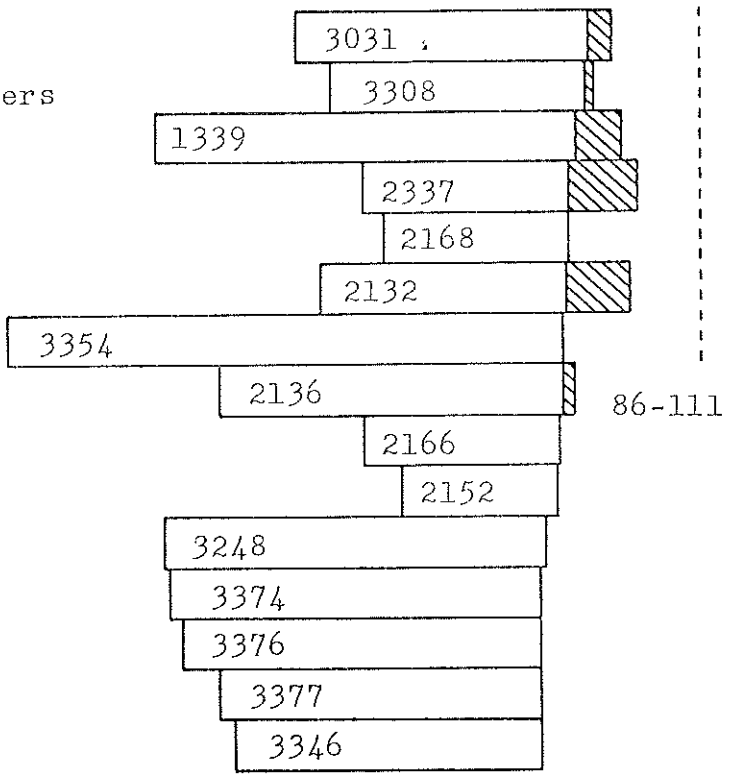


Fig 7.1

PUDDING LANE

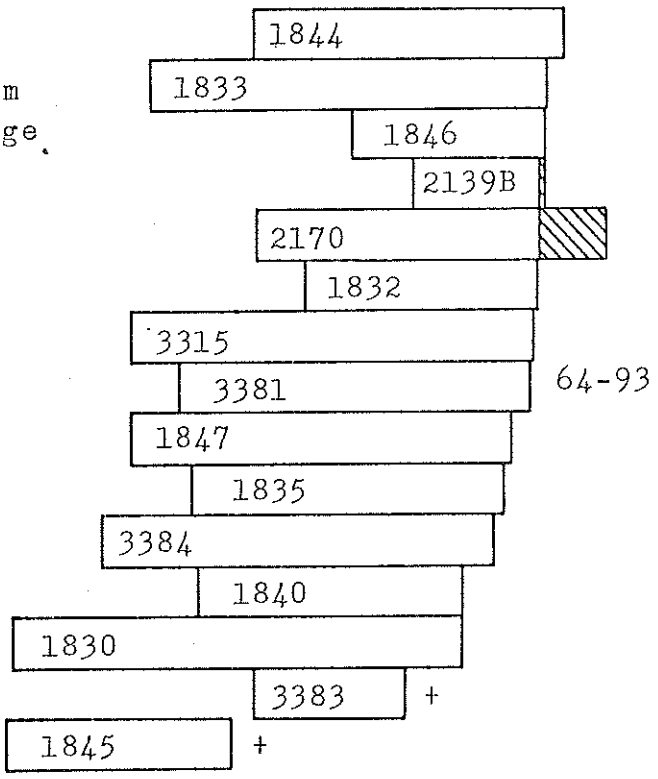
EAST QUAY

Primary timbers



EAST QUAY

?robbed from landing stage



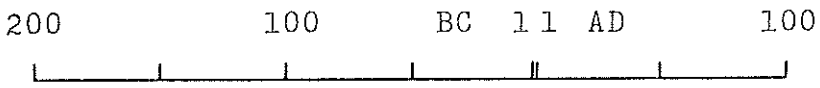


Fig 7.2

PUDDING LANE

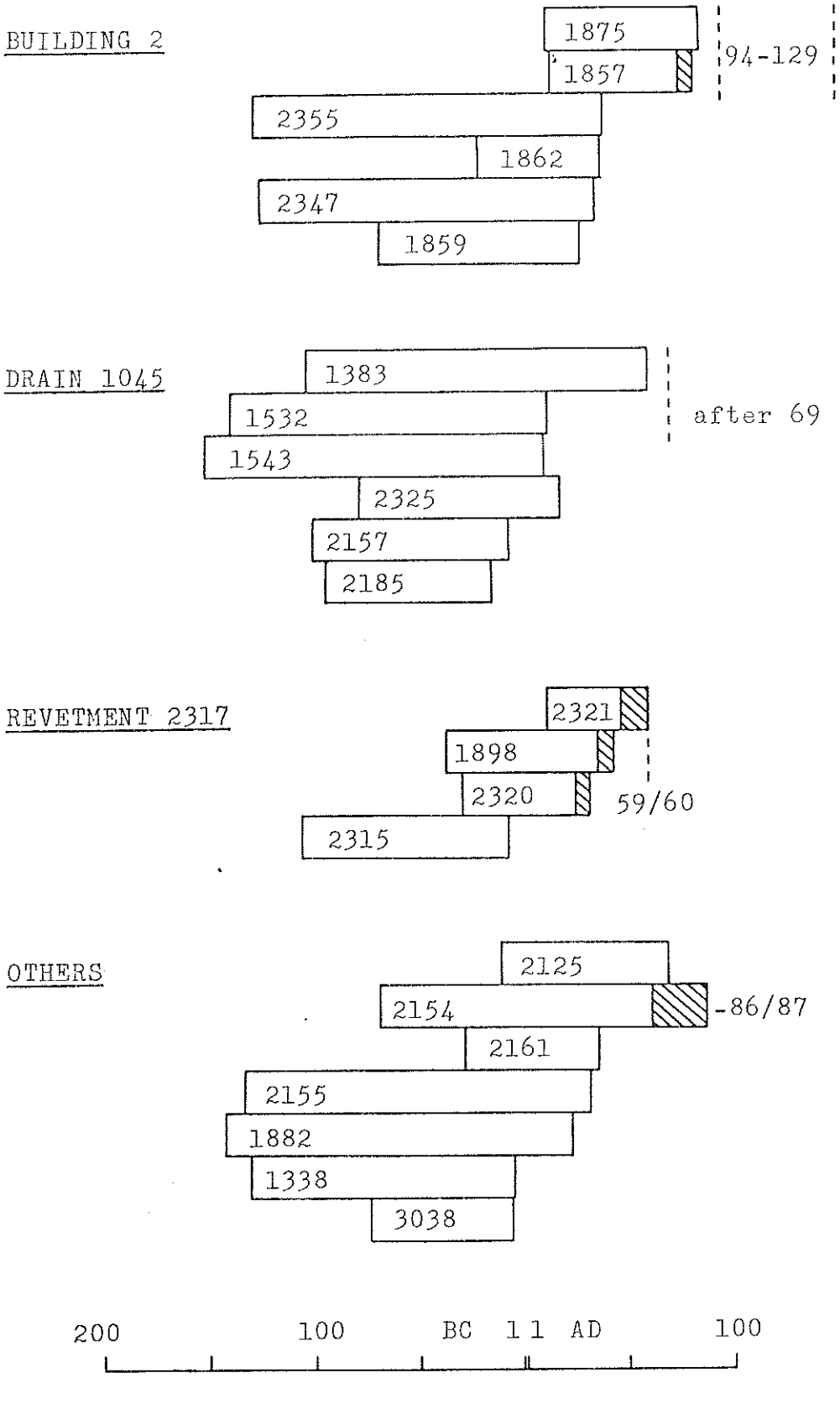


Fig 7.3

Table 1: List of timbers from a) Miles Lane and b) Pudding Lane (sufficient information is not available for Peninsular House). Timbers are listed in numerical order according to timber number (field reference number). Prefix to Pudding Lane numbers indicates priority class; asterisks indicate duplicate samples.

a) Miles Lane

number	structure	function
664	drain 2	post
665	"	post
668	"	plank
669	"	plank
784	drain 1	post
790	"	plank
793	"	plank
794	"	plank
823	"	plank
827	in fill of drain	-
981	drain 1	plank
982	"	post
983	"	post
1038	revetment extension	post
1040	"	-
1042	"	beam
1045	drain 1	post
1046	"	post
1054	revetment extension	post
1055	"	post
1059	"	post
1082	drain 1	post
1088	"	post
1123	"	plank
1130	"	plank
1136	revetment extension	-
1166	drain 1	plank
1169	"	plank
1176	"	plank
1177	"	plank

Table 1/cont

number	structure	function
1179	drain 1	plank
1214	"	beam
1225	"	plank
1226	"	plank
1234	"	plank
1235	buildings A-F	beam
1236	west quay	beam
1262	drain 1	post
1263	"	post
1271	west quay	beam
1461	?	horizontal
1462	?	"
1485	west quay	"
1486	"	"
1487	"	"
1488	?	plank
1489	?	plank
1492	west quay	horizontal
1771	?jetty south of quay	pile
1772	"	pile
1802	post-medieval well	horizontal
1809	revetment extension	pile
1810	terrace wall	pile
1811	"	pile
1812	"	pile
1813	"	pile
1814	"	pile
1815	"	pile
1816	revetment	horizontal
1817	"	pile
1818	"	pile
1819	"	pile
1820	"	plank
1825	"	pile or horizontal
1827	west quay	beam
1828	"	beam
1829	"	beam
1830	"	beam

Table 1/cont

number	structure	function
1831	west quay	beam
1833	"	beam
1847	"	horizontal
1849	"	"
1856	revetment post-quay	pile
1857	"	pile
1872	terrace wall	horizontal
1885	west quay, back of	"
1886	"	"
1905	"	"
2102	buildings A-F	foundation pile
2103	"	"
2104	"	"
2199	"	horizontal
2200	"	"
2217	under terrace wall	pile
2251	buildings A-F	horizontal
2254	"	"
2255	"	"
2256	"	"
2257	west quay, back of	"
2258	"	"
2259	"	" , see 2279
2260	"	" , see 2254, 2261, 2264
2261	"	" , under 2260
2262	"	" , jointed to 2261
2263	"	" , " to 2261, 2264
2264	"	" , " to 2263
2265	"	" , " to 2261
2266	"	" , " to 2260, above 2265
2272	"	"
2279	"	" , butted 2259

b) Pudding Lane

number	structure	function
A276	Saxon pit	in pit fill
A321	drain, early 3rd c	pile
A789*	"	pile
A950	"	plank
A955	"	plank
A956	"	plank
A957	"	plank
A958	"	plank
B959	"	plank
B960	"	plank
B961	"	plank
B966	"	plank
C1071	"	plank
A1303	drainside feature	foundation
A1313	structure south of quay	-
C1333	?	plank
C1338	?later quay	-
A1339	east quay	highest timber
B1382	drain 1045	-
B1383	"	-
B1394	"	-
A1513	south of quay	post
A1514	"	post
A1530	drain 1045	-
A1532	"	-
A1537	"	-
A1543	"	-
A1545*	"	-
A1547	"	-
A1810	building 2	floor timber
A1818	drain 1045	-
A1830	east quay	E-W timber, ?re-used
B1831	"	"
B1832	"	"
B1833	"	"
A1834	"	"
A1835	"	"

Table 1/cont

number	structure	function
B1840	east quay	E-W timber, ?re-used
B1842	?intrusive	-
B1844	east quay	N-S tieback
B1845	"	"
A1846	"	"
B1847	"	"
A1848	?intrusive	-
B1856	?associated building 2	?floor timber
B1857	"	"
A1858	building 2	floor pile
A1859	"	"
A1860	"	"
B1861	"	"
B1862	"	"
B1863	"	"
B1864	"	"
B1865	intrusive	pile
A1870*	side of drain 1045, ?earlier drain	-
C1871	east quay	subsidiary timber
B1872	"	"
A1875	building 2	floor pile
B1876	"	"
B1877	"	"
A1879	intrusive	pile
C1882	east quay dump	pile
A1884	revetment 2317	pile
A1886	"	pile
A1887	"	pile
B1888	"	pile
B1889	"	pile
A1890	east quay dump	pile
B1895	landing stage	pile
B1898	E-W revetment in quay dump	plank
A2104	early flood bank	pile
A2105	"	pile
A2107	"	pile
B2108	"	pile
B2110	"	pile

Table 1/cont

number	structure	function
B2114	early flood bank	pile
B2117	landing stage	post
B2118	"	post
C2119	east quay dump	-
C2120	"	-
C2121	"	-
C2122	"	-
A2123	landing stage	post
B2124	"	post
C2125	?	pile
C2127	?	pile
A2130	E-W revetment, pre-quay	-
A2131	"	-
B2132	small structure for quay	-
B2133	"	-
A2135	landing stage	beam
B2136	east quay	pile
A2139*	"	pile
B2140	"	pile
B2141	landing stage	pile
B2142	"	pile
C2147	waste	-
B2149	E-W revetment, pre-quay	supporting post
A2150	landing stage	main E-W beam
A2151	?landing stage	-
B2152	east quay dump	post
C2154	un-identified feature	post
C2155	"	post
C2157	near drain 1045	wedge
C2158	"	wedge
A2159	wall 1008, post-AD150	post
A2160	"	post
A2161	1870 revetment/drainside	plank
B2163	flood bank 2162	-
C2165	east quay	pile
B2166	"	E-W beam
A2168	"	make-up plank
C2170	"	wedge under tieback

Table 1/cont

number	structure	function
C2173	east quay dump	pile
B2175	landing stage	pile
B2176	"	pile
A2177	2317 revetment	pile
A2179	"	pile
A2180	landing stage	vertical
A2181	2317 revetment	pile
B2183	east quay dump	-
B2184	"	-
C2185	?associated drain 1045	plank wedge
A2268	early foundation	plank
A2302	landing stage	bottom N-S timber
C2307	east quay dump	unused pile
C2313	landing stage	wedge
B2314	2317 revetment, pre-dump	horizontal log
A2315	"	"
B2316	"	"
A2318	"	plank
A2319	"	log
B2320	"	beam
A2321	"	beam
A2322	"	beam
A2324	west side of drain 1045	post
A2325	"	post
A2326	"	post
A2327	"	post
A2328	"	post
C2333	pre east quay dump	pile
B2334	?landing stage	pile
C2335	east quay	post
B2337	"	post
A2339	"	cross strut
A2347	building 2	pile foundation
A2352	landing stage	vertical
A2353	structure north of quay	post
B2354	"	post
A2355	building 2	pile foundation
B3031	east quay	west wall

Table 1/cont

number	structure	function
A3038	drain	-
C3248	east quay	pile for tieback
A3259	"	pile re-used from a base-plate
C3260	?	-
B3267	east quay	south wall, 4th tier
A3307	?bridge pier	north wall, highest member
B3308	east quay	south wall, 4th tier
B3314	"	west wall
B3315	"	"
B3316	"	"
A3319	"	south wall
A3320	"	"
A3321	"	" , base-plate
A3346	"	pile below south wall base-plate
A3354	"	south wall, ?re-used
A3359	landing stage	tie-back
A3360	"	"
A3369	?bridge pier	north wall
A3370	"	"
A3371	"	"
A3372	"	"
B3374	east quay	south wall, 3rd tier
A3376	"	" , 2nd tier
A3377	"	" , base-plate
A3381	"	tie-back, ?re-used
B3382	"	"
B3383	"	"
B3384	"	"
A3385	landing stage	west wall

Table 2: Details of tree-ring samples. Cross-sectional sketches are not to scale; + - unmeasured rings; * - samples not measured; sapwood is indicated on sketches by shading.

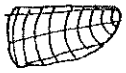
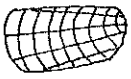
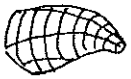
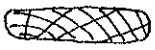
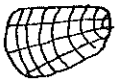
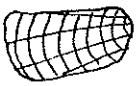
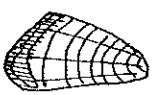
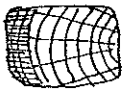
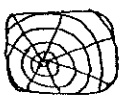
number	total no of rings	sapwood rings	average width(mm)	sketch	maximum dimensions (mm)
a)Miles Lane					
664	113	-	1.25		150 x 90
665	84	-	1.92		170 x 120
668	63	-	2.93		210 x 30
669	73	-	1.49		380 x 40
784	74	-	1.83		160 x 70
790	71	-	1.25		250 x 50
793	103	-	1.27		170 x 40
794	80	-	1.51		170 x 50
823	44	-	1.97		190 x 40
827*	33	-	3.88		180 x 180
981	75	-	2.54		270 x 50
982	47	-	2.66		130 x 80
983	78	-	1.61		150 x 80
1038	66	13	1.97		170 x 120
1040	47	17	2.83		140 x 100
1042	47	-	3.43		290 x 280

Table 2a/cont

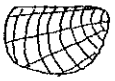
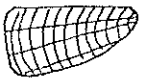
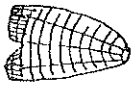
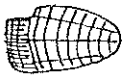
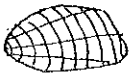
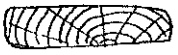
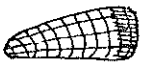
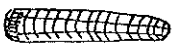
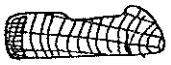
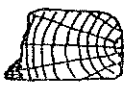
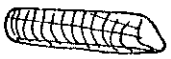
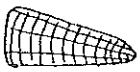
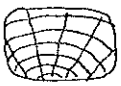
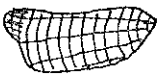
1045	54	-	1.51		160 x 90
1046	45	-	2.14		100 x 70
1054	86	-	1.91		180 x 130
1055	43	15	2.67		130 x 120
1059	60	21	1.69		130 x 90
1082	65	-	1.85		140 x 80
1088	62	-	1.23		130 x 70
1123	43	-	2.74		300 x 40
1130	56	-	3.39		290 x 40
1136	77	20	1.91		180 x 80
1166	109	-	1.23		250 x 50
1169	49	-	2.43		210 x 30
1176	166	8	1.72		290 x 30
1177	56	14	3.01		180 x 80
1179	159	5	1.68		290 x 30
1214	56	7	3.40		200 x 110
1225	52	-	2.47		280 x 50
1226	58	-	2.08		280 x 50
1234	83	-	1.30		260 x 50
1235	226+	c39	0.98		440 x 280

Table 2a/cont

1236	139	-	1.93		350 x 140
1262	139	-	1.10		160 x 100
1263	50	-	1.91		120 x 90
1271	163	25	1.81		280 x 130

Miles Lane watching brief:

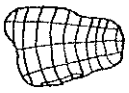
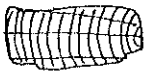
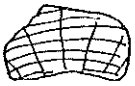
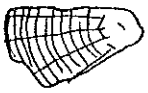
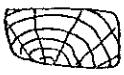
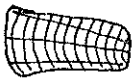
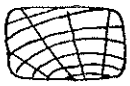
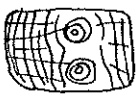
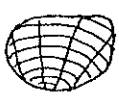
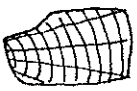
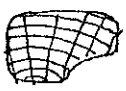
1461	88	-	1.58		160 x 150
1462	84	-	1.45		140 x 70
1485	75+	-	2.23		280 x 170
1486*	-	-	-		200 x 110
1487	+61	-	1.64		230 x 170
1488*	-	-	-		150 x 70
1489*	-	-	-		120 x 80
1492*	-	-	-	-	broken
1771	80	-	1.88		160 x 120
1772*	-	-	-	-	broken
1802	79	-	2.08		330 x 140
1809*	39	-	-		150 x 120
1810	114	-	1.52		230 x 210
1811	164	-	1.74		240 x 180
1812	126	-	1.51		220 x 190

Table 2a/cont

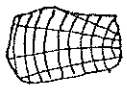
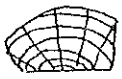
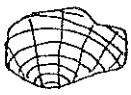
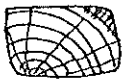
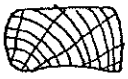
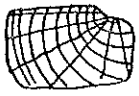
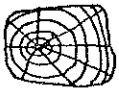
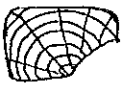
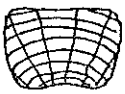
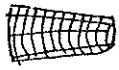
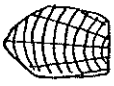
1813	127	-	1.52		200 x 190
1814	129	-	1.49		240 x 220
1815	116	-	1.37		200 x 170
1816*	-	-	-		330 x 260
1817	39	-	2.10		160 x 120
1818*	-	-	-		200 x 150
1819	44	9	3.16		230 x 120
1820	100	-	1.72		260 x 80
1825*	-	-	-		290 x 290
1827	126	-	1.26		370 x 200
1828	129	-	1.41		360 x 230
1829	148	-	1.63		230 x 160
1830	89+	-	2.10		280 x 260
1831	161	-	1.62		280 x 270
1833	147	-	1.55		260 x 220
1847	96	-	1.76		280 x 270
1849	111	-	1.61		350 x 230
1856	74	-	1.91		180 x 150
1857	79	-	1.74		150 x 100
1872	110	-	1.93		220 x 190

Table 2a/cont

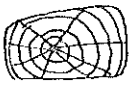
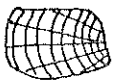
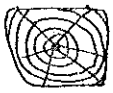
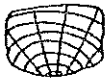
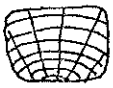
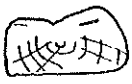
1885	163	-	1.59		440 x 280
1886	81	-	2.82		400 x 260
1905	57	-	2.78		260 x 230
2102*	37	-	-		260 x 190
2103*	35	-	-		170 x 150
2104	59+	-	1.57		140 x 100
2199	+81	-	2.07		340 x 300
2200	176	-	1.36		430 x 310
2217	64+	-	1.68		220 x 200
2251	+111	?	1.53		420 x 240
2254	128	-	1.95		280 x 260
2255	156	-	1.61		430 x 260
2256	69	-	2.33		310 x 260
2257	56	-	3.64		410 x 240
2258	147+	-	1.67		440 x 290
2259*	-	-	-		420 x 280
2260	116	-	1.53		290 x 280
2261	73	-	3.02		450 x 290
2262	+104	-	2.07		440 x 420

Table 2a/cont

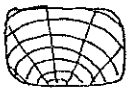
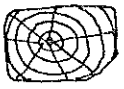
2263	84	-	3.59		450 x 280
2264*	-	-	-		440 x 290
2265	142	-	1.82		440 x 400
2266	136	-	1.70		290 x 280
2272	136	-	1.82		460 x 290
2279	+110	-	1.80		430 x 350

Table 2b: Peninsular House sample details

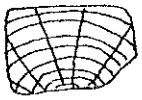
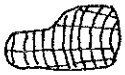
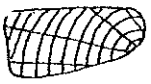
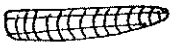
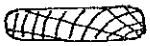
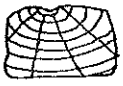
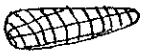
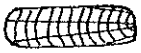
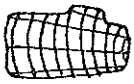
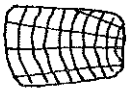
341*	c31	-	-		230 x 160
746	119	-	1.17		170 x 140
778	149	-	1.98		480 x 220
783	147	-	2.11		440 x 260
788	126+	-	2.12		450 x 310
789	54	-	2.04		140 x 90
797	52	-	2.10		250 x 210
995	180	-	1.71		450 x 190
996	68	-	2.85		400 x 180
1022	121	-	1.50		270 x 130
1183*	c30	-	-		150 x 100
1184	140	-	1.17		210 x 30
1186	36	-	2.74		190 x 20
1190	42	-	1.55		80 x 70
1192	105	-	0.96		130 x 30
1193	96	-	1.32		150 x 30
1196	88	-	2.18		210 x 140
1367*	-	-	-	-	broken
1368	214	-	1.21		270 x 40
1381	141	-	0.98		145 x 75

Table 2b/cont

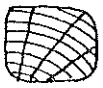
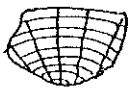
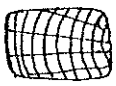
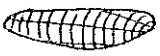
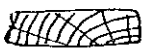
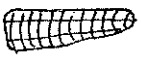
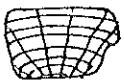
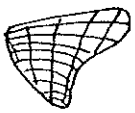
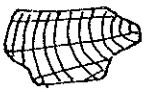
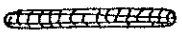
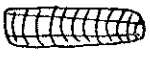
1390	47	-	1.23		70 x 50
1493*	c30	-	-		175 x 130
1508	73	7	2.72		320 x 190
1513	152	-	1.14		190 x 150
1514	42	10	3.20		190 x 170
1532	95	-	1.45		170 x 30
1534	35	-	1.51		130 x 25
1535	71	-	1.28		170 x 35
1665	76	-	0.83		75 x 20
1708	106	?	1.14		180 x 140
1710	78	-	2.47		190 x 170
1716	59	-	2.80		200 x 140
1717*	c28	-	-		120 x 90
1731	58	-	2.46		160 x 10
1735	74	8	1.81		220 x 150
1742*	c30	-	-		160 x 30
2020	49	-	2.88		150 x 25
2023	125	11	2.31		310 x 15
2114	52	-	3.64		440 x 170

Table 2b/cont

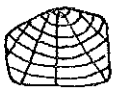
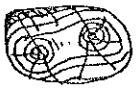
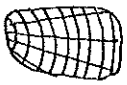
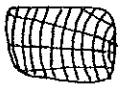
2115	185	-	1.40		490 x 350
2119	89	2	2.76		430 x 280
2120	146	-	2.70		550 x 220
2122	92+	-	1.39		220 x 120
2123*	c35	-	-		160 x 150
2125	45	13	2.26		190 x 190
2126	142	-	2.17		290 x 220
2134	179	-	1.16		200 x 180

Table 2c: Pudding Lane sample details

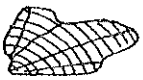
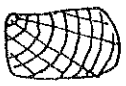
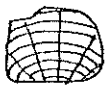
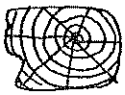
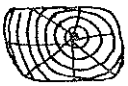
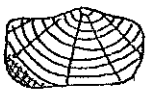
276	104	-	0.74		170 x 140
321	75+	-	1.63		210 x 130
789A	75	-	2.02		170 x 120
789B*	c30	-	-		140 x 80
950	69	-	1.58		170 x 95
955*	-	-	-	-	broken
956	80	-	1.43		280 x 70
957*	17	-	-		60 x 45
958*	37	-	-		220 x 50
959*	32	-	-		105 x 50
960*	16	-	-		100 x 40
961*	29	-	-		210 x 40
966*	39	-	-		220 x 45
1071*	16	-	-		135 x 100
1303	72	-	2.10		240 x 240
1313	58	-	2.44		250 x 180
1333*	29	-	-		350 x 210
1338	126	-	2.08		450 x 270
1339	187	20	1.83		450 x 250

Table 2c/cont

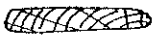
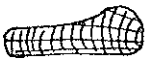
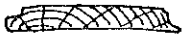
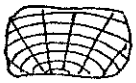
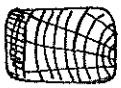
1382*	-	-	-	-	280 x 15
1383	163	-	0.92		210 x 20
1394	71	-	1.42		400 x 40
1513*	39	15	-		140 x 130
1514	41	11	2.87		150 x 120
1530	80	-	2.28		190 x 50
1532	151	-	1.60		380 x 40
1537	51	-	3.61		360 x 50
1543	156+	-	1.88	-	broken
1545A	148	-	1.36		180 x 40
1545B*	43	-	3.66		170 x 130
1547	140	26	0.95		120 x 90
1810*	-	-	-	-	broken
1818*	36	-	-		340 x 45
1830	168	-	2.00		600 x 460
1831	161	-	1.79		550 x 300
1832	94	-	1.69		570 x 420
1833	159	-	2.52		560 x 400
1834	78	-	2.97		580 x 280
1835	125	-	2.30		560 x 430

Table 2c/cont

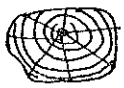
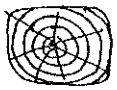
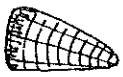
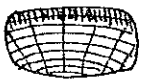
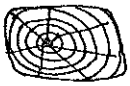
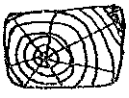
1840	106	-	2.71		360 x 280
1842	53	6	2.29		180 x 170
1844	124	1	2.68		430 x 300
1845	90+	-	2.27		400 x 280
1846	78	-	3.00		410 x 290
1847	152	-	1.59		300 x 250
1848*	27	7	-		170 x 140
1856	148	1+	1.05		175 x 120
1857	69	8	1.31		190 x 100
1858*	c35	4	-		170 x 130
1859	76	3	1.93		150 x 120
1860*	28	12	2.89		160 x 150
1861*	33	-	-		160 x 120
1862	59	-	2.23		210 x 140
1863*	42	-	-		180 x 140
1864*	37	-	-		125 x 120
1865*	c30	14	-		175 x 150
1870A*	25	4	-		150 x 120
1870B	55	-	2.15		130 x 110
1871	59	12	3.37		205 x 200

Table 2c/cont

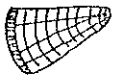
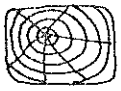
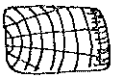
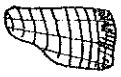
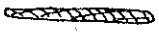
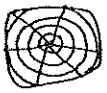
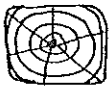
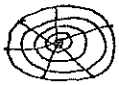
1872*	44	-	-		170 x 90
1875	80	30	1.11		170 x 130
1876	46	2	3.14		160 x 160
1877*	32	-	-		170 x 130
1879	70	16	2.64		190 x 140
1882	165	-	1.44		270 x 240
1884	32	21	2.08		130 x 130
1886	36	11	2.56		190 x 150
1887	44	20	2.32		200 x 180
1888	42	13	1.67		170 x 170
1889	40	?40	2.20		175 x 130
1890*	34	12	-		200 x 150
1895*	-	-	-	-	broken
1898	80	8	1.54		160 x 3
2104*	c30	-	-		160 x 160
2105*	c36	-	-		180 x 160
2107*	29	-	-		140 x 140
2108*	33	-	-		200 x 130
2110*	34	13	-		180 x 150
2114*	-	?	-	-	broken

Table 2c/cont

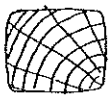
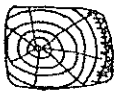
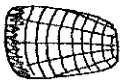
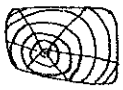
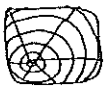
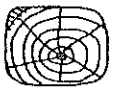
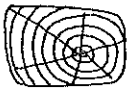
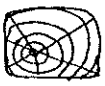
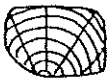
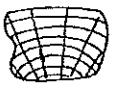
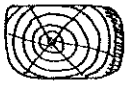
2117	142	-	1.94		210 x 190
2118*	37	13	-		190 x 180
2119	117	19	1.09		135 x 80
2120*	36	-	-		180 x 150
2121*	45	-	-		190 x 140
2122*	34	6	-		170 x 125
2123*	c30	-	-		210 x 180
2124*	42	1	-		230 x 220
2125	80	-	1.95		190 x 160
2127*	26	16	-		130 x 110
2130	59	-	1.95		270 x 40
2131	60	-	2.55		260 x 30
2132	124	26	1.43		190 x 190
2133	54	12	2.14		180 x 115
2135	159	-	2.01		300 x 250
2136	143	6	1.18		200 x 200
2137	36	11	4.00		220 x 200
2139A	96	-	1.60		290 x 290
2139B	54+	3	3.70		280 x 210
2140	36	15	3.02		200 x 180

Table 2c/cont

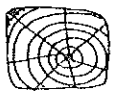
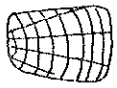
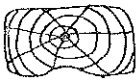
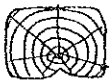
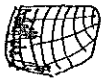
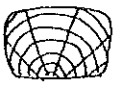
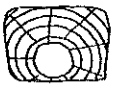
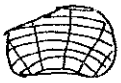
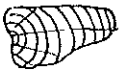
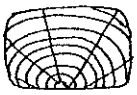
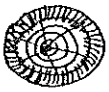
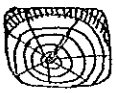
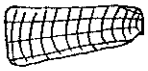
2141*	45	3	-		240 x 190
2142	69	15	2.24		190 x 180
2147	50	-	4.02		230 x 180
2149*	-	-	-		150 x 130
2150	114	-	2.40		470 x 310
2151	55	-	2.54		240 x 220
2152	63	-	2.03		170 x 150
2154	156	27	1.07		160 x 140
2155	165	-	1.35		290 x 220
2157	94	-	1.75		330 x 220
2158*	39	-	-		250 x 120
2159	75	-	2.23		170 x 120
2160	57	-	2.18		170 x 130
2161	65	-	1.80		170 x 140
2163*	22	10	-		170 x 150
2165	47	24	2.22		190 x 190
2166	79	-	2.48		580 x 440
2168	75	-	2.00		540 x 30
2170	140	27	1.17		230 x 40
2173*	-	-	-		160 x 90

Table 2c/cont

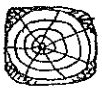
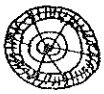
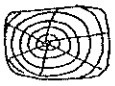
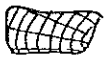
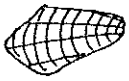
2175	55	-	1.53		160 x 150
2176	130	12	0.95		200 x 190
2177	30	17	2.09		130 x 120
2179	40	16	1.71		150 x 130
2180	148	-	1.99		450 x 410
2181	40	16	2.36		150 x 140
2183	86	-	0.94	-	broken
2184*	-	-	-		120 x 70
2185	80+	-	1.92		250 x 70
2268*	38	-	-		230 x 50
2302	133	-	2.20		430 x 280
2307	91	28	1.63		230 x 170
2313*	25	12	-		210 x 100
2314*	28	13	-	-	broken
2315	100	-	1.47		150 x 130
2316*	28	-	-		90 x 60
2318	43	-	2.09		150 x 60
2319*	25	10	-		120 x 80
2320	61	8	1.80		200 x 130
2321	49	14	1.83		140 x 90

Table 2c/cont

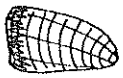
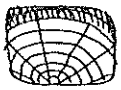
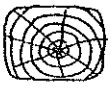
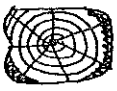
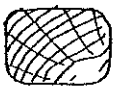
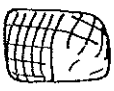
2322	93	24	1.60		150 x 120
2324	174	12	1.01		170 x 140
2325	96	-	1.70		190 x 160
2326*	14	14	-		130 x 90
2327	72	-	1.54		170 x 120
2328*	30	3	-		160 x 100
2333*	39	-	-		200 x 170
2334*	41	-	-		190 x 160
2335	58	10	3.12		210 x 160
2337	110	28	1.07		180 x 170
2339*	29	7	-		140 x 110
2347	160	9?	0.65		210 x 200
2352	102+	22	1.18		270 x 260
2353	66	-	2.23		150 x 130
2354*	c40	-	-		170 x 120
2355	167	-	0.98		210 x 200
3031	127	10	2.73		590 x 390
3038	68	-	2.02		33- x 220
3248	+153	-	1.14		230 x 200
3259	99	-	1.80		220 x 200

Table 2c/cont

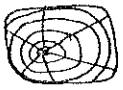
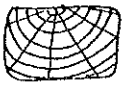
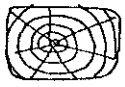
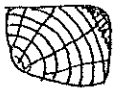
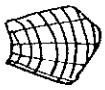
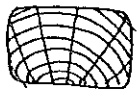
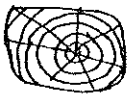
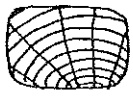
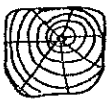
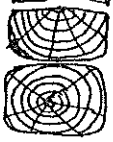
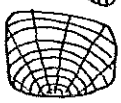
3260*	-	-	-		230 x 200
3267	121	-	2.32		500 x 320
3307	84	-	2.49		340 x 270
3308	106	4	2.51		620 x 400
3314*	-	-	-		570 x 420
3315	161	-	1.73		300 x 280
3316	160	14	1.91		290 x 280
3319	135	-	2.20		350 x 300
3320	132	-	2.40		530 x 330
3321	140	-	2.10		430 x 290
3346	123	-	1.10		190 x 160
3354	215+	-	2.17		600 x 370
3359	62	-	2.40		270 x 150
3360	143	-	1.30		320 x 300
3369	98	-	2.10		330 x 300
3370	80	-	2.00		230 x 200
3371	109	11	2.60		330 x 200
3372	83	-	1.80		350 x 280
3374	149	-	2.90		600 x 460
3376	144	-	2.76		460 x 330

Table 2c/cont

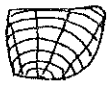
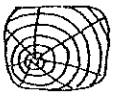
3377	129	-	2.28		520 x 440
3381	137	-	1.50		380 x 260
3382	62	3	2.43		290 x 270
3383	61	-	1.70		130 x 110
3384	157	-	1.46		290 x 280
3385	204	19	1.50		300 x 270

Table 3: Miles Lane master chronology, 169BC-AD61.

years	ring widths (0.1mm)									
	0	1	2	3	4	5	6	7	8	9
0		330	210	330	480	370	315	245	265	295
10	275	240	240	380	360	292	157	252	190	232
20	202	170	230	180	157	182	235	207	195	195
30	198	201	176	169	166	225	123	173	215	188
40	187	190	173	188	200	136	153	180	210	240
50	189	301	296	227	217	214	144	161	183	238
60	194	188	218	188	153	185	214	193	220	197
70	231	220	208	181	164	168	192	200	154	142
80	197	169	198	154	183	174	147	191	163	221
90	186	170	155	145	171	170	193	208	231	217
100	196	164	161	172	152	177	176	153	183	158
110	150	152	146	128	154	143	97	136	141	169
120	201	178	139	187	163	189	167	150	145	124
130	172	179	175	141	206	163	181	161	137	160
140	180	179	145	214	229	226	165	158	176	130
150	117	122	181	197	183	212	210	175	168	111
160	137	188	162	197	229	197	182	156	160	128
170	142	213	179	142	130	152	159	122	200	158
180	175	147	150	128	157	160	171	190	171	202
190	172	185	154	171	122	167	202	186	226	145
200	169	163	185	204	222	169	181	254	187	125
210	172	148	112	157	122	167	157	210	170	143
220	130	85	50	55	60	80	80	70	90	90
230	100									

Table 4: Dating the Miles Lane timbers. Date of heartwood-sapwood transition, if present, is given in brackets; + - unmeasured rings; t-values against the City/Southwark chronology are given.

number	date span of rings	t-value	
664	120-8BC	2.5	(3.8 with 1176)
668	12BC-AD51	5.5	
669	35BC-AD38	4.7	
784	100-27BC	3.7	
790	66BC-AD5	5.2	
793	82BC-AD21	7.2	
794	91-12BC	4.4	
981	119-45BC	5.8	
982	101-55BC	2.1	(3.7 with ML1)
983	85-8BC	3.8	
1038	AD49-114(102)	4.1	
1040	AD58-104(88)	4.5	
1042	11BC-AD36	3.4	(4.4 with 1176)
1046	17BC-AD28	7.8	
1054	25BC-AD61	7.9	
1082	94-30BC	4.2	
1123	93-51BC	4.8	
1130	122-67BC	9.2	
1136	AD29-105(87)	5.7	
1166	122-14BC	6.6	
1169	55-7BC	3.8	
1176	120BC-AD46(36)	10.0	
1179	116BC-AD43(39)	12.0	
1225	92-41BC	4.2	
1226	118-61BC	6.4	
1234	56BC-AD27	5.8	
1235	169BC-cAD67(29)	11.0	
1236	149-11BC	6.6	
1262	141-3BC	4.5	
1263	18BC-AD32	4.1	
1271	145BC-AD18(7BC)	8.3	
1461	45BC-AD43	10.0	

Table 4/cont

1462	57BC-AD27	9.4	
1485	40BC-AD35+	6.8	
1771	64BC-AD16	5.2	
1802	AD1553-1631??	-	
1810	151-38BC	5.6	
1811	157BC-AD7	8.9	
1812	113BC-AD13	2.9	(matches 1811, 1814)
1813	128-2BC	6.6	
1814	148-20BC	3.4	(6.9 with 1872)
1815	117-2BC	1.9	(4.8 with 1814)
1820	97BC-AD3	5.3	
1827	120BC-AD6	4.9	
1828	101BC-AD28	4.5	
1829	115BC-AD33	5.9	
1830	70BC-AD19+	6.7	
1831	133BC-AD28	8.2	
1833	102BC-AD45	6.5	
1847	88BC-AD8	10.0	
1849	84BC-AD27	9.0	
1872	103BC-AD7	5.8	
1885	140BC-AD23	8.4	
1886	40BC-AD41	5.1	
1905	151-95BC	6.4	
2104	36BC-AD23+	4.0	
2199	+47BC-AD34	6.1	
2200	164BC-AD12	7.9	
2251	+86BC-AD25(?25)	5.1	
2254	103BC-AD25	8.4	
2255	155BC-AD1	6.5	
2256	28BC-AD41	4.1	
2257	26BC-AD30	3.0	
2258	122BC-AD25+	7.5	
2260	99BC-AD17	3.7	
2261	35BC-AD38	5.5	
2263	43BC-AD41	10.0	
2265	109BC-AD33	6.7	
2266	110BC-AD26	4.2	
2272	119BC-AD17	8.7	
2279	+87BC-AD23	5.3	

Table 5: Dating the Bridgehead chronologies. t-values between the site masters and other reference chronologies. n - overlap, 30 years or less. ML - Miles Lane; PEN - Peninsular House; PUD - Pudding Lane; CS - City/Southwark; Germany 1 - Hollstein (1980); Germany 2 - Becker (1981); Ireland 1-4 - Mill Lough, Keenagh, Dorsey/Navan, Teeshan (Baillie pers comm); Droitwich - A Crone, unpubl; Carlisle - Baillie, pers comm.

	ML1	ML2	PEN	PDN	CS	Germany 1	Germany 2	Ireland 1	Ireland 2	Ireland 3	Ireland 4	Droitwich	Carlisle
ML1	-	13.5	13.3	14.8	14.5	6.2	5.6	2.9	n	2.2	2.7	3.5	2.6
ML2		-	17.9	17.5	19.5	5.8	4.3	2.4	n	1.0	2.1	4.1	2.6
ML			14.9	17.7	18.5	6.1	5.0	2.8	n	1.9	2.3	4.3	3.1
PEN			-	14.0	-	5.2	4.3	3.4	4.5	3.8	2.2	3.9	3.3
PDN				-	17.4	6.3	5.5	2.6	n	2.2	2.7	4.7	1.9
Bridgehead chronology					-	7.1	5.4	3.7	4.1	4.2	3.7	3.7	3.7

Table 6: Dating the Peninsular House timbers. t-values are against the Roman London chronology. AD dates in brackets indicate heartwood-sapwood transition.

number	date span of rings	t-value	
778	118BC-AD31	8.0	
783	130BC-AD17	8.9	
788	114BC-AD32	4.9	
789	44BC-AD10	7.8	
995	169BC-AD11	9.9	
996	111-44BC	3.5	
1022	104BC-AD17	6.5	
1184	127BC-AD13	8.8	
1186	21BC-AD15	3.5	
1192	98BC-AD7	6.8	
1193	136-41BC	8.1	
1196	140-53BC	5.1	
1368	252-39BC	7.6	
1381	174-34BC	6.8	
1390	140-102BC	4.4	
1508	44BC-AD29(23)	7.2	
1513	169-18BC	5.3	
1532	25BC-AD70	5.0	
1535	7BC-AD64	3.2	(4.1 with City/S'wark)
1665	AD827-902	-	
1708	136-31BC	3.9	
1710	39BC-AD39	4.4	
1716	24BC-AD35	4.6	
1731	49BC-AD9	5.4	
1735	31BC-AD43(37)	4.7	
2020	82-34BC	4.4	
2023	94BC-AD31(21)	8.3	
2114	17BC-AD35	2.8	(5.0 ")
2115	156BC-AD29	4.3	
2119	45BC-AD44(43)	8.1	
2120	132BC-AD14	6.4	
2122	88BC-AD16	5.3	
2126	144-3BC	10.9	
2134	199-21BC	7.0	

Table 7: Peninsular House master chronology, 252BC-AD70.

year	ring widths (0.1mm)									
	0	1	2	3	4	5	6	7	8	9
0		180	100	90	70	100	70	70	90	140
10	90	100	100	110	80	90	80	90	100	70
20	130	120	100	70	80	70	70	80	80	100
30	140	100	130	110	110	90	120	100	90	80
40	80	100	80	90	100	80	80	110	80	90
50	110	100	90	90	145	120	100	140	110	110
60	150	135	115	145	115	165	125	155	145	135
70	130	125	150	160	125	200	140	105	100	180
80	160	120	135	175	217	190	212	247	285	275
90	242	185	220	227	217	182	268	280	200	115
100	202	150	147	160	135	212	165	162	147	200
110	192	164	144	158	186	198	164	147	223	145
120	157	193	173	174	184	175	218	219	152	163
130	183	211	216	161	216	219	180	168	198	150
140	158	192	199	158	173	192	185	157	171	223
150	191	212	187	226	237	207	162	172	176	224
160	222	162	141	216	185	220	173	181	169	138
170	209	180	245	198	176	153	160	190	164	182
180	197	236	179	186	139	139	135	159	174	171
190	141	154	149	156	154	146	141	154	151	109
200	135	129	154	167	157	125	161	144	181	157
210	144	160	140	192	202	196	161	232	187	216
220	195	139	185	199	207	162	241	261	241	181
230	153	188	157	148	145	226	228	200	246	231
240	193	189	134	182	244	208	216	285	197	205
250	212	185	164	159	245	193	162	172	216	175
260	161	219	186	188	175	193	169	169	168	197
270	253	226	290	244	205	191	225	140	151	169
280	166	204	141	169	176	162	204	184	135	115
290	230	215	140	193	197	140	120	130	160	140
300	120	140	90	110	100	120	100	140	70	80
310	100	140	100	120	100	160	140	130	100	120
320	180	140	130							

Table 8: Dating the Pudding Lane timbers. t-values are with the City/Southwark chronology. AD dates in brackets indicate the heartwood-sapwood transition; + - unmeasured rings; f - felled.

number	date span of rings	t-value
1338	131-6BC	5.5
1339	107BC-AD80(62)	8.2
1383	104BC-AD59	5.9
1532	140BC-AD11	6.7
1543	152BC-AD4+	8.7
1830	173-6BC	6.2
1832	57BC-AD37	7.5
1833	118BC-AD41	8.9
1835	102BC-AD23	7.3
1840	100BC-AD6	5.7
1844	77BC-AD47	8.2
1845	176-87BC+	6.6
1846	38BC-AD40	5.9
1847	126BC-AD26	6.1
1857	AD13-81(74)	5.2
1859	49BC-AD27	4.5
1862	22BC-AD37	7.7
1875	AD11-84	3.7
1882	143BC-AD22	7.1
1898	38BC-AD42(35)	7.1
2117	83BC-AD59	6.5
2125	12BC-AD68	5.3
2132	41BC-AD83(58)	4.5
2135	143BC-AD16	7.6
2136	82BC-AD61(56)	5.9
2139B	14BC-AD40(38)	6.3
2150	106BC-AD8	5.4
2151	AD4-58	6.5
2152	9BC-AD54	4.8
2154	70BC-AD86(60) f 86	8.5
2155	134BC-AD31	7.6
2157	+101-8BC	4.5
2161	29BC-AD35	7.0
2166	24BC-AD55	3.2

Table 8/cont

2168	16BC-AD59	5.7	
2170	76BC-AD64(38)	7.6	
2176	61BC-AD69(58)	4.5	
2180	+104BC-AD24	5.3	
2185	95-16BC	4.2	
2302	78BC-AD55	10.6	
2315	106-8BC	5.1	
2320	30BC-AD31(24)	7.1	
2321	AD11-59(46) f 59/60	4.2	
2325	79BC-AD17	3.9	
2337	24BC-AD86(59)	0.9	- (7.7 with PDN2132; 3.8 with Roman London)
2347	126BC-AD34	3.3	
2352	39BC-AD63(42)	4.0	
2355	129BC-AD38	6.5	
3031	51BC-AD76(67)	6.6	
3038	74-7BC	6.3	
3248	104BC-AD49	8.6	
3307	59BC-AD25	3.7	
3308	37BC-AD69(66)	9.0	
3315	126BC-AD35	7.0	
3316	106BC-AD54(41)	6.4	
3319	130BC-AD5	7.5	
3320	130BC-AD2	7.5	
3321	129BC-AD11	4.8	
3346	76BC-AD47	6.1	
3354	166BC-AD49+	6.5	
3359	12BC-AD50	4.0	
3360	109BC-AD34	7.1	
3369	51BC-AD49	4.2	
3370	32BC-AD49	4.3	
3371	28BC-AD78(68)	5.8	
3372	50BC-AD33	4.0	
3374	102BC-AD47	8.6	
3376	97BC-AD47	8.9	
3377	82BC-AD47	8.3	
3381	107BC-AD30+	8.2	
3383	78-18BC+	5.9	
3384	138BC-AD19	8.4	
3385	145BC-AD60(42)	9.5	

Table 9: Bridgehead chronology, 252BC-AD86. Includes ring sequences from Miles Lane, Peninsular House and Pudding Lane.

year	ring widths (0.1mm)									
	0	1	2	3	4	5	6	7	8	9
0		180	100	90	70	100	70	70	90	140
10	90	100	100	110	80	90	80	90	100	70
20	130	120	100	70	80	70	70	80	80	100
30	140	100	130	110	110	90	120	100	90	80
40	80	100	80	90	100	80	80	110	80	90
50	110	100	90	90	145	120	100	140	110	110
60	150	135	115	145	115	165	125	155	145	135
70	130	125	150	160	125	200	140	216	158	214
80	192	196	235	284	296	282	334	428	370	368
90	287	219	262	261	217	183	317	294	216	124
100	212	166	177	175	152	220	171	161	167	197
110	207	176	161	199	207	201	187	172	260	156
120	190	223	211	189	198	183	189	205	141	164
130	190	204	224	176	262	265	225	199	212	140
140	153	179	217	170	178	202	177	167	192	229
150	197	222	198	229	229	215	170	166	176	210
160	207	161	144	203	180	208	164	183	171	149
170	206	179	242	190	179	162	159	181	164	182
180	197	231	196	193	153	150	156	163	183	182
190	148	168	156	158	159	156	139	166	152	106
200	138	135	167	172	169	133	174	162	194	170
210	151	157	134	182	189	190	153	212	171	189
220	172	139	165	186	190	149	219	242	227	167
230	152	184	139	131	133	197	210	186	227	219
240	182	175	119	157	207	177	201	242	188	185
250	180	175	145	149	222	188	157	150	180	166
260	137	203	166	176	156	168	140	155	158	172
270	210	187	233	187	184	162	193	130	157	177
280	177	210	137	159	161	165	186	190	144	138
290	228	194	129	174	171	134	145	128	159	147
300	165	156	130	130	109	103	105	114	102	94
310	94	114	104	126	121	148	151	129	123	137
320	151	134	113	108	90	104	120	90	88	50
330	76	70	78	70	58	66	40	28	32	

Table 10: Summary of felling dates for timbers used to construct the main features at the three sites. The structures are listed in chronological order, based on stratigraphical evidence.

structure	felling date	comment
EAST QUAY SITES		
PEN building raft	AD 31-76	
PEN revetment	after AD 49	
PDN revetment 2317	AD 59/60	built 59/60 or soon after
landing stage, primary	AD 69-96	built 69-93
" , re-used	AD 64-93	" , see also w quay
bridge	AD 78-123	
quay, PEN	AD 53-98	built 86-98
quay, PDN	AD 86-111	"
building 2	AD 94-129	contemporary with quay
drain, PEN	after AD 80	
drain, PDN 1045	after AD 69	
WEST QUAY		
terrace wall	AD 23-?55	?contemporary with revetment 2317
quay	AD 55-?72	contemporary with buildings A-F, so 66-68
buildings A-F	AD 66-68	built 66-68 or soon after
drain 1	AD 49-94	later than above, so c70-94
drain 2	after AD 61	contemporary with extension, so 114-142
revetment extension	AD 114-142	