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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. The conifer timber assemblage uncovered during the archaeological excavation at the Giltspur Street Compter was considered suitable for inclusion in the project. These conifer timbers were thought likely to constitute a valuable data resource for the research project, particularly as the construction date of the Compter is well documented. There was also some potential to aid the archaeological understanding of the complex. Unfortunately, although several site master chronologies were produced, none of these, or any of the individual sequences, could be reliably dated.

Keywords

Dendrochronology

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Introduction

This document is a technical archive report on the dendrochronological analysis of timbers from the archaeological excavations of the Giltspur Street Compter, City of London (TQ 3190 8144; Figs 1 and 2). It is beyond the dendrochronological brief to describe the excavation in detail or to undertake the production of detailed drawings. This analysis is part of a multi-disciplinary series of studies on the site, and thus the conclusions presented here may be modified in the light of other archaeological or environmental evidence. The information produced will also be incorporated into an on-going dendrochronological research project.

Giltspur Street Compter

Prior to redevelopment at the corner of Newgate Street and Giltspur Street, City of London, archaeological investigations were undertaken during AD 1998/99 which revealed the foundations of the Compter Prison (site code KEW98). These foundations incorporated interlaced planks and beams of conifer timber. Construction of the Prison began in AD 1787 and it was ready for occupation by AD 1791. It closed in AD 1853 and was demolished the following year at which time the below ground foundations were extensively robbed (Watson 1993).

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). 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).

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 (Simpson pers comm). Initially it was brought in for specialist purposes such as oak planking 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, usually conifer baulks and boards, is potentially an indicator of the depleted state of our local woodland resources by that time.

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 forthcoming (a)).

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). Initially the Norwegian forests could satisfy England's requirements, though a small percentage of timber came 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. By the AD 1820s North America had become England's main timber supplier, although northern Europe still provided timber of a more specialist nature.

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 been investigating the viability of analysing conifers used in historic contexts (Groves

1997; Groves 2000b; Groves 2000c; Groves 2002). The primary aim of this is to extend the scope of British dendrochronology to incorporate structures built of coniferous 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 dates of construction and demolition of the Compter, combined with the large number of available timbers meant, that this project provided an excellent opportunity to further the English Heritage research programme on the dendrochronological analysis of conifers.

The analysis was undertaken with the following aims:
1. to determine the wood type and, where possible, the actual species
2. to provide dates for timbers and if possible additional dating evidence for the construction of the Compter
3. to determine the geographical source of the timbers and identify any variation in source through time

These aims would be considered fairly routine if the wood was oak, but it was accepted that they were more ambitious when dealing with an historic conifer assemblage in England.

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 the Giltspur Street Compter.

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 as their ring patterns may not be unique. Thus timbers were sought which had at least 50 rings and if possible had bark/bark edge surviving. The selected timbers were sampled by the removal of cross-sectional slices.

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 of each sample was determined through reference material in the form of permanent slides, an identification key (Schweingruber 1990), and a computer database (Wheeler *et al* 1986). 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 1999). 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 (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, 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. Species such as pine consist of inner inert heartwood and an outer band of active sapwood. 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 (Zetterberg and Hiekkanen 1990). For instance the number of sapwood rings in northern Sweden tends to be over 100, where as in the south (ie south of Stockholm) it is generally circa 50±30 (Eggertson pers comm). Consequently, if the timbers originate from an area where a sapwood estimate does exist, then this can be used to interpret the final ring dates. If the sample ends within 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 that may be missing. While this is the date after which the timber was felled, the actual felling date may be many decades later depending on the number of outer rings removed during timber conversion. Where some of the outer sapwood or the heartwood/sapwood boundary survives on the sample, a felling date range can be calculated using the maximum and minimum number of sapwood rings likely to have been present. If the 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 medieval 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; Groves forthcoming (b); Simpson pers comm). Clarification of this aspect may well rely on the analysis of very well documented buildings, such as the Giltspur Street Compter, which should therefore have the potential to play an important role in the conifer research project.

Results

All conifer timbers were examined and recorded by Bruce Watson and those that were clearly unsuitable (ie too few rings) were not sampled. Forty-nine timbers, just under 50% of the total conifer assemblage, were sampled by the removal of cross-sectional slices. All of the timbers sampled were associated with the primary construction of the Compter. Further, microscopic identification indicated that all samples were of a single wood type (genus *Pinus*), which contains the following species options: *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). Due to these subtle variations it was not microscopically possible to determine the wood type down to species level. However, successful determination of the geographical source of the timber would have made it possible to narrow the species options down further.

Details of the samples are provided in Table 1. Seven samples were rejected as unsuitable for analysis as they contained insufficient numbers of rings. The ring sequences of the remaining 42 samples were compared with each other. Twenty-four samples formed seven groups of matching ring sequences, some of which included possible same-tree pairs or groups (Tables 2-8). Each group of matched samples was combined to produce a site master chronology, KEW98/1-KEW98/7 (Tables 9-15).

The site master chronologies and all unmatched individual ring sequences were compared but no additional conclusive crossmatching was established.

Since the timbers were likely to date to the mid to late-eighteenth century, it was anticipated that they were probably imported from ports on the Baltic or White seas or possibly Scandinavia rather than North America. The seven site master chronologies were therefore tested against an extensive range of European reference chronologies for pine. These span the last millennium and range from Russia to Spain on an east-west axis and Norway to Greece on a north-south axis. However no consistent conclusive results were obtained. Consequently the site master chronologies were also compared with reference chronologies from Canada and the north-eastern United States of America, but again no consistent conclusive results were obtained. All unmatched individual samples were then compared with the same extensive set of European and North American reference chronologies, but to no avail. The data from the seven master chronologies was sent to various colleagues for further comparisons to be made 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 precise calendar dates for any of the timbers.

Discussion

The crossmatched ring sequences are derived from planks, quartered, and halved timbers. Possible 'same-tree' groups were identified within these three conversion types but no 'same tree' groups were identified between the different conversion types. However crossmatching has been identified between timbers from the different layers of the foundation lattice and wall foundations.

The failure to produce reliable dendrochronological dates for any of the timbers associated with the Giltspur Street Compter is clearly disappointing, particularly in the light of the recent successes with various conifer assemblages (Groves 2000c; Groves 2002; Groves forthcoming (b); Groves forthcoming (c)). One of the immediate 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 Giltspur Street Compter assemblage.

In addition to the possible use of multiple diverse sources, the intra-site crossmatching may also have been adversely affected by a combination of a number of other factors. Potentially, reuse of material could result in timbers being obtained from multiple sources, though there is no evidence that these timbers have been reused. Erratic growth patterns where the ring widths change suddenly, either becoming very narrow or very wide, will reduce the dating potential. Conifers, in particular, are subject to 'missing rings' where a tree either lays down a partial ring or fails to grow at all, false/shadow rings, and rings that wedge out (Schweingruber 1988, 47), all of which reduce the chances of successful crossmatching. Whilst the measured ring sequences and samples have been systematically checked for these potential measurement difficulties, it remains a possibility that at least some of the sequences could have unrecognised problems. However the extensive sampling programmes employed at other single-phase sites have certainly assisted in the identification of missing or false/shadow rings in problematic samples. Poor intra-site crossmatching can also result from the use of a mixture of primary and reused material. However in this instance there was no physical evidence that would indicate the presence of reused timbers.

Conclusion

The analysis of the timber assemblage associated with the foundations of the Giltspur Street Compter has unfortunately provided no absolute dating evidence. The dating quality of the material is likely to have been adversely affected by unrecognised or unresolved problems with missing/false rings, the occurrence of bands of incredibly narrow rings, and also the potential use of timber from multiple sources. The ring sequences will remain in the database and will be retested as the conifer research project progresses. Whilst unsuccessful in achieving absolute dates, the analysis has, however, provided useful information for the conifer research project concerning potential difficulties that may be encountered with future sites.

Acknowledgements

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Figure 1: General location of Giltspur Street Compter

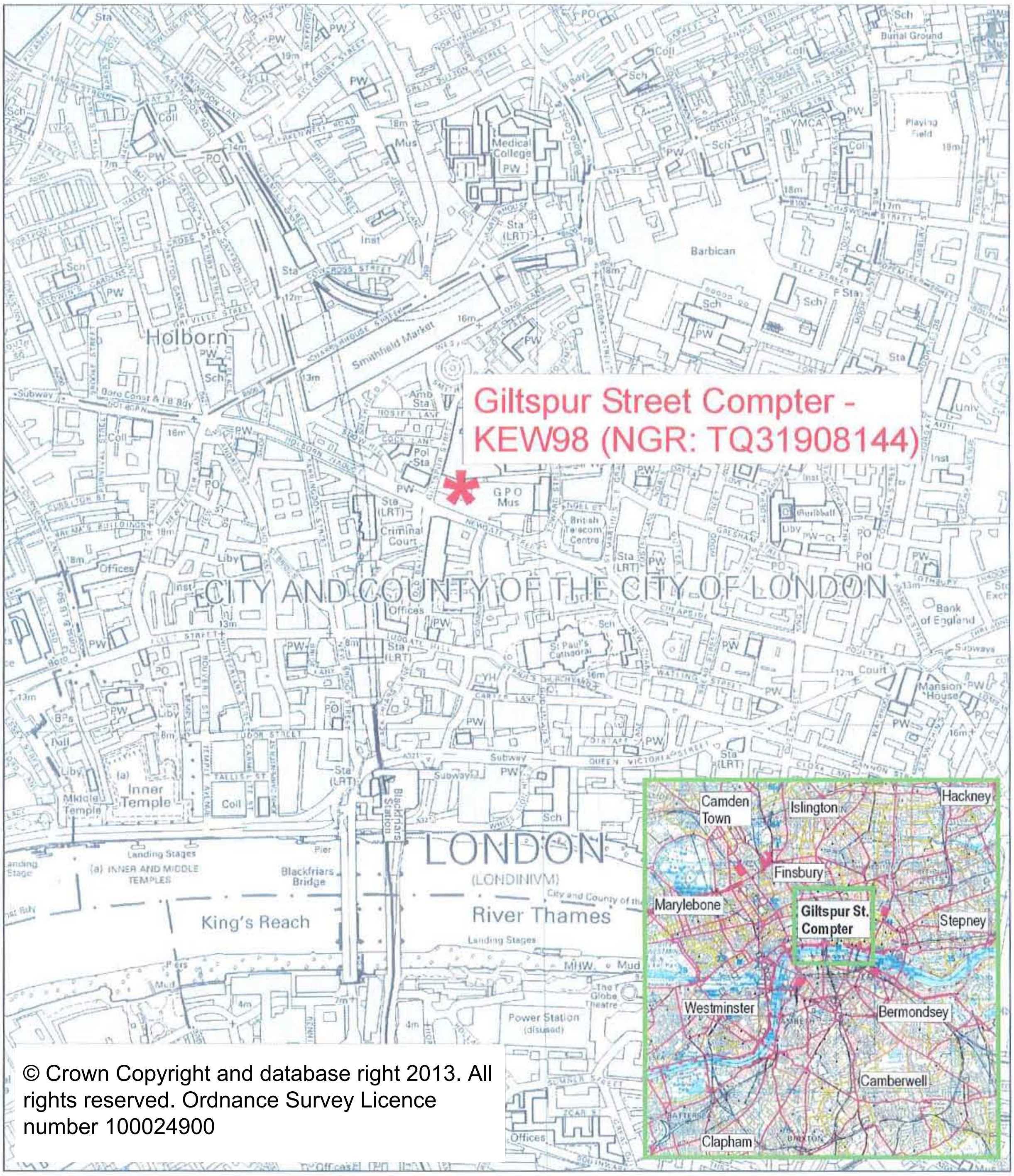

Figure 2: Location of Giltspur Street Compter

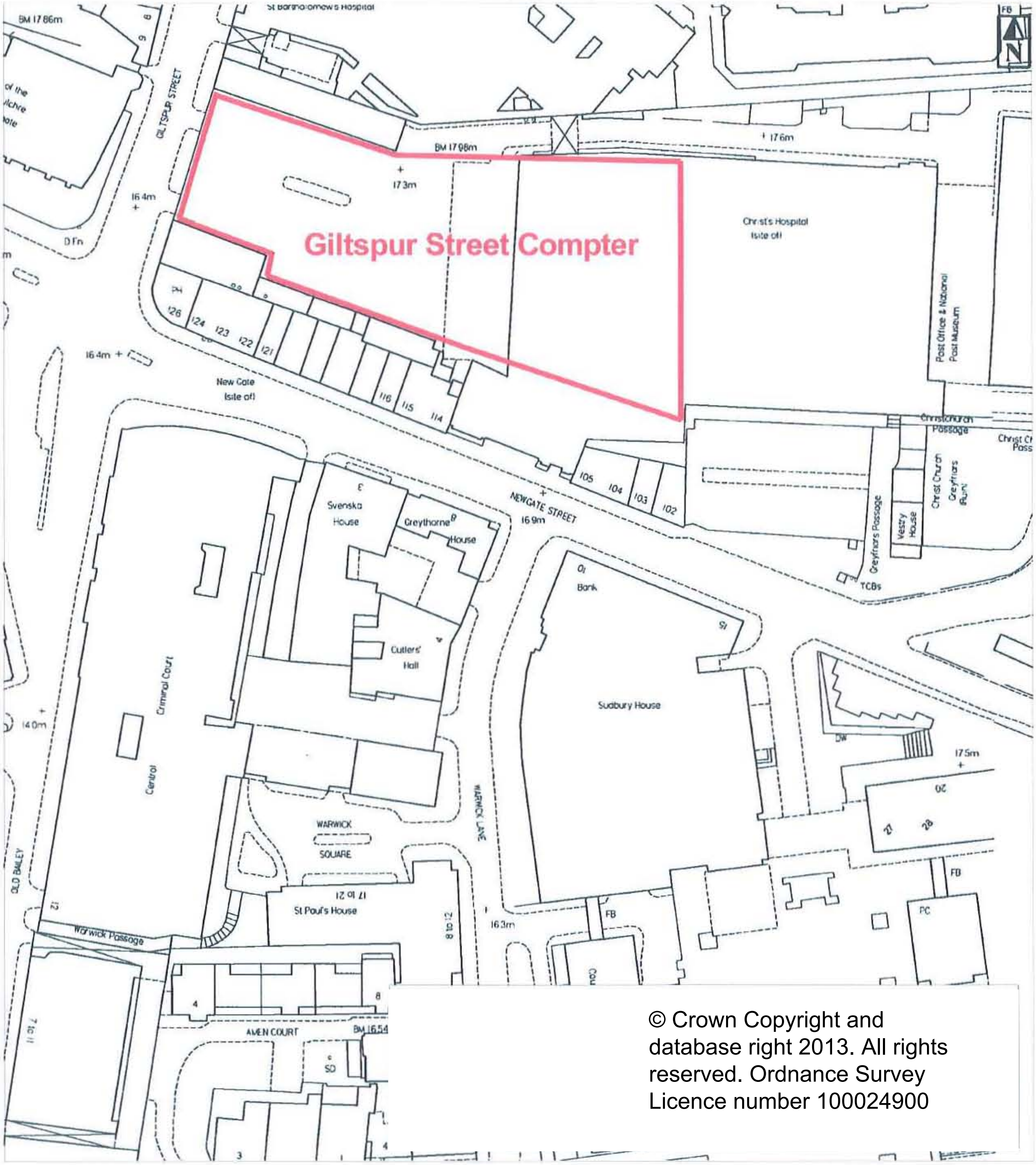

Table 1: Details of the samples from the Giltspur Street Compter. All samples are *Pinus* sp.

Rings - total number of measured rings
ARW - average ring width in millimetres
Cross-section type - guide to conversion type
Dimensions – maximum dimensions of the cross-section in millimetres

Sample	Rings	ARW	Cross-section type	Dimensions	Comment
878	64	2.07	plank: tangential	330 x 65	component of KEW98/4
887	254	0.81	quartered	170 x 140	component of KEW98/7
888	222	0.70	quartered	165 x 130	
889	90	1.60	plank: tangential	380 x 60	component of KEW98/7
890	94	1.56	plank: tangential	350 x 65	component of KEW98/7
942	72	2.17	plank: tangential	330 x 60	
945	53	3.39	plank: tangential	330 x 65	component of KEW98/3
948	126	1.29	halved	155 x 135	component of KEW98/7
949	86	1.78	halved	145 x 140	component of KEW98/7
966	<50	-	halved	150 x 145	rejected
967	104	1.43	quartered	150 x 145	
968	84	1.39	plank: tangential	355 x 60	
970	62	2.87	plank: tangential	335 x 65	component of KEW98/3
981	100	1.94	quartered	160 x 155	component of KEW98/5
982	96	1.83	quartered	155 x 155	component of KEW98/5
983	104	1.90	quartered	155 x 150	component of KEW98/5
1385	91	1.84	plank: tangential	335 x 60	
1386	57	2.43	plank: tangential	320 x 65	component of KEW98/4
1387	108	1.45	plank: tangential	320 x 65	component of KEW98/4
1395	81	2.14	quartered	155 x 145	
1396	50	3.20	halved	155 x 140	
1397	72	1.70	plank: tangential	315 x 65	

Table 1: (continued)

Sample	Rings	ARW	Cross-section type	Dimensions	Comment
1399	79	1.17	plank: tangential	305 x 55	
1417	87	2.12	quartered	155 x 145	
1418	117	1.18	quartered	165 x 130	
1419	111	1.33	quartered	165 x 125	
2099	60	2.68	plank: tangential	315 x 65	
3079/1	<50	-	plank: tangential	160 x 20	rejected
3079/2	117	1.17	plank: radial	140 x 30	
3079/3	125	1.33	plank: radial	170 x 35	
3079/4	89	1.40	plank: radial	140 x 30	
3655	130	1.09	plank: tangential	345 x 60	component of KEW98/2
3657	116	1.61	plank: tangential	365 x 55	component of KEW98/6
3658	83	1.57	plank: tangential	345 x 50	component of KEW98/6
3659	119	1.46	plank: tangential	350 x 60	component of KEW98/6
3660	123	1.57	plank: tangential	350 x 65	component of KEW98/6
3661	<50		plank: tangential	350 x 50	rejected
3662	101	3.03	plank: tangential	320 x 55	component of KEW98/1
3665	64	2.95	plank: tangential	330 x 60	component of KEW98/3
3701	<50	-	plank: tangential	320 x 60	rejected
3710	59	3.51	plank: tangential	320 x 60	component of KEW98/1
3718	<50	-	quartered	145 x 145	rejected
3719	<50	-	quartered	150 x 150	rejected
3720	<50	-	quartered	155 x 150	rejected
3721	84	2.00	quartered	145 x 140	
3722	240	0.87	quartered	170 x 165	component of KEW98/2
3723	228	0.91	quartered	165 x 145	component of KEW98/2
3724	169	1.19	quartered	155 x 140	
3725	98	1.83	quartered	160 x 155	component of KEW98/5

Table 2: Matrix showing the *t*-values obtained between the matching ring sequences included in KEW98/1

	3710
3662	6.61

Table 3: Matrix showing the *t*-values obtained between the matching ring sequences included in KEW98/2; *t*-values over 10, suggesting possible 'same tree' groups, are highlighted

	3722	**3723**
3655	6.18	5.83
3722		***23.29***

Table 4: Matrix showing the *t*-values obtained between the matching ring sequences included in KEW98/3; *t*-values over 10, suggesting possible 'same tree' groups, are highlighted

	970	**3665**
945	***13.86***	***11.41***
970		***15.91***

Table 5: Matrix showing the *t*-values obtained between the matching ring sequences included in KEW98/4

	1386	**1387**
878	5.44	4.95
1386		8.82

Table 6: Matrix showing the *t*-values obtained between the matching ring sequences included in KEW98/5; *t*-values over 10, suggesting possible 'same tree' groups, are highlighted

	982	**983**	**3725**
981	7.67	***14.37***	8.30
982		8.19	8.19
983			***11.22***

Table 7: Matrix showing the *t*-values obtained between the matching ring sequences included in KEW98/6; *t*-values over 10, suggesting possible 'same tree' groups, are highlighted

	3658	**3659**	**3660**
3657	5.70	9.14	6.92
3658		3.70	5.76
3659			***10.25***

Table 8: Matrix showing the *t*-values obtained between the matching ring sequences included in KEW98/7; *t*-values over 10, suggesting possible 'same tree' groups, are highlighted

	889	**890**	**948**	**949**
887	4.82	5.86	4.25	5.50
889		6.00	5.10	7.09
890			6.18	5.83
948				***12.18***

Table 9: The ring width data from the undated site master chronology, KEW98/1

Ring widths (units of 0.01mm)									
703	274	556	715	724	729	825	908	658	544
614	604	415	554	528	801	578	651	611	589
719	706	523	600	356	411	441	300	375	357
292	418	391	347	271	173	180	234	281	306
148	175	204	268	300	270	246	237	201	240
259	199	220	210	182	187	167	238	205	191
230	192	152	164	198	232	209	194	193	204
233	210	73	34	46	58	53	85	89	119
83	124	121	139	176	216	302	322	269	357
351	326	217	237	232	241	201	215	171	277
330									

Table 10: The ring width data from the undated site master chronology, KEW98/2

Ring widths (units of 0.01mm)

268	387	291	311	95	202	199	136	174	203
203	190	226	252	144	183	260	216	231	221
194	236	105	253	314	289	204	166	140	127
199	286	205	60	78	108	145	179	149	129
156	162	135	110	79	52	63	80	120	194
161	138	93	105	52	40	57	86	98	128
91	87	65	65	58	36	33	43	84	112
103	100	133	133	121	127	126	147	126	82
75	57	73	83	62	64	46	42	46	94
81	55	56	77	99	103	105	109	87	87
95	114	124	96	105	84	85	103	63	70
83	75	60	74	68	103	78	64	54	93
95	94	77	98	87	79	78	83	78	102
97	99	123	117	96	93	57	77	83	97
100	138	117	161	157	104	103	84	130	92
71	67	92	108	94	81	81	91	99	94
79	80	84	85	84	96	95	119	106	132
91	107	104	119	111	122	109	99	89	95
69	62	68	69	62	67	66	62	65	83
121	107	61	67	71	78	67	62	64	54
60	59	58	49	41	32	31	49	45	41
52	52	60	61	52	42	53	66	57	45
66	70	73	54	36	37	43	52	46	43
38	33	46	48	33	31	41	47	43	64
57	67								

Table 11: The ring width data from the undated site master chronology, KEW98/3

Ring widths (units of 0.01mm)

537	402	368	395	346	382	367	390	231	268
258	283	303	256	307	395	450	408	319	355
396	48	76	172	221	227	255	262	278	331
355	371	463	367	440	431	444	405	364	359
356	329	321	348	339	338	257	284	384	349
316	216	194	192	225	221	284	254	324	204
156	167	168	140	139	188	235			

Table 12: The ring width data from the undated site master chronology, KEW98/4

Ring widths (units of 0.01mm)

539	690	326	329	300	419	360	345	476	308
307	267	241	356	337	398	379	304	370	239
229	412	367	295	247	279	311	241	247	196
159	270	203	193	175	220	225	183	187	216
224	238	194	127	182	237	160	146	116	229
217	156	160	139	160	138	80	115	148	108
96	79	110	173	198	159	128	114	137	192
171	134	138	144	212	153	126	143	104	65
64	34	57	49	39	31	37	42	47	65
69	70	64	42	38	56	66	66	68	68
49	50	36	31	22	28	27	32	37	37
43	57	50	37	41	41	57	59	71	54
56	40	31							

Table 13: The ring width data from the undated site master chronology, KEW98/5

Ring widths (units of 0.01mm)

231	490	446	429	620	542	537	419	423	416
437	617	666	520	531	468	497	427	407	407
482	362	406	362	323	286	222	254	305	258
217	263	298	295	221	129	148	121	108	82
77	88	100	120	115	101	133	137	133	130
146	109	107	156	164	151	85	46	116	102
79	78	80	94	97	109	109	71	29	36
49	55	64	114	125	101	100	129	120	129
63	79	85	142	124	148	115	97	123	87
83	89	102	112	109	112	102	72	74	74
54	74	88	97	98	95	83			

Table 14: The ring width data from the undated site master chronology, KEW98/6

Ring widths (units of 0.01mm)

257	161	165	134	65	62	59	153	130	172
142	124	100	71	88	95	69	33	32	16
34	76	104	113	126	115	105	129	108	120
138	104	151	169	130	126	103	159	155	189
224	210	212	240	201	221	196	176	158	153
162	120	103	127	125	142	164	182	132	105
81	67	52	66	84	78	66	62	80	88
85	104	87	125	120	103	98	151	226	258
156	192	195	197	226	221	263	233	169	140
171	214	209	156	145	203	209	190	196	176
207	246	207	154	186	200	199	188	187	225
246	212	173	131	122	167	163	139	174	175
184	153	155	123	95	103	161	207	166	122
124	147	187	135	132	105	157	121	120	95
145	182	162	131	122	162	166	187	169	196
201	176	165	154	176	196	248	160	167	201
277	217	272	168						

Table 15: The ring width data from the undated site master chronology, KEW98/7

Ring widths (units of 0.01mm)

229	241	247	269	217	247	215	208	211	200
117	136	119	168	208	172	197	197	162	171
123	143	163	151	167	115	100	100	104	95
125	88	99	86	81	80	85	114	118	144
129	128	109	111	100	77	94	122	125	128
127	119	114	92	76	103	100	97	70	48
43	48	82	53	53	75	97	94	134	151
144	88	117	129	120	118	113	116	113	110
98	149	150	140	118	89	141	137	70	55
51	77	42	33	61	58	91	78	64	87
98	120	119	118	117	92	90	93	109	71
71	110	131	135	113	139	103	59	64	68
113	133	149	154	116	104	82	117	99	79
57	60	91	91	83	96	101	89	72	54
24	33	43	22	19	30	42	54	33	33
36	29	47	53	52	75	60	69	40	30
243	338	337	283	272	255	266	247	252	285
243	273	237	259	276	211	208	213	210	185
198	203	146	102	139	133	154	127	158	130
128	116	138	142	149	115	91	98	99	112
121	116	147	180	173	142	153	140	102	105
91	63	79	89	85	75	96	94	115	116
83	89	89	117	116	96	104	108	98	87
84	96	99	81	100	105	83	79	64	94
88	92	105	108	98	81	69	65	60	61
60	58	65	78	113	110	72	85	69	87
111	118	135	82	41	35	32	38	42	33
37	23	42	49	24	26	28	37	43	42
46	44	32	29	31	43	42	43	47	35
52	60								