Results from the tree-ring analysis of Roman timbers excavated at Number 1 Poultry, City of London

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Author: Ian Tyers

Museum of London Archaeology

Mortimer Wheeler House, 46 Eagle Wharf
Road, London N1 7ED
tel 0207 410 2200 fax 0207 410 2201 email
mola@mola.org.uk

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Introduction

Tree-ring or dendrochronological analysis relies upon a number of basic concepts. Trees in temperate zones of the world have a single growing season and a single resting season each year. The anatomical result of this is an identifiable tree-ring within the trunk of the tree that has a distinct boundary marking the end of one growing season and the start of the next. Since the growing point of the trunk is the cambium layer directly under the bark, it follows that each years growth appears on the outside of the previous years growth. The oldest rings of a trunk are thus in the middle and the most recent rings are directly under the bark. Counting the rings provides an easy method of ageing trees but does not provide a method of dating the trees.

In contrast, dendrochronology attempts to provide absolute dates for the rings present in individual timbers (Baillie 1982; Schweingruber 1988). This is achieved by measuring very precisely the widths of each successive ring within a sample and comparing the pattern of narrow and wide rings with reference chronologies built up by previous work. The technique can be successful and reliable only when a number of conditions are met. Firstly, there have to be contemporary chronologies of the relevant species, or genus, of timber from sufficiently nearby that some degree of cross-correlation is possible. For Britain and Ireland there is now a composite tree-ring chronology for oaks stretching back just over 7000 years. There are some periods and areas that are under-represented in this composite. However for the last 1500 years almost any building or archaeological structure should, all other things being suitable, manage to be reliably dated by the method. Before this period success is more determined by the geographical and chronological vagaries of the currently available reference data. In order to be dated however, the timbers have to have a long enough sequence of tree-rings that they match in only one position to other chronologies. For oaks from Britain a widely accepted minimum for each sample is 50 annual rings. However, it is actually almost always necessary that at least some samples from a structure contain significantly more than this minimum figure.

Analysis of many thousands of timbers across Britain has also revealed that there is a consistent number of samples for which no reliable date can ever be obtained, even when many more than the minimum number of rings are present. Usually, for any sample group, between a quarter and a half of all samples cannot be reliably dated, although at some sites virtually every timber dates and at a few sites none can be dated. Faster growing trees are more likely to be undatable and trees that have suffered extreme growth reductions at certain points always give problems. Since many of these influences are potentially anthropogenic in origin it follows that at times of extensive woodland exploitation more timbers are potentially unsuitable for analysis than when under-exploited woodlands are being used.

Finally, the technique can only date the rings in a sample. The outer rings are the most recent (and only the ring directly under the bark is capable of providing the actual felling year of the tree), and these outermost edges of trees are often cut off during the process of converting round trees into square beams. In oak these rings are also sapwood, rather than heartwood, which makes them much more vulnerable to beetle attack or physical abrasion whilst above ground. With waterlogged material such as discussed here sapwood is less likely to survive through poor preservation conditions and is more easily damaged during excavation and sampling. Hence, it is

only by careful selection of the available material, and no small amount of skill and luck, that samples that provide dates precise to the felling year are obtainable, otherwise estimates of the numbers of missing rings have to be made which provide a less precise date for the structure of interest.

The general methodology and working practises used for this project are described in English Heritage (1998). Slices were cut from excavated timbers at what were thought to be the best locations; knot free positions with sapwood or bark and the maximum possible numbers of rings. Chainsaws and handsaws were used for this. In the laboratory the ring sequences from the samples were revealed by plane, knife, or surform whilst they were frozen, in the original horizontal plane of the parent tree. The complete sequences of growth rings in the slices were measured to an accuracy of 0.01mm using a micro-computer based travelling stage. The ring sequences were plotted onto semi-log graph paper to enable visual comparisons to be made between sequences. In addition a standard cross-correlation algorithm (e.g. Baillie and Pilcher 1973) was employed to search for positions where the ring sequences were highly correlated (Tyers 1999). These positions were checked using the graphs and, where these were satisfactory, new mean sequences were constructed from the synchronised sequences. A statistic known as a *t*-value derived from the original CROS algorithm (Baillie and Pilcher 1973) is used to identify highly correlated sequences. A *t*-value of 3.5 or over is usually indicative of a good match, although this is with the proviso that high *t*-values at the same relative or absolute position must be obtained from a range of independent sequences, and that these positions are supported by satisfactory visual matching.

Any tree-ring dates can obviously only date the rings present in the timber. The correct interpretation of those dates relies upon the nature of the final rings in the individual samples. If the sample ends in the heartwood of the original tree, a *terminus post quem* (*tpq*) 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 that may be missing. This *tpq* may be many decades prior to the real felling date. Where some of the outer sapwood or the heartwood/sapwood boundary survives on the sample, a felling date range can be calculated using the maximum and minimum number of sapwood rings likely to have been present. Alternatively, if bark-edge survives, then a felling date can be directly utilised from the date of the last surviving ring. The sapwood estimates used in this monograph are a minimum of 10 and maximum of 46 annual rings, where these figures indicate the 95% confidence limits of the range. These figures are applicable to oaks from England and Wales (Tyers 1998). The dates obtained by the technique do not by themselves necessarily indicate the 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 of structures before the dendrochronological dates given here can be reliably interpreted as reflecting the construction date of phases within the structure (see Goodburn this volume?).

An additional strand of information can be obtained through the use of same-tree identifications. Samples are interpreted as being derived from the same parent log if two or more tree-ring sequences are obtained that are very highly correlated, and visual inspection of the graphs and where possible the samples shows that they are not just highly correlated but exhibit the same longer-term growth trends and other characteristic. Such pairs, or sometimes more, are then used as a same-tree group and each can safely be given the interpreted date of the best of the samples. If one has bark but one does not they can both be used as if they do. They are most useful where several slices each have lots of rings but only one has any sapwood.

Samples from Number 1 Poultry
More than 1200 structural timbers were recorded from the Poultry site during the excavations. This is less than had been anticipated before the excavation began, since we thought there might be more than 2000. Nevertheless this represents a substantial quantity of material that had to be dealt with in a highly efficient manner. Any delays in sampling structural timbers can introduce larger delays into an already highly constrained excavation timetable and inappropriate handling can lead to the loss of valuable dating information from waterlogged timbers. From the outset of the project the excavations at Poultry had intended to follow an extensive timber sampling strategy, modified from previous practise such that clearly unsuitable material was discarded at the earliest possible moment. In the end over 800 structural timbers were sampled for tree-ring analysis, the remainder having been discarded during site work either because they proved too decomposed for any useful structure to be retained, or because they were clearly recognised as being unsuitable for tree-ring analysis because they contained too few rings, or in a few cases because modern heavy-metals contamination meant they could not be excavated and studied because of health risks. The initial post-excavation assessment further reduced this total to around 450 samples by eliminating those timbers that were identifiable, after sampling, as also being unsuitable for analysis due to the paucity of rings in them. This assessment also recorded the presence of sapwood, and bark, and approximate ring counts on those samples that were retained for analysis.

Excavations in the previous decade at an adjacent site (Bucklersbury, see Nayling 1990) had demonstrated that tree-ring analysis of large quantities of worked timbers from pile groups produced relatively small amounts of high quality dating evidence. This is because of the widespread absence of sapwood and bark edge from the driven pile assemblages. Due to the highly variable numbers of sapwood rings on oaks any samples either without sapwood or with partially missing sapwood cannot be expected to usefully contribute to a discussion revolving around whether a particular period of activity occurred in, for example, AD 53 or AD 59. At Bucklersbury the resources expended in obtaining this information were not felt to be entirely justified given that the stratigraphic control already tightly constrained the dates of many of these features. The Poultry project planning team were determined to avoid this problem from repeating itself with this site. As a result a strategy for selecting those tree-ring samples most appropriate for analysis was developed in association with the overall aims of the post-excavation project. The main periods of interest identified in the post-excavation assessment were those associated with the dating of the earliest Roman activities on the site (Periods 2-4), the scale and the speed of the post-Boudican reconstruction (Periods 5 and 6) and the dates of the later Roman structures (Periods 20-22). Samples with bark-edge, which do clearly indicate the felling year, were thus of prime importance to any attempts to date structures from Periods 2-6 inclusive where a period of only 25 years covers the initial laying out of this part of the City, its destruction in the Boudican revolt, and its post-Boudican reconstruction. This selectivity was not so critical for the later Roman samples since these were both much less numerous and less well preserved, this latter feature resulting in this material being less likely to have retained sapwood and bark. The vigorous selectivity proved particularly useful as a way of dealing with the Period 6 material, which was the most numerous (a third of the total samples derived from this period) and due to the extensive piling in this Period the group with least surviving sapwood, Period 18 also benefited from a highly selective approach.

Analysis was undertaken in three stages. An initial group of 28 timbers was sampled and analysed in 1994 during the original site evaluation (Tyers 1994), that is before the main excavation. These were analysed in order to confirm the presence of

archaeological layers of the predicted dates. The second group submitted for spot-dating consisted of 70 samples derived from the excavations selected specifically for the purpose of providing a dating framework for the site and to assist with the compilation of the updated project design for the post-excavation programme (Tyers and Hall 1997). Finally, the remaining 350 or so timbers were despatched to Sheffield and worked through selectively, that is by period and by each structure within each prioritised period. For each group the selection aimed at identifying the most appropriate samples from each structure. During this process a further 112 timbers were part processed to allow final assessment of their suitability and 72 of these timbers were analysed (Tyers 2000). There were two other agreed criteria operating on this selection process; the evaluation samples had unexpectedly yielded a sample that extended the tree-ring sequence for London back across a part of the third century BC for which we previously had no London data. Tree-ring samples that extend chronologies are exceedingly rare and it was accepted that long lived material from early Roman layers even without sapwood was of legitimate interest. At the other end of the sequence during the first phase of spot-dating a number of late third century AD timbers were identified. Analysis of all the later Roman timbers with a view to either extending or bulking out the tree-ring sequence for the end of the third century AD was also seen as an appropriate aim for the analyses from Poultry.

It is important that it is understood that the highly selective analysis of the material from the site has left structures without tree-ring dates that could have had them for relatively little additional effort. It is a strategy not above criticism, and will particularly amaze archaeologists unused to the depth of stratigraphy routinely exposed in London on sites such as at Poultry. The quality of stratigraphic control from such sites means that once a framework of dating is identified through spot-dating programmes (primarily by a combination of pottery, coins and dendrochronology) the correct chronological date of many features are known to within twenty years. This is better than can be obtained from the analysis of incomplete tree-ring samples from the structure itself (the same argument doesn't apply to pottery and coin assemblages because the achievable dating quality isn't so significantly affected by preservation issues in these cases).

The results

A total of 446 samples were obtained from Roman contexts on the site that were assessed as having some dating potential. These were derived from 102 structures grouped into 18 periods. Of these 210 were selected for tree-ring analysis by the prioritisation methods outlined. Forty of these were rejected after selection due to them having too few rings, or aberrant anatomical features, or for many timbers from priority groupings in Periods 2-4 because they didn't have sapwood or bark. The overall numbers of suitable samples located and analysed is summarised in Table 1.

Period	Samples initially assessed as suitable	Samples selected for measurement	Samples dated	Structure groups total	Structure groups dated
2	32	19	9	10	4
3	54	32	12	18	5
4	15	15	12	6	5
5	8	7	7	1	1
6	148	30	19	21	9
7	29	1	-	11	-
8	20	4	4	6	2

Period	Samples initially assessed as suitable	Samples selected for measurement	Samples dated	Structure groups total	Structure groups dated
10	1	-	-	1	-
11	15	5	3	7	2
12	9	1	-	3	-
14	5	5	-	1	-
15	4	-	-	2	-
16	1	-	-	1	-
18	64	14	8	9	4
19	4	-	-	3	-
20	9	9	4	2	2
21	17	17	10	2	2
22	11	11	8	1	1
totals	446	170	96	102	37

Table 1. Numbers of tree-ring sampled contexts from different Periods. Note the values for all samples columns generally excludes duplicate samples from a single timber and that the 'samples selected for measurement' column excludes the many additional samples part-processed before it was clear they could not be reliably measured, or they had too few rings or that due to the lack of sapwood they could not improve on the dating already obtained for the relevant structure.

Dates were obtained from 96 oak (*Quercus* spp) timbers from 37 structures grouped into 11 periods (Figure 1). In addition five fir (*Abies alba*) barrel staves from a single barrel from Period 3 were combined into a single undated sequence. For most Periods felling dates were obtained from several different years with some overlap between Periods. These are not major problems since it was always expected that the fairly broad categorisation by Period would introduce some inconsistency into the chronological sequence. The only major anomalies lie with two wells. One assigned to Period 3 (group 392) many of whose timbers are re-used, probably dates from after AD 90 and probably should have been assigned to Periods 7 or 8. A Period 22 well (structure 856) dating to AD 181 probably belongs in Periods 14-16. Table 2 summarises the results from each studied structure group.

Fig 1 Bar diagram of dated Roman timbers from 1 Poultry

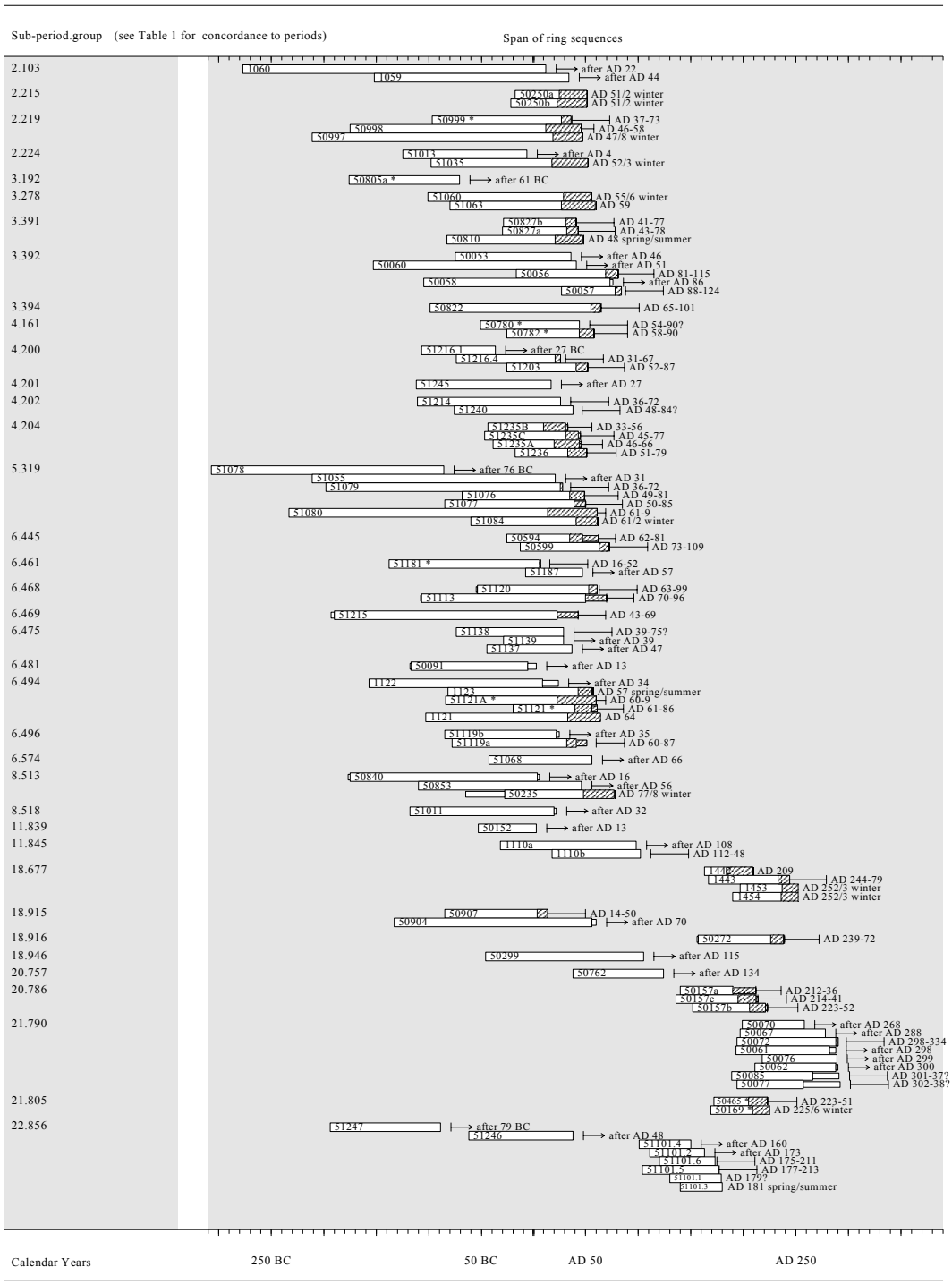

Fig 1 Diagram showing the chronological spread of rings from each dated sample, sorted by Period and Group. White sections of a bar are heartwood, hatched areas are sapwood, bark-edge is indicated by a thicker line. The likely felling date calculated as tpq's for heartwood only samples, felling ranges for samples with some sapwood or the heartwood/sapwood boundary, and felling dates for samples with bark are also shown, re-used timbers are marked with an *.

Period.Group	Summary of the results
2.103	Two post pads were recovered during the initial site evaluation. The second oldest timber from the site is from this group
2.188	This group had no useable or datable samples with sapwood or bark
2.215	Part of a drain beneath road R1, felled in the winter of AD 51/2
2.219	Part of a drain beneath road R1?, felled in the winter of AD 47/8. 50999 may be re-used. One of the oldest timbers from the site in this group
2.224	Land revetment for terracing, felled in the winter of AD 52/3
2.226	This group had no useable or datable samples with sapwood or bark
2.229	This group had no useable or datable samples with sapwood or bark
2.232	This group had no useable or datable samples with sapwood or bark
2.289	This group had no useable or datable samples with sapwood or bark
2.291	This group had no useable or datable samples with sapwood or bark
3.114	A fir wood barrel (*Abies alba*), five of the eight measurable staves from this were found to cross-match to create a 122 year sequence, which has not been found to date with any known reference data
3.153	This group had no useable or datable samples with sapwood or bark
3.160	This group had no useable or datable samples with sapwood or bark
3.164	This group had no useable or datable samples with sapwood or bark
3.182	This group had no useable or datable samples with sapwood or bark
3.185	This group had no useable or datable samples with sapwood or bark
3.192	A re-used timber with lots of rings but no sapwood
3.193	This group had no useable or datable samples with sapwood or bark
3.194	This group had no useable or datable samples with sapwood or bark
3.195	This group had no useable or datable samples with sapwood or bark
3.246	This group had no useable or datable samples with sapwood or bark
3.278	Foundations for a building, the majority of the material had no surviving sapwood, the two that were comple to bark and dated have two different felling dates one for the winter of AD 55/6 and the other in AD 59. One is presumably re-used or residual
3.391	Drain planks, one felled in the spring of AD 48
3.392	A well, mis-assigned to this period? Some of the timbers are re-used others possibly not, there may be two phases in the results, some possibly pre-Boudican material and a later group felled in the period AD 88-115

Period.Group	Summary of the results
3.393	This group had no useable or datable samples with sapwood or bark
3.394	A post pad, mis-assigned to this period? Felled in the period AD 65-101
3.395	This group had no useable or datable samples with sapwood or bark
3.396	This group had no useable or datable samples with sapwood or bark
4.161	This groups includes some timbers identified as re-used wall studs, both the dated timbers can only just be pre-Boudican since they are dated AD 58-90, it is perhaps more likely they are re-used in a post-Boudican piling
4.200	This group includes floor planks and a pile, combining the results suggests felling occurred between AD 52-67
4.201	A drain plank, no surviving sapwood
4.202	Drain planking felled in the period AD 48-72
4.204	Plank flooring and a support chock felled AD 51-6
5.319	A timber lined tank well or soakaway from the post-Boudican hiatus on the site, timbers were felled in the winter of AD 61/2.This group includes the oldest material from the site, extending the tree-ring sequence back to 307 BC
6.371	A fir wood (*Abies alba*) barrel, none of the measured series were cross-matched with either each other, other material from the site (3.114) or other available reference data
6.445	Baulks and chocks associated with a revetment structure. If neither the dated timbers are re-used a combined felling date of AD 73-81 is indicated for this structure
6.461	A cistern, dated after AD 57, that includes re-used material that is pre-Boudican
6.462	A timber with lots of rings from this group was not datable
6.468	A drain dating from AD 70-99
6.469	A drain dating from AD 43-69
6.475	A series of door planks re-used in a floor, dating from AD 47-75, a re-used chock was not suitable for analysis
6.481	A drain plank with lots of rings but no sapwood
6.493	A re-used dugout drain from this group was not suitable for analysis
6.494	A drain or trough with lots of identifiably re-used timbers, partially sampled during the evaluation excavations. The tree-ring analysis suggests pre- and post-Boudican material is combined in this group with felling dates of spring AD 57 and AD 64. Possibly all the material is re-used
6.496	Two parts of a dugout drain felled in the period AD 60-87
6.574	A post pad for a wall, felled after AD 66
8.513	A box drain associated with road R1 phase 2, the single sample with bark-edge was felled in the winter of AD 77/8
8.518	A drain from the re-alignment of road R2, has no sapwood
11.839	A re-used piece of possible furniture, has no sapwood
11.845	A drain, from the evaluation trenches, dating to the period AD 112-48
12.873	A series of samples from a drain associated with road R1 phase 3 were not suitable for analysis

Period.Group	Summary of the results
18.677	A large drain associated with road R1 phase 4, partially sampled in the evaluations, several other suitable timbers recovered but not analysed from the main excavation. Two timbers were felled in the winter of AD 252/3, another is presumably either re-used or residual since it dates from AD 209, this perhaps relates to an earlier phase of the road.
18.915	A large timber lined drain for road R1. Two timbers from this were examined as part of the spot-dating work, and although not evidently re-used there were others timbers from this structure that were, and the results from these suggest at least one of them may have been.
18.916	Drain modification or repair from road R1, from the period AD 239-72
18.946	Drain for road R2, a plank with lots of rings but no sapwood
20.757	A timber associated with building B61, lots of rings but no sapwood
20.786	Piles from building B64, felled in the period AD 223-36
21.790	Piles from the second phase of building B64, felled in the period AD 302-34
21.805	Re-used timbers associated with rebuilding B65 as B66, felled in the winter of AD 225/6
22.856	A well, mis-assigned to this period? None of the timbers were recognisably re-used. One timber felled in the spring of AD 181, the two dated base planks have exceptionally early sequences perhaps indicating they were residual or re-used from disturbed drains

Table 2, summary of the results for all the analysed Roman structures. Timbers are oak except where specified.

Discussion

Dating

The earliest material includes a timber in a Period 2 drain felled in the winter of AD 47/8, and another from a Period 3 drain felled in the spring or summer of AD 48. These are the earliest felling dates yet located on any Roman structures in London or indeed elsewhere in England. These results have repercussions for archaeologists and historians attempting to understand when *Londinium* was founded. The important point to appreciate is that although we can never entirely eliminate the possibility that these timbers are not re-used in later structures, the presence of two samples felled in AD 47-8 on the site is clear evidence somebody was doing something at this date in the vicinity. The previous earliest identified felling dates in the city are those from a waterfront at Regis House dating from the spring of AD 52 (Tyers 1995; Tyers 1996; Boswijk and Tyers 1996), and from an offcut in a pit on 72-5 Cheapside felled in AD 53 (Tyers 1992). The Poultry AD 47-8 material pushes back activity to within 5 years of the invasion in AD 43, this is earlier than the favoured foundation date of *c* AD 50 from most modern reviews (for example Merrifield and Perring 1997; Bird 1994; Selkirk 1995). The Poultry tree-ring evidence demonstrates these need to re-assessed but still encourages the view that the founding of *Londinium* occurred during the governorship of Scapula (AD 47-52).

At the other end of the Roman stratigraphy the Period 21 structure 790 building is the latest Roman tree-ring dated structure from London with a combined felling date range of AD 302-34. Remarkably there appear to have been no structures containing analysable timbers that are stratigraphically later than this earlier fourth century

building from Poultry. This may indicate a building hiatus, a lack of suitable material, or may be related to taphonomic issues. Dendrochronology is finding significant difficulty in extending the Roman sequences into the fourth century throughout England. Till now the latest tree-ring dated structure has been the monumental arch base at Sunlight Wharf/St Peters Hill in London dating to AD 293/4 (Hillam 1992). Outside London the only tree-ring dated fourth century structures are two wells from Godmanchester dating to AD 309 and AD 316-48 respectively (Hillam 1993).

The Poultry site thus contains a Roman occupation sequence more extensive in time than any previously identified for England by tree-ring analysis. The overall site tree-ring chronology is complete from 307 BC to AD 290 and at the early end timbers from this site have extended the London tree-ring sequence from 252 BC back to 307 BC. This is its first extension backwards since the Peninsular House material was analysed in the 1980s (Hillam 1986). This should in the future prove useful reference data for dating later Iron-age structures from the south-east of England. Currently there are no dated Iron age sequences from this region. The two nearest dated Iron age sequences are both from sites around 200 kms from London. Fiskerton, in Lincolnshire (Hillam 1985), has a sequence which runs up to 339 BC so this doesn't overlap with the Poultry series. Goldcliff, in Gwent (Hillam unpubl.) has a series which runs up to 276 BC but with the distance between them and the short overlap of the data it is hardly surprising that there is no correlation between them. At present the only two opportunities for extending the sequence are either by locating very old Roman trees in London or elsewhere or by finding late Iron age assemblages that overlap the Roman sequences and which themselves extend it further into the fourth and fifth centuries BC.

The selective nature of the analysis of the second and third centuries timbers prevent a firm conclusion being made about the relative amounts of timber from these periods. However, the impression given by the available spot-dating and phasing information is that there are no major timber structures from these periods.

A second area where the selective nature of the analysis reduces the amount of information produced is in the matching of sections of timber derived from the same parent log. Analysis of large assemblages often reveals huge amounts of this type of information (cf. Fennings Wharf, Tyers forthcoming), the Poultry selection process has significantly reduced this for this assemblage.

Sampling

The analysis of the timbers excavated at Poultry represents a fairly radical departure from the previously accepted practise, specifically in terms of selection of material. Tree-ring sampling strategies from waterlogged archaeological sites have gone through two major shifts in focus as the subject has developed and archaeologists have begun to understand the best application of the technique. In what may be regarded as the first phase of archaeological dendrochronology, as applied in London, small numbers of samples, usually with lots of rings and relatively little sapwood was collected specifically to yield the tree-ring sequences within them for chronology construction purposes, the archaeological dating was to some extent of secondary importance to the dendrochronologists and the sampling was rarely tuned to the archaeologists needs. From the mid 1980's the London chronologies were fixed and were sufficiently replicated that shorter and more difficult material began to work consistently. At this point sampling strategies could be modified to begin to address specifically archaeological issues; sampling was routinely total and better aimed at surviving sapwood and bark and the analysis was undertaken on all of the suitable material from a site, usually in phase groups and after assessing the entire assemblage for suitability. The approach taken with the Poultry samples perhaps

represents a more mature version to that second strategy. Such a selective strategy is only feasible because of the underlying strength of the local tree-ring sequence. Although these changes may also have been dictated by time and financial constraints in this instance they were also dictated by the appreciation that although all the material needs to be sampled the analysis of it all is unnecessary. This is because selective sub-groups are going to provide the same information in a much more structured fashion (the Bucklersbury results (Nayling 1990) perhaps provided this idea originally). Such an approach is only feasible where large numbers of samples and lots of tightly constrained stratigraphy are available, and where the post-excavation analysis of the contexts into land-uses, periods, groups and sub-groups can take place sufficiently in advance of the bulk of the post-excavation analyses. Since tree-ring spot dates are often a critical component of the stratigraphic analysis there are inevitably conflicts between spot-dating everything so that they don't spring late surprises into the stratigraphy and delaying any tree-ring analysis to enable a very much more focussed task. The Poultry approach may be a model for the future version of best practise, extensive spot-dating of sample groups with good preservation to yield a reasonably robust dating framework and then archaeologically directed selectivity.

Late Iron-age woodland and landscape

At the time of the inception of the Poultry project the Roman section of the London tree-ring chronology, a composite sequence of data derived from over 500 dated trees, included only 4 samples that went back beyond 200 BC. Three of these were from two other sites adjacent to the Poultry site; one starting at 211 BC from Bucklersbury (Nayling 1990), and two from 72-5 Cheapside starting at 205 BC and 204 BC respectively (Tyers 1992). The oldest of all at that time was from a water tank on the waterfront site of Peninsular House which had a single tree starting at 252 BC (Hillam 1986). The Poultry site has yielded another five of these long lived oaks, two more from 211 BC, then one each at 233 BC, 277 BC and 307 BC. Since these are all timbers used in the earliest periods of Roman occupation it indicates that the trees used were in the order of 260-350 years old when cut and used. Oaks these ages are not uncommon in the present landscape, many estate parks and gardens include trees planted in the decades after the English Civil War as part of a fashion for replanting schemes promoted by books such as John Evelyn's *Silva* (1664). Oaks older than 350 years are relatively uncommon in the modern British landscape, although there are still several areas of 450-550 year old oaks (such as Windsor, Cadzow, Chatsworth, Sherwood) which often have origins as wood pasture or hunting forests. Semi-natural woodland oaks on the continent can grow to 400-600 years of age, e.g. Białowieża on the Polish/Belorus border (Falinski 1994). Analysis of bog-oaks and other naturally deposited trees shows that in both England and Ireland 400 year and older oak trees were not uncommon in the prehistoric, and the log-boat from Hasholme was built from a 600 year old oak tree (Hillam 1987). Similarly analysis of timbers used for Roman fort construction in the northern frontier of England routinely reveal 400-500 year old oaks used both in Carlisle (Groves 1990; Groves 1991; Groves 1993; Groves 1996) and also at Vindolanda (Hillam 1993) for some of the earliest Roman structures on these sites.

This raises two questions, neither of which are readily answerable; why does the Walbrook area around Poultry have 8 of the 9 examples of long lived trees we currently know of from Roman London? In contrast the major warehouse and waterfront complex on Lower Thames street have only one, whilst the western waterfronts around Bull Wharf and Vintry have none. The second question is why can a Roman building a fort in Carlisle find and use 400 and 500 year old oaks, when a Roman building a waterfront in London can only find routinely find 250 and 300 year old oaks?

One possibility for the latter question is that it could be because of growth rate differences meaning the trees are not dissimilar diameters and that there is some sort of limit to Roman felling and hauling technologies. More likely I think it's a reflection of landscape differences, trees 250-300 years old may have been commoner in the south-east because of an unrecognised prehistoric phase of field abandonment in the third century BC resulting in natural forest regeneration, or because a population boom resulted in over-exploitation of trees in the fourth or fifth centuries BC. Whatever it is it caused this marked contrast in resources between north and south in the first century AD.

The first question is even less easy to answer. Such differences may be chance or they may reflect some very obscure differences in timber supply. For example it may be a function of excavation practise, although since all three areas have had extensive modern excavations using the same level of resources, the same sampling strategies and often the same staff this seems inherently unlikely. Land-use patterns are obviously different in the waterfront zones, but this is unlikely to impact on the survival of long-lived oaks in archaeological layers. It is possible that the Poultry occupation is generally earlier than other waterlogged areas of the city and there may have been more readily accessible long lived trees at this time. This seems a little unlikely since three of the very oldest examples are from post-Boudican structures. Similarly, little is known about the speed of clearance of trees within the city itself, so it is possible the first structures off the *via Decumanus* may be using timber cut from trees actually derived from the area. In contrast it is often thought that the waterfronts may have been built from timber brought into the city by boat. Tree-ring analysis cannot tell us how mixed this material is in terms of source areas since even the most 'exotic' timber may be coming only a few kilometres up or down the river.

Late Roman

A further area of comment is that yet again the 'late Roman' archaeology at Poultry is not as late as envisaged at the time of excavation. This site, as with several others, has failed to unveil tree-ring data later than late third century. This could be due to a number of factors. Changes in the design of building foundations, with a move towards stone construction is one possibility. It could be due to extensive reuse of earlier building materials in later structures, or that the later structures are above the eventual height of the water table and they haven't survived. Another possibility is that since they didn't have a capping layer of immediately later Roman structures they have been lost through post-depositional disturbance. The Poultry site definitely does have a fourth century building on it which is a first for tree-ring studies within London, and provides only the second fourth century structure to be tree-ring dated from England. Perhaps the solution to the tree-ring problem will be found outside the city on either the smaller towns or the villas rather than within the walls.

Re-use

Several excavated timbers were identified as re-used either during excavation, or during the technological recording of the timbers (see Goodburn this volume). The tree-ring analysis of those timbers identifies the primary use period, not their secondary use. However there are several instances where the analysis shows internal inconsistencies in the dating evidence within a single structure. These may be cases of unrecognised re-use, or possibly residual early timbers intruding into later structures. The two clearest cases of this are from the later sequence, the Period 18 drain structure 915 has two timbers of different date, whilst the Period 22 well structure 856 dating to the late second century includes two timbers apparently of much earlier date. More subtle inconsistencies occur in the early sequence. The Period 3 foundation structure 278 includes timbers felled in AD 55 and AD 59,

presumably the latter is the real date whilst the earlier is either stockpiled or re-used. Similarly the Period 6 drains structure 494 includes some recognised re-used timbers but the tree-ring evidence shows that some others were felled in both AD 57 and AD 64, again the implication being that this phase includes unrecognised re-used timbers perhaps salvaged from intact pre-Boudican structures (drains carrying water seem unlikely to have been destroyed by the Boudican fire). Such extensive evidence for re-cycling of timbers may be a reflection of the intensity of land-use on the site over the period. It also suggests that for those early phases where there is both only a single bark-edge sample dated, and there were definitely re-used timbers in the structure, that some caution is appropriate over the interpretation of the date of the structure.

Silver fir artefacts

One of the aspects suggested by the post-excavation assessment of the material was the extensive analysis of artefacts made of imported fir wood (*Abies alba*). The Poultry site contained more of this material than any comparable recent site from London and there was better contact with specialists working on the same material abroad than had hitherto been the case. It is thus a disappointment to report another round of failures to date any of the fir material recovered from Poultry that has been analysed. Fir wood has to be derived from an area where the timber grows naturally (Fig 2). Classical references indicate quite an extensive exploitation of the material by the Romans, with barrels and writing tablets being the most common artefacts of fir that occur in *Londinium*. Continental dendrochronologists routinely cross-match fir data from their Roman excavations with their local fir reference sequences. None has thus far managed this with data derived in England. Since these workers are exclusively in the northern half of the natural distribution of fir in seems likely that our material is coming from elsewhere with the Pyrenees or the Alps perhaps being a more likely source than the central European region.

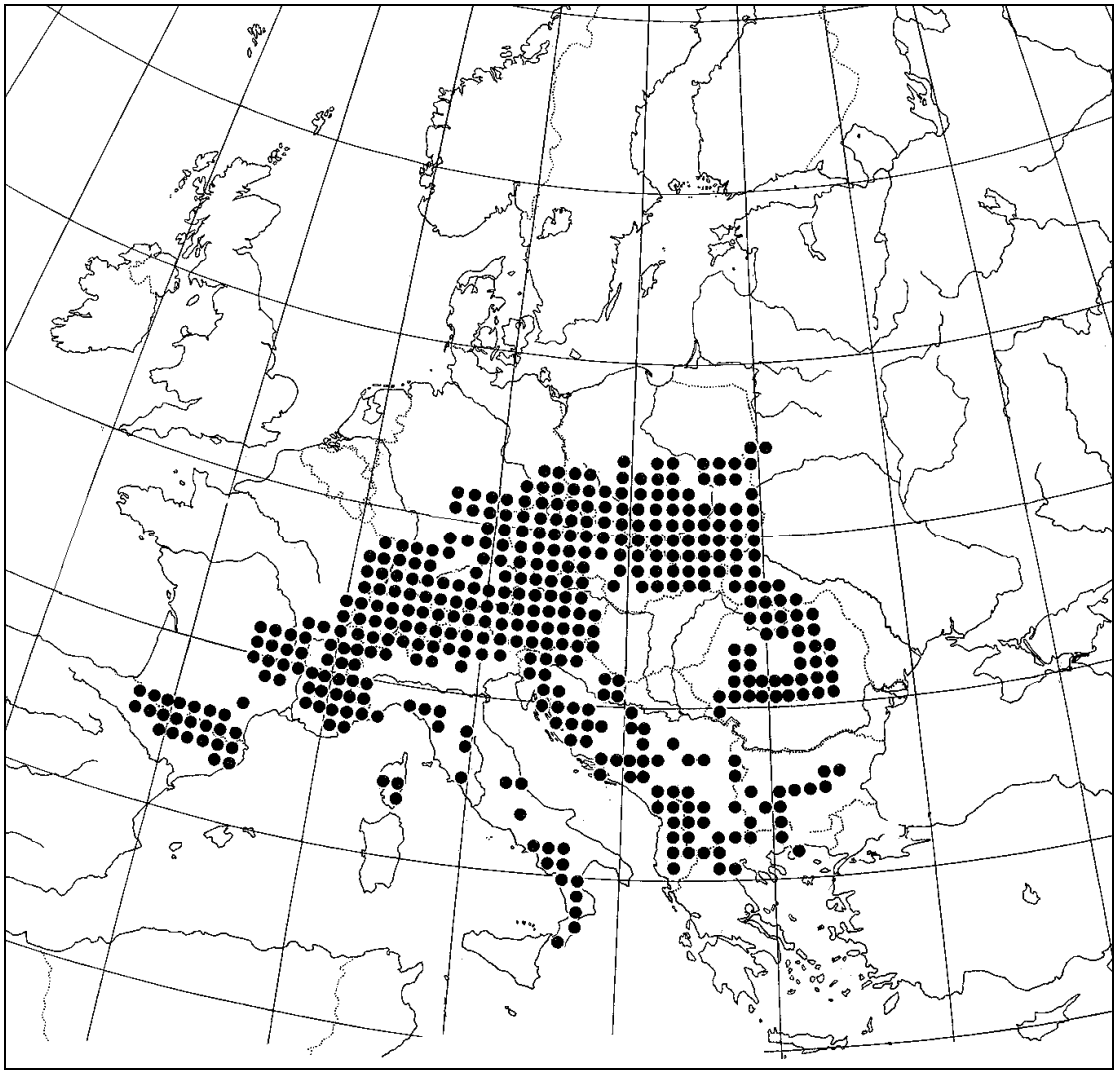

Figure 2 Modern distribution of silver fir (*Abies alba* Miller), (after Jalas and Suominen 1973). Roman tree-ring chronologies for the species are confined to southern Germany and western Switzerland so it is perhaps not unexpected that imported examples in England are proving difficult to correlate with this restricted part of the natural distribution of the timber.

Comparison with the results from Bucklersbury and 72-5 Cheapside

To some extent the different methodology employed for the selection of timbers for analysis from Poultry argues against a very detailed comparison with the results from either of these assemblages. The Roman samples from Cheapside were primarily derived from first century structures along the same road as at Poultry, various sections of this discussion have already noted the presence of dated timbers felled in AD 52/3 from Cheapside, and the presence of similar long-lived oaks from some of the features. Clearly despite being a smaller assemblage this part of the Cheapside sequence shows great similarity to the Poultry first century material. However, the Cheapside site did not produce any datable later Roman samples. Bucklersbury also produced datable samples, most of which were piles associated with a number of later first century buildings (dated AD 77-79). There was also some evidence for later Roman activity on this site with some mid-third century material being successfully dated. Bucklersbury clearly did not have the extensive pre-Boudican assemblage present on both Poultry and Cheapside, but it does have one of the very long lived trees seen on both the other sites in this case a 273 year old example possibly felled

in AD 62 (note the bark was not definitely present on this sample). Poultry probably has reasonable amounts of timber from the Hadrianic to Antonine periods but these have been ignored for the purposes of the project, neither the other two sites seem to have any second century timbers. Later still Cheapside also included an extensive Saxo-Norman assemblage of timbers, but these were virtually absent from Poultry (2 timbers examined) and completely absent from Bucklersbury. To summarise, although there are underlying similarities especially between Cheapside and the early sequence from Poultry if we compare the differences in the temporal spread of timbers from the three sites it would appear to indicate that the overall patterns of land-use for them differed markedly through the period of the Roman settlement.

Conclusions

Analysis of tree-ring sequences from Roman timbers excavated at Poultry has provided a firm dating framework for the analysis of the stratigraphy and associated finds from the site. An innovative selection process has yielded high quality results from a substantially reduced amount of analysis. The remarkable precision only possible via dendrochronology has produced the suggestion that *Londinium* was founded several years prior to the generally accepted date. The data from the site provides a significant extension into the Iron-age for London tree-ring chronologies, and increases the strength of the third century AD section of the sequence. It also appears to highlight consistent differences between the northern and southern English woodland resources from the first century AD. A failure to date any of the imported fir wood artefacts may imply the material is derived from southern Europe rather than the commonly assumed central European area.

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