Research Department Report 17/2006

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ISSN 1749-8775

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Summary

An English Heritage funded research project is currently investigating the viability of dendrochronological analysis of conifer timbers imported into England. A short section of wall of West India Docks was recorded during demolition. The wall, thought to date to c. AD 1800, incorporated conifer timbers which were considered a potentially valuable source of data for the project, particularly as the construction date of the dock is well documented. The timbers proved to be pine but none could be reliably dated and hence provenanced.

Keywords

Dendrochronology
Standing Building

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Introduction

This document is a technical archive report on the dendrochronological analysis of conifer timbers from the southern wall of the former Export Dock of West India Docks on the Isle of Dogs in the London Borough of Tower Hamlets (TQ 3757 8012; Figs 1 and 2). The analysis was commissioned by English Heritage. It is beyond the dendrochronological brief to describe the structure in detail or to undertake the production of detailed drawings. This analysis forms part of the survey undertaken by Alison Telfer and Andrew Westman of the Museum of London Archaeological Service (MoLAS) during demolition of a section of the wall for an extension to Canary Wharf underground station. The information produced will be incorporated into the on-going dendrochronological research project on conifers in England.

Brief details of the structure from information provided by Telfer and Westman and from the London Archaeological Archive and Research Centre (www.museumoflondon.org.uk/laarc) are presented below, followed by a resume of the dendrochronological conifer programme, and the aims of the dendrochronological analysis.

West India Dock

West India Docks and warehouses opened in AD 1802, indicating construction *c*.AD 1800. In AD 1988 they were in-filled with sand. The southern wall of the former Export Dock of West India Docks is a substantial structure surviving to a height of 10 metres. It was constructed of brick producing a curved section with its sloping base and buttresses to the landward side resting on an unjointed timber grillage which is in turn supported on vertical timber piles driven into the natural gravels (Figs 3 and 4). The timber elements included some that were clearly reused.

Dendrochronology, Conifers, and Importation

British dendrochronology is based on the analysis of oak and is steadily revealing an increasingly detailed picture of the changing nature of timber size and availability (Tyers *et al* 1994), as well as providing information concerning the source of timber and its acquisition from increasingly distant sources (Tyers 1998; Bridge 2000; Groves 2000a; Tyers 2002). In the post-medieval period, in both rural and urban contexts, there was not only a noticeable rise in the occurrence of native hardwood species other than oak, but also a dramatic escalation in the utilisation of conifer timbers which, in the absence of native species, are presumed to have been mostly imported. Scots pine (*Pinus sylvestris* L.), for instance, grew in England up to the Bronze Age but, apart from some isolated relict forests, it was not present until reintroduced around AD 1500 (Clapham *et al* 1989). Other species such as Norway spruce (*Picea abies* Karsten) and European larch (*Larix decidua* Mill.) were introduced in the early to mid-sixteenth century and early seventeenth century respectively (Evelyn 1729; James 1990). However the increasing presence of locally grown non-native conifer trees does not appear to have threatened the extensive trade in imported timber.

In the medieval period the development of agriculture and the steadily increasing demand for building timber caused considerable deforestation. In addition, the requirements of industry and warfare ensured that the need for timber remained high. This meant exploiting new sources of timber, and for that reason it became an increasingly important item in north European trade. Documentary sources indicate that timber was imported through organised routes as early as the thirteenth century (Salzman 1952, 247-8) and potentially the twelfth century (Simpson unpubl). Initially it was brought in for specialist purposes such as oak planking or deal boards and formed only part of the cargo, but by the mid-eighteenth century a number of Baltic ports were sending cargoes consisting solely of timber to England. These were dominated by material suitable for general construction purposes (Dollinger 1970; Kent 1973; Fedorowicz 1980). This change from importing specialist timber to that required for general construction purposes (ie conifer baulks) is potentially an indicator of the depleted state of our local woodland resources by that time and the unsuitability, undesirability, or unavailability of conifer plantation trees.

Advances in dendrochronology over the last decade have seen the development and exchange of a large network of oak chronologies covering northern Europe. This has allowed oak timbers that were exported considerable distances away from their region of origin to be dated, and has had the added bonus of identifying the geographical region from which they were derived (Bonde and Jensen 1995; Bonde *et al* 1997). This increasingly large body of data is currently dominated by groups of timbers imported into various parts of north-west Europe, probably from the eastern Baltic region (Baillie 1984; Wazny 1990). In Britain dendrochronology has identified eastern Baltic oak boards being used for panel paintings, coffins, boat planking, barrel staves, wall and ceiling panelling, doors, altars, and decorative screens. Documentary evidence indicates its importation all along the eastern seaboard of both England and Scotland, and round the south and west coasts as far as Bristol (Simpson pers comm). Dendrochronological evidence has demonstrated the presence of eastern Baltic oak imports at various locations in England and Scotland, ranging from east coast ports as far north as Aberdeen, locations further inland, and as far west as Exeter (Tyers 1991; Howard *et al* 1995; Lewis 1995; Mills and Crone 1998; Tyers 1998; Groves 2004a).

In the mid-seventeenth century there was a marked shift in patterns of trade. Ports such as Gdansk and others in the eastern Baltic went into recession, perhaps as a result of the exhaustion of forests but also due to changing political circumstances. Although small quantities of conifer timbers are thought to have been imported prior to this, it is only in the mid-seventeenth century that the trade in conifer timber flourishes, with Norway becoming the leading timber supplier to England (Kent 1973). It is thought that initially the Norwegian forests could satisfy England's requirements, with a small percentage of timber coming in as supplementary cargoes from Sweden. However by the mid-eighteenth century the structure of English imports had changed considerably with regard to both the sources of supply and the types of timber supplied (Zunde 1998). Ports on the Baltic and White seas began to rival Norwegian ports, and Norway lost its pre-eminence as the main timber supplier to England. Conifer baulks suitable for general construction work started to form a significant proportion of the total exports and to play an important part in the increased prominence of Baltic ports, although Norway retained its dominance in the export of deals. However, by the late-eighteenth and early-nineteenth centuries the focus of trade shifted again, as North American imports increased in importance.

Conifers are routinely used for dating purposes elsewhere in Europe (Storsletten and Thun 1993). Norway and Sweden, for instance, lie at the northern limits of the natural distribution of oaks, and therefore dendrochronologists in those countries have concentrated their efforts on the species of conifers that were readily available for construction. This fact, combined with the proven ability to date oak timbers imported into Britain from countries around the southern and eastern shores of the Baltic Sea, suggests that the conifers imported and subsequently used extensively in many post-medieval buildings may also be dateable.

Over the past few years an English Heritage funded research project has, when the opportunity has arisen, been investigating the viability of analysing conifers used in historic contexts (eg Groves 2000a; Groves 2002; Groves 2004b; Arnold *et al* forthcoming). The primary aim of this is to extend the scope of British dendrochronology to incorporate structures built of conifer timber. In addition, as the majority of medieval and post-medieval conifer timbers used for building are likely to be imported, successful dating has the added advantage of providing information about the source of timber, and hence the trade in timber during these periods. It was also recognised that the work might reveal information concerning the production and utilisation of timber from plantations of non-native species grown in England that would enhance our understanding of the history of forestry. The English Heritage project is now complemented by a similar project in Scotland being undertaken by Anne Crone and Coralie Mills of AOC Archaeology Group.

Aims

The excellent documentary evidence for the date of construction of the docks meant that this assemblage of timbers provided a good opportunity to further the English Heritage research programme on the dendrochronological analysis of conifers. The *c*.AD 1800 construction date indicated coincides with the increasing importance of North American imports. Previous analyses have so far only provided dating evidence for assemblages imported from northern Europe. As yet none of the assemblages analysed have proven to be North American imports.

The analysis was therefore undertaken with the following aims:
1. to determine the wood type and, where possible, the actual species
2. to provide dates for timbers and hence ascertain whether timbers are primary or reused
3. to determine the geographical source of the timbers and add to the information concerning variation of timber source through time

Methodology

Professional practice at the Sheffield Dendrochronology Laboratory follows that described in English Heritage (1998), although some modifications are required when dealing with conifer assemblages. The following summarises relevant methodological details used for the dendrochronological analysis of the timbers from West India Docks.

Discussions with Scandinavian and eastern Baltic colleagues, all of whom use similar analytical techniques to those employed here, have indicated that conifer timbers with less than 50 annual growth rings are generally considered unsuitable for analysis, though it is preferable to have an assemblage dominated by material with significantly more rings. Previous results from the current research programme suggest that it may prove necessary to raise this lower limit when dealing with imported and hence potentially variable source conifer assemblages, perhaps to about 80 rings. Thus timbers were sought which had at least 50 rings, preferably significantly more, and if possible had sapwood and bark/bark edge surviving.

Each sample was prepared by being frozen for a minimum of 48 hours before its surface was cleaned with a surform plane, scalpels, and razor blades until the annual growth rings were clearly defined. The wood type was determined through reference material in the form of permanent slides and an identification key (Schweingruber 1990). Any samples that failed to contain the minimum number of rings, or that had unclear ring sequences, were rejected. The sequence of growth rings in the samples selected for further analysis were measured to an accuracy of 0.01mm using a purpose built travelling stage attached to a microcomputer based measuring system (Tyers 2004). The ring sequences were plotted onto semi-logarithmic graph paper, enabling visual comparisons to be made between them with the aid of a lightbox. In addition, cross-correlation algorithms (Baillie and Pilcher 1973; Munro 1984) were employed to search for positions where the ring sequences were highly correlated. The Student's *t*-test is then used as a significance test on the correlation coefficient and those quoted below are derived from the original CROS algorithm (Baillie and Pilcher 1973). With oak ring sequences a *t*-value of 3.5 or over is usually indicative of a good match (Baillie 1982, 82–5). These statistical tests were designed for use with oak but some species, such as pine or beech, tend to exhibit much greater differences between successive rings than is normal for oak, which results in a noticeable increase in the *t*-values calculated. Discussions with various Scandinavian and eastern Baltic colleagues indicate that the equivalent to the 'oak 3.5' varies slightly between laboratories. The suggested CROS *t*-values ranged from 4.0 to 6.0 (eg Zetterberg 1988), with 4.0 commonly used. Consequently in this analysis a *t*-value of 4.0 or over is considered indicative of a good match for the conifer sequences, provided that high *t*-values are obtained at the same relative or absolute position with a range of independent sequences and that the visual match is satisfactory.

Dating is usually achieved by cross-correlating, or crossmatching, ring sequences within a phase or structure and combining the matching patterns to form a phase or structure master curve. This master curve and any remaining unmatched ring sequences are then tested against a range of reference chronologies, using the same matching criteria as above. The position at which all the criteria are met provides the calendar dates for the ring sequence. A master curve is used for absolute dating purposes whenever possible as it enhances the common climatic signal and reduces the background noise that results from the local growth conditions of individual trees.

During the crossmatching stage of the analysis an additional important element of tree-ring analysis is the identification of 'same-tree' timber groups. The identification of 'same-tree' groups is based on very high levels of similarity in year-to-year variation, longer-term growth trends, and anatomical anomalies. Such information should ideally be used to support possible 'same-tree' groups identified from similarities in the patterns of knots/branches during detailed recording of timbers for technological and woodland characterisation studies. Oak timbers derived from the same parent log generally have *t*-values greater than 10.0, though lower *t*-values do not necessarily exclude the possibility. It is a balance of the range of information available that provides the 'same-tree' link. At present the equivalent value for post-medieval conifers from Scandinavia and the eastern Baltic is not known and of course it may vary between species and potentially geographical location. Previous work on sub-fossil pines in the British Isles suggests that *t*-values in the order of 10–15 or over probably indicate that the samples/timbers were derived from the same tree (Boswijk 1998). This is supported by the analysis of a small number of known duplicate samples from coffin boards (Groves and Boswijk 1998). However, as the conifer research project develops, it is possible that more detailed information may be obtained from the analyses carried out in relevant countries and therefore this value may be revised.

The crossdating process provides precise calendar dates only for the rings present in the timber. The nature of the final ring in the sequence determines whether the date of this ring also represents the year the timber was felled. The inner inert heartwood and the outer band of active sapwood are readily distinguishable in some species, such as oak. Thus, if the sample ends in the heartwood of the original tree, a *terminus post quem* for the felling of the tree is indicated by the date of the last ring plus the addition of the minimum expected number of sapwood rings which may be missing. This is the date after which the timber was felled, but the actual felling date may be many decades later, depending on the number of outer rings removed during timber conversion. Where some of the outer sapwood or the heartwood/sapwood boundary survives on the sample, a felling date range can, at least in theory, be calculated using the maximum and minimum number of sapwood rings likely to have been present. The sapwood estimate applied must be appropriate to the source and species of the timber, as there are geographical variations in the number of sapwood rings present. For oak the number of sapwood rings increases from east to west across north-west Europe (Baillie *et al* 1985; Hillam *et al* 1987; Wazny and Eckstein 1991). Information provided by other European colleagues indicates that the number of sapwood rings in conifers is highly variable between regions and periods and is strongly influenced by the age of the trees (eg Zetterberg and Hiekkanen 1990). For instance for pine the number of sapwood rings in northern Sweden tends to be over 100, but in the south (ie south of Stockholm) it is generally circa 50±30 (Eggertson pers comm). In southern Norway it ranges from as few as 20 to over 100 depending on tree age (Bartholin pers comm); for example, a 100 year old tree has in the order of 30–70 sapwood rings, whereas a 200 year old tree has in the order of 45–110 sapwood rings. Thus in order to calculate a felling date range it will be necessary to determine the source of the timber and take into account the likely age at felling of the tree. Alternatively, if bark-edge survives, then a felling date can be directly obtained from the date of the last surviving ring.

The felling dates produced do not by themselves necessarily indicate the construction date of the structure from which they are derived. It is necessary to incorporate other specialist evidence concerning the reuse of timbers and the repairs or modifications of structures, as well as factors such as stockpiling, seasoning, and (of particular relevance here) transport, before the dendrochronological felling dates given can be reliably interpreted as reflecting the construction date of phases within a structure. There is evidence, at least suggesting, that the seasoning of timber for structural purposes was a fairly rare occurrence until relatively recent times and that timber was generally felled as required and used whilst green (Rackham 1990; Charles and Charles 1995). As far as the lag between felling and actual use of imported timber is concerned, the evidence from Baltic oak imports and the conifer timbers at House Mill suggests that usage takes place as little as a few months after felling, and certainly within a handful of years even allowing for the seasoning of panels (Fletcher 1980; Lavier and Lambert 1996; Tyers 1998; Arnold *et al* forthcoming; Simpson pers comm). Clarification of this aspect may well rely on the analysis of very well documented buildings which therefore have the potential to play an important role in the conifer research project.

Results

Twelve timbers associated with the southern wall were sampled by the removal of a cross-sectional slice. Microscopic identification indicated that the samples were of a single wood type (genus *Pinus*) of the anatomically defined red-pine group. The relevant species options within this group are: *Pinus sylvestris* L. (Scots pine), *Pinus mugo* Turra (Mountain pine), *Pinus nigra* Arnold (Black pine) or *Pinus resinosa* (Red pine). *Pinus sylvestris* and *Pinus mugo* cannot be distinguished on the basis of their wood anatomy but *Pinus mugo* is a dwarfed tree with dense shrubby growth, sometimes multi-trunked, and therefore not suitable for structural timber. *Pinus sylvestris* occurs throughout Europe; *Pinus mugo* and *Pinus nigra* are native to central/southern Europe; and *Pinus resinosa* is a native of North America. *Pinus nigra* can sometimes be distinguished from *Pinus mugo* and *Pinus sylvestris* as the early/latewood transition may be more abrupt than in the other two species (Schweingruber 1990). *Pinus resinosa* cannot normally be distinguished from these three European species on the basis of its wood anatomy (Wiedenhoft pers comm). Thus due to these subtle variations it was not microscopically possible to determine the wood type down to species level. The expected date of the structure coincides with a period of major change in the focus of the timber trade and thus it is not possible to conjecture as to which pine species the West India Docks timbers are most likely to be.

Details of the samples, all 12 of which were considered suitable for analysis, are provided in Figure 5 and Table 1. The 12 ring sequences were compared with each other and two, **02** and **12**, were found to crossmatch ($t = 5.95$). These were combined to produce an 85-year site master chronology, **WDA-T2**, at the relative positions indicated in Figure 6.

The site master chronology and the remaining ten unmatched individual ring sequences were compared with an extensive range of north European reference chronologies for pine that span the last millennium and the available reference chronologies from possible export areas within North America. The data were sent to various colleagues in possible source areas but, despite these exhaustive checks, no consistent results were obtained for any of the ring sequences, and thus the dendrochronological analysis has been unable to provide calendar dates for any of the timbers.

Conclusion

The analysis of twelve pine timbers associated with the southern wall of West India Dock has unfortunately provided no absolute dating evidence and hence no indication of the source of the timber. An east-west lower baseplate and a north-south crossbeam proved to be broadly coeval but no other relative dating evidence was produced to aid the identification of primary and reused material.

The failure to produce reliable dendrochronological dates for any of the timbers from West India Docks is clearly disappointing, particularly in the light of the recent successes with various conifer assemblages (Groves 2002b; Groves and Locatelli 2005; Groves forthcoming). One of the objectives of the conifer research project was to determine whether it was possible to produce well-replicated, and hence more readily dateable, chronologies from individual sites, or whether substantial mixing had occurred at the point of export or import. This could severely hamper the successful production of chronologies if the timbers present in a single construction phase were from multiple diverse sources. The evidence from the large single-phase structures previously analysed suggests that this is less of a problem than anticipated. However the use of multiple diverse sources remains a possibility with the timbers analysed from West India Docks, particularly as it had already been noted that some of the timbers were reused.

In addition to the possible use of multi-sourced material, the intra-site crossmatching may also have been adversely affected by the relative shortness of the ring sequences. A significant percentage of timbers from successfully analysed sites have far more than 100 rings, and indeed at 107 Jermyn Street it was noticeable that none of the samples analysed which had less than 100 rings were successfully dated (Groves and Locatelli 2005).

The ring sequences from the West India Docks timbers will remain in the database and will be retested as the conifer research project progresses. Whilst unsuccessful in the production of independent dating evidence, the analysis has provided useful information for the conifer research project concerning potential difficulties that may be encountered with future sites.

Acknowledgements

This analysis was funded by English Heritage. We are grateful to Alison Telfer and Andrew Westman for organising the sampling of the timbers and providing information about the site. The MoLAS drawings and photographs used in this report are by Andy Chopping, Maggie Cox, and Sylvia Kennedy. We would also like to thank Ian Tyers, Sheffield University, for discussion and encouragement. Various dendrochronologists from Scandinavia and countries around the Baltic Sea have been happy to discuss the analysis of conifers and have provided reference data and general assistance. Reference data has also been obtained from the International Tree-Ring Data Bank based in Boulder, Colorado, funded by the National Geophysical Data Center (part of the World Data Center). Tim Lawrence, Rowena Gale, and Alex Wiedenhoeft provided valuable advice concerning the identification of pine species.

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Figure 1 General location of West India Docks, London Borough of Tower Hamlets.

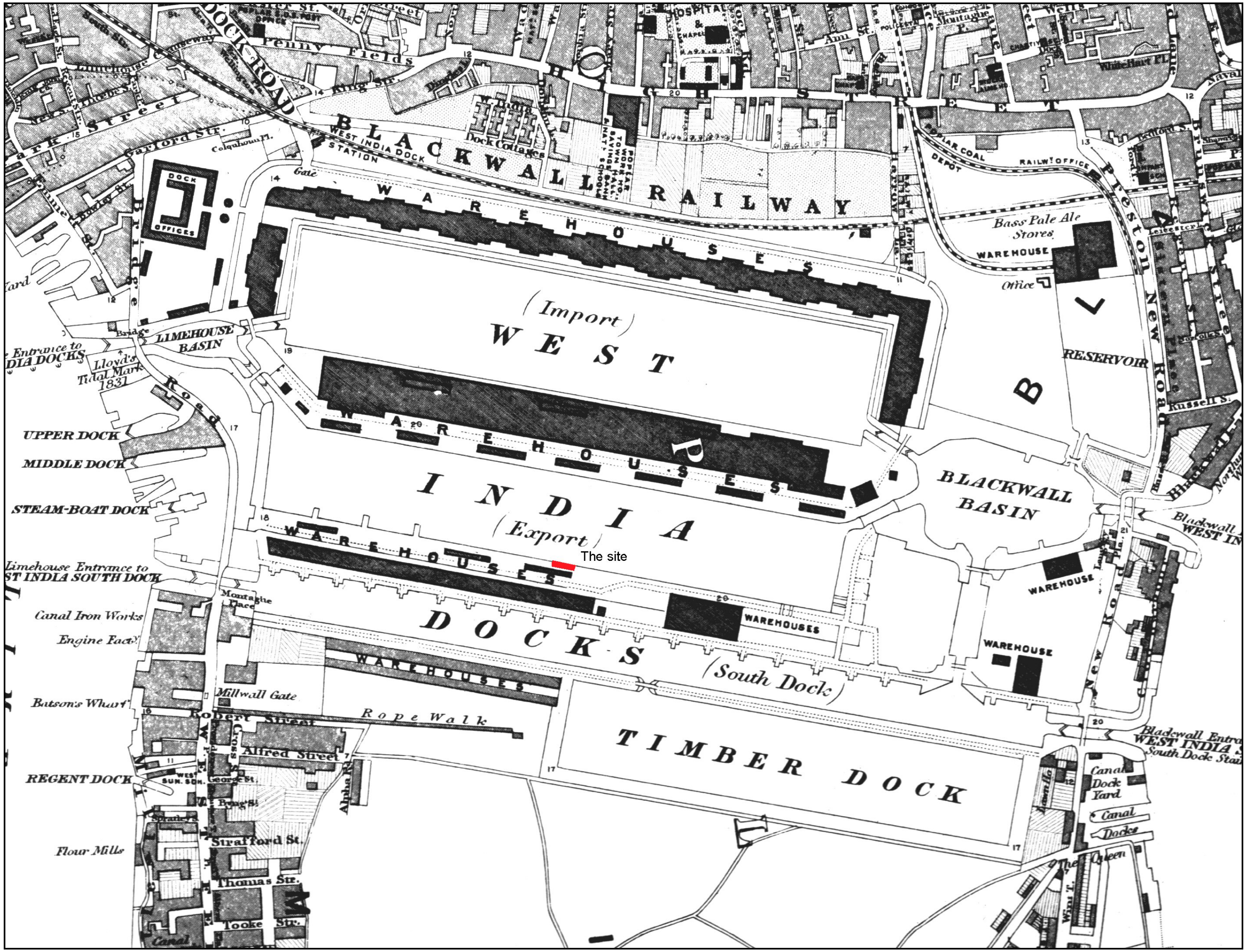

Figure 2 Location of the site, marked in red, on Stanford's map of West India Docks, London Borough of Tower Hamlets, from 1862

Figure 3 Curving brick wall supported by timber grillage (photograph MoLAS)

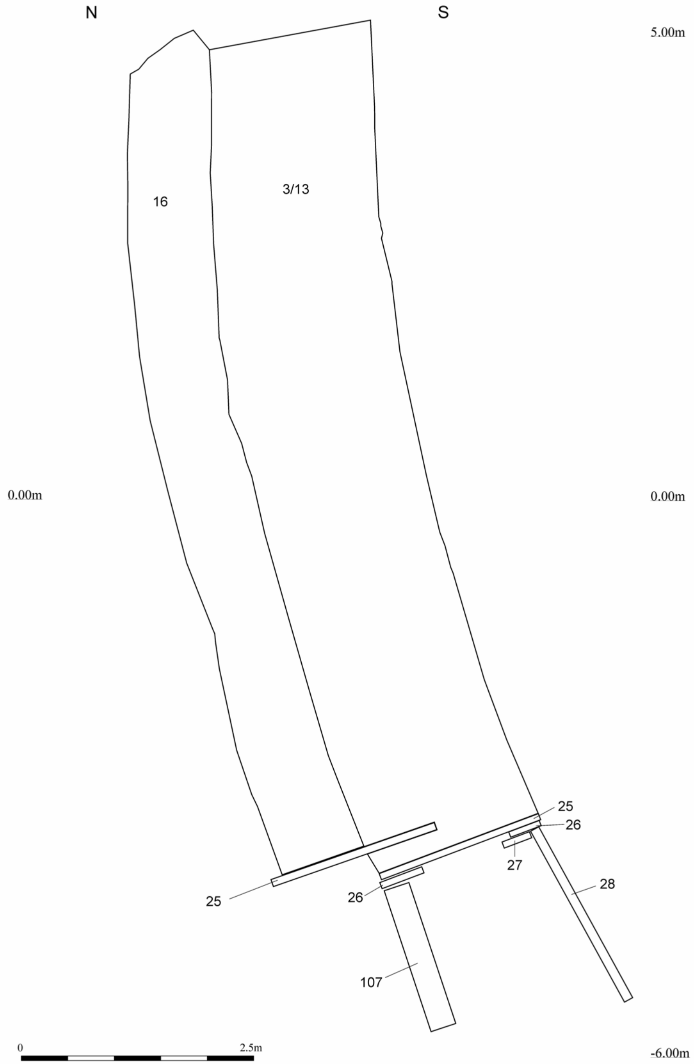

Figure 4 East facing section through the brick wall and buttress (©MoLAS)

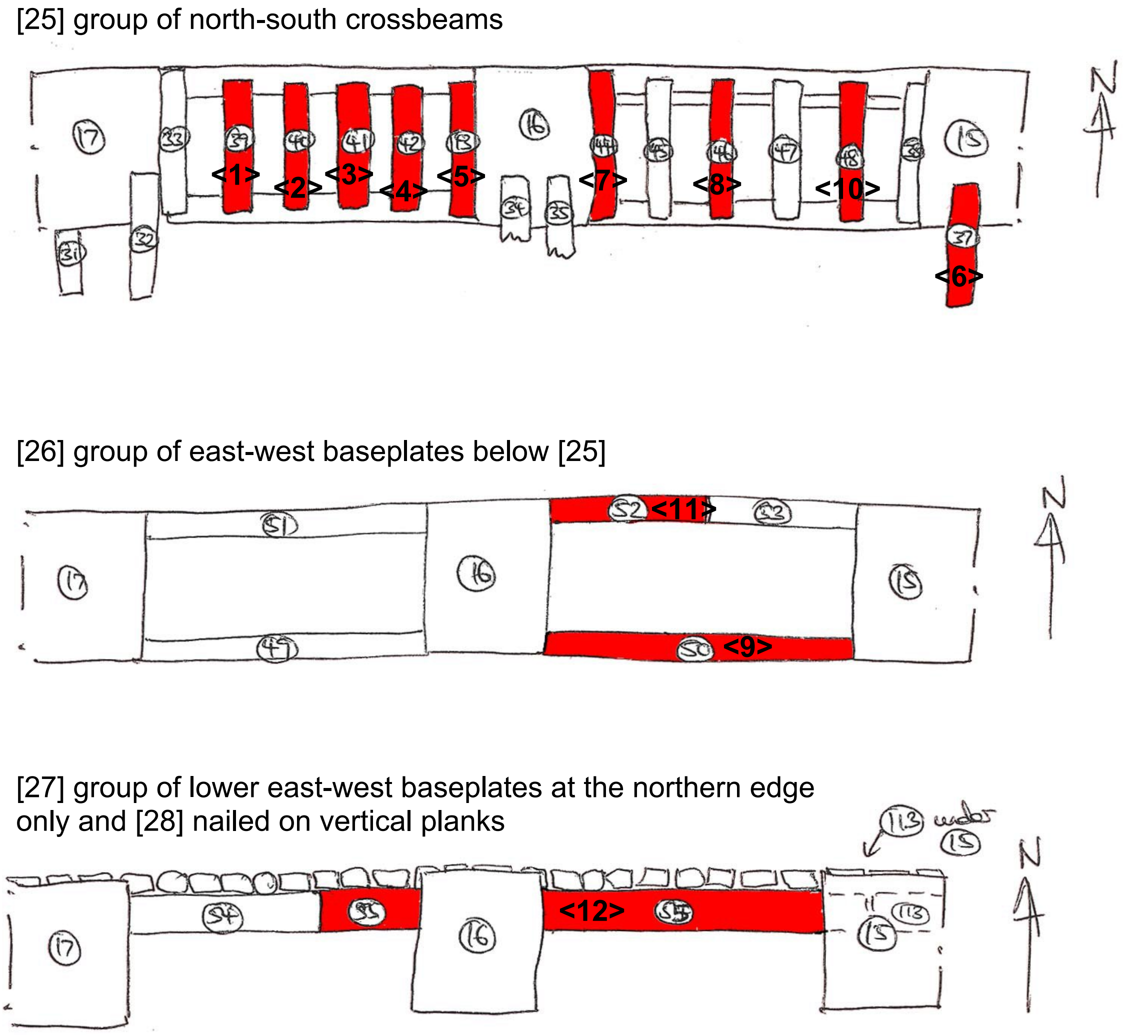

Figure 5 Plans showing the timbers sampled for analysis in red with sample numbers indicated by <> (©MoLAS)

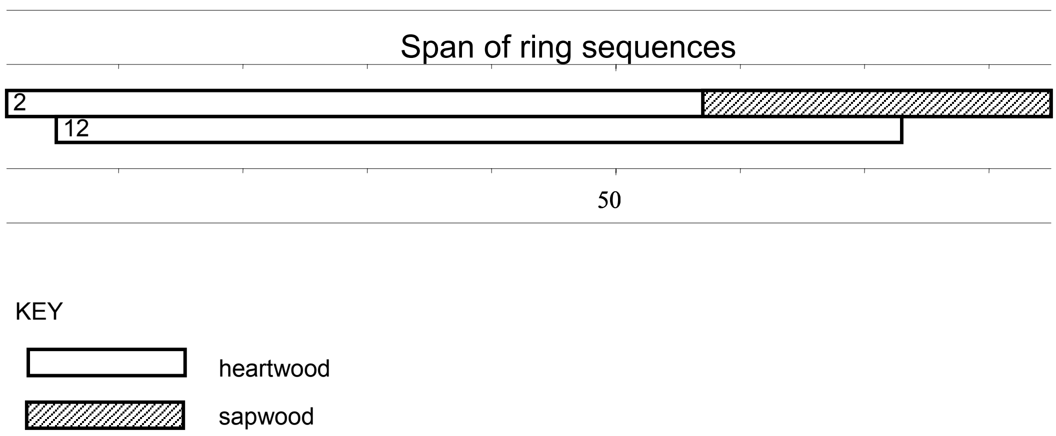

Figure 6 Bar diagram showing the relative positions of the two matching ring sequences

<u>Table 1</u> Details of the samples from West India Docks, London Borough of Tower Hamlets, Greater London

Location and function – location and function of timber sampled
Rings - total number of measured rings including both heartwood and sapwood; + - indicates additional unmeasured rings
Sapwood – number of measured sapwood rings only; hs – heartwood/sapwood boundary present; b – bark edge present; ?b – bark edge possibly present
ARW – average ring width in millimetres
Dimensions – maximum dimensions of the cross-section in millimetres

Sample	Context	Species	Rings	Sapwood	ARW	Dimensions	Comment
1	39	pine	104	47	1.34	340 x 75	+*c.*2 outer unmeasured rings
2	40	pine	85	28	1.50	380 x 60	-
3	41	pine	91	-	1.80	320 x 75	-
4	42	pine	106	39	1.81	290 x 100	+*c.*2 outer unmeasured rings
5	43	pine	70	-	2.13	370 x 100	+*c.*5 outer unmeasured rings
6	37	pine	83	35	1.35	290 x 75	
7	44	pine	166	53	1.26	410 x 75	
8	46	pine	77	-	1.98	290 x 70	
9	50	pine	110	21	2.88	490 x 80	
10	48	pine	57	38	1.53	305 x 55	
11	52	pine	113	55	0.93	315 x 60	+*c.*30 outer unmeasured rings
12	55	pine	69	-	4.36	280 x 130	