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Summary

Excavations at Shinewater Park and Willingdon Drove, Eastbourne, revealed timber structures of late Bronze Age date. Tree-ring analysis of 46 timbers resulted in the production of a 75-year tree-ring chronology. Although the chronology remains undated at present, the precise relative dating provides valuable information about the construction of these timber trackways and platforms.

Keywords

Dendrochronology

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TREE-RING ANALYSIS OF OAK TIMBERS FROM SHINEWATER PARK AND WILLINGDON DROVE, EASTBOURNE, EAST SUSSEX

INTRODUCTION

This document is a technical archive report on the tree-ring analysis of oak timbers from Shinewater Park and Willingdon Drove, Eastbourne (NGR TQ56161030). It is beyond the dendrochronological brief to describe the sites in detail or to undertake the production of detailed drawings. As part of a multifaceted and multidisciplinary study of the site, elements of this report may be combined with detailed descriptions, drawings, and other technical reports at some point in the future to form either a comprehensive publication or an archive deposition. The conclusions presented here may therefore have to be modified in the light of subsequent work. The final production of this report has been delayed due to the ill health and subsequent retirement of the author.

The site was discovered in AD 1995 during the construction of a large lake at Shinewater Park, near Eastbourne (Fig 1). The area is a low-lying coastal bay with a waterlogged peat horizon sandwiched between layers of clay. The waterlogging had allowed the preservation of large quantities of timbers which were revealed by the machinery used to clear the area. The timbers consisted of post alignments, including possible trackways, and timber platforms. Artefactual remains included human skeletal fragments, axes, and pottery. On the basis of these finds, a late Bronze Age date was suggested by South Eastern Archaeological Services, who undertook the recording of the site. Following the discovery of the Shinewater timbers and artefacts (SPE95), a watching brief was extended to all the area covered by the development. This led to further timbers being excavated at Willingdon Drove (WDE96); these appeared to be part of a trackway leading towards Shinewater Area D, which may have been a continuation of the same trackway.

Sheffield Dendrochronology Laboratory were asked to advise on the dendrochronological potential of the timbers. A visit to the Shinewater site by Ian Tyers in September AD 1995 revealed that the uprights and horizontals were almost exclusively oak (*Quercus* spp.) and that they had been cut from young trees aged from under 10 to about 60 years. Such timbers are not well suited to dendrochronology because dating is usually reliant on ring sequences containing at least 50 rings (see below). However, dendrochronological analysis was recommended for several reasons:

- Prehistoric timbers of any date are relatively scarce in England and Wales. For this reason a research project, funded by English Heritage, is underway at Sheffield to construct a prehistoric tree-ring chronology with a special emphasis on timbers from the southern part of the country. The data from Eastbourne could potentially add to this project.
- The timbers were unworked for most of their length and therefore retained bark or bark edge. If some of the ring sequences could be crossmatched, this would result in precise relative dating. This

had proved successful for timbers from the Iron Age causeway at Fiskerton, near Lincoln, where precise dates had been produced for timbers with about 30-100 rings (Hillam 1992).

- If several phases of timber were present, it might be possible to extend the site chronology longer than about 60 years, the maximum age of the oak trees used; absolute dating might then become possible.
- It might also be possible to extract information of a non-chronological nature from the tree-rings, such as construction techniques, type of woodland exploited, and evidence of management.

On this basis, 16 samples were cut from the timbers at Shinewater and 30 from those at Willingdon (Table 1). The Shinewater samples came from the four exposures of timbers revealed by the machinery (Fig 1). Area A contains a cluster of unorientated vertical posts. Like all the vertical timbers, the tops had been damaged by machinery and the bottoms were buried in the basal clay beyond the limit of the excavation. The exact length of timbers could not be ascertained but at least one was over 1.4m. Six timbers from Area A were sampled for dendrochronology. Three samples were taken from Area B, the area with skeletal remains. 1265 (SPE 12) was a vertical post, over 1m long, which had been driven through the occupation layer. 1272 (SPE 15) was a horizontal found on top of the peat and below the occupation layer. 1311 (SPE 16) was similar but was found in the slump rather than the section. The two sampled timbers from Area C were part of a post alignment which was aligned north-east to south-west, whilst the five from Area D were from another line of posts, similarly aligned (Fig 1). Minimum lengths of posts sampled for dendrochronology were over 0.9m and over 2.61m in Areas C and D respectively. A sketch plan showing the location of the sampled timbers was unavailable at the time of the initial production of this report.

The Willingdon Drove trackway was found within the top 50mm of the peat close to the Shinewater Area D alignment. It was made up of three parallel rows of vertical posts aligned roughly east-west. It was excavated as three trenches, each about 20m long by 8m wide. The location of the timbers sampled for dendrochronological analysis is given in Figure 2.

Apart from the two horizontals from Shinewater Area B, all the dendrochronology samples were from vertical posts. With two exceptions at Willingdon, there was no archaeological evidence to determine how many phases of timbers were present. The exceptions were 1063 and 1071 (WDE 29, WDE 30) from Trench A and 1033 and 1034 (WDE 15, WDE 16) from Trench B. 1063 (WDE 29) was immediately north of 1071 (WDE 30) suggesting that one of them was a repair. Similarly, 1033 (WDE 15) and 1034 (WDE 16) were side by side, perhaps indicating that one or the other was a repair.

METHODS

The samples were frozen for at least 48 hours to harden the wood; they were then cleaned with a Surform plane which highlights the boundaries of the annual growth rings. If the cross-sections were still not clear, an edge was pared with a Stanley knife. Samples unsuitable for dating purposes were rejected at this stage. These included non-oak samples, samples with unmeasurable ring patterns due to knots or narrow rings, and those with less than about 25 rings. Normally samples with less than 50 rings are rejected because their ring patterns may not be unique (Hillam *et al* 1987). However, analysis of Iron Age timbers from Fiskerton in Lincolnshire (Hillam 1985 and 1992) had showed that samples with about 30-50 rings can sometimes be dated reliably, provided that there is unequivocal stratigraphical evidence indicating contemporaneity and that the sampled assemblage is sufficiently large. In view of the scarcity of prehistoric tree-ring data from southern England, it was also felt that the maximum amount of data should be collected from the site and therefore analysis was extended to those samples with 25-50 rings.

Where possible, the ring widths were measured across at least two radii per sample, and the two sets of measurements then averaged to produce a single sequence. This is standard procedure with such short-lived roundwood in order to maximise the potential of the data. This was not possible with most of the Willingdon timbers which were not as well preserved as those at Shinewater. The ring widths were measured to an accuracy of 0.01mm on a travelling stage connected to a microcomputer which uses a suite of dendrochronology programs written by Ian Tyers (1997). The ring width data were plotted as graphs. Crossmatching was carried out first visually by comparing the graphs on a light box, and then using a computer program to measure the amount of correlation between two ring sequences. The program uses crossmatching routines which are based on the Belfast CROS program (Baillie and Pilcher 1973; Munro 1984). This calculates the correlation coefficient r for each position of overlap between two ring sequences, and then tests the significance of the results using Student's t test. Generally t-values of 3.5 or above indicate a match provided that the visual match between the tree-ring graphs is acceptable (Baillie 1982, 82-5). t-values over c 10 usually indicate an origin in the same tree, although t-values less than 10 may be produced when different radii are measured on the same trunk. This is particularly true for young trees. Visual matching can sometimes aid the decision as to whether timbers come from the same tree but inevitably some same tree samples will go undetected by dendrochronology.

The data from matching ring sequences are averaged to produce a structure or site master curve. Unmatched sequences are then compared to the master. Matching is accepted if the sequence to be dated matches visually and statistically with the working master and with the individual components of that master. The data from the newly matched sequences are then incorporated into the master and the process repeated until no more samples can be crossmatched. The site master is tested for similarity against dated reference chronologies. Master curves are used for dating whenever possible because they enhance the general climatic signal at the expense of the background noise from the growth

characteristics of the individual samples. Any unmatched sequences are tested individually against the reference chronologies.

Once tree-ring dates have been obtained, calendar dates can be assigned to each of the annual rings within the sample, but the date of the outer ring is not necessarily equivalent to the year of felling. If a sample has bark or bark edge, the date of the last measured ring is the date in which the tree was felled. A complete outer ring indicates that the tree was felled during its period of dormancy between autumn and early spring (referred to as "winter felled"). A partially formed ring indicates that the tree died in late spring or summer (known as "summer felled") or, if the springwood is just beginning to form, in spring (Baillie 1982, fig 2.1; Varley and Gradwell 1962). Partially formed rings are not measured so, for spring- and summer-felled trees, there will be a one-year discrepancy between the date of the measured ring sequence and the felling date. It is not always possible to distinguish between an incomplete ring and a complete narrow ring and therefore the season of felling is sometimes indistinguishable. The outer edge of a sample may also be damaged because of the delicate nature of sapwood and, whilst it is known that bark edge was originally present, a few outer rings may have been lost or be so compressed as to be unmeasurable. In cases such as these, the felling dates are precise to within a few years. Where bark edge is absent, felling dates are calculated using the sapwood estimate of 10-46 rings. This is the range of the 95% confidence limits for the number of sapwood rings in British oak trees over 30 years old (Tyers 1998). Where sapwood is absent, felling dates are given as *termini post quem* (*tpq*) by adding 10 years, the estimated minimum number of missing sapwood rings, to the date of the last measured heartwood ring. This is the earliest possible felling date but the actual felling date could be much later depending on how many heartwood rings have been removed during conversion of the trunk into its component timbers.

The estimation of felling date ranges gives some indication of when a tree was felled. This information must then be related to the date that the timber was used. At this stage, factors such as seasoning, reuse, and/or stockpiling have to be considered. Seasoning is unlikely to have had an impact at the Eastbourne sites since timber was usually felled and used green until relatively recently (eg Hollstein 1980). However, the reuse of timber has been a common practice since prehistoric times and stockpiling may also occur. Therefore, although the production of tree-ring dates is an independent process, the interpretation of these dates can sometimes be improved by drawing on other archaeological evidence such as that provided by wood technology or stratigraphy.

The above gives a brief introduction to dendrochronological methodology. Further information about the history, principles, and methodology of dendrochronology can be found in Baillie (1982) and English Heritage (1998).

RESULTS

All the samples except 1210 (SPE 7) were oak. The Shinewater samples contained 24-55 rings whilst those from Willingdon had 23-62 rings (Table 1). Five samples were rejected: SPE7 because it was not oak; 1001 (WDE 3), 1030 (WDE 14), and 1061 (WDE 25) because their rings were unmeasurable, and 1026 (WDE19) because it had insufficient rings. Thirteen of the Shinewater ring sequences crossmatched to produce a 56-year master curve (Fig 3 and Table 2a). Eighteen Willingdon ring sequences crossmatched to produce a 66-year master (Table 2b). There was also crossmatching between the Shinewater and Willingdon sequences (Table 2c). The data from the two masters were therefore averaged to give a combined Shinewater/Willingdon master of 75 years (Table 3). The master was tested against all available reference chronologies for the period 6000 BC to the present but no consistent results were obtained, thus the chronology remains undated.

The shortness of the ring sequences made it difficult to determine if any of the timbers were from the same tree. None of the *t*-values between ring sequences from different timbers were over 10, the value over which samples are usually assumed to be from the same tree (see above). Instead, some of the comparisons between the measurements from the same tree resulted in *t*-values less than 10 (Table 4), and therefore the value of 10 does not appear applicable for Shinewater and Willingdon.

RELATIVE DATING

Willingdon

The earliest relative felling date from the two sites is at Willingdon (Fig 3). Timber 1023 (WDE17) ends in relative year 58. The last ring, which was complete, was thought to be possibly bark edge but severe distortion of the sapwood prevented a positive identification of bark edge. This timber is therefore recorded as possibly being felled in the winter of relative year 58/9. This is about seven years earlier than any of the other Willingdon timbers. Possible interpretations are that it is part of an earlier structure or that it was old timber. However, it is also possible that the outer ring was not bark edge and that some rings were missing; the actual felling date may therefore be a few years later.

Bark edge was not present on 1004 (WDE 1), which has a relative felling date range of 61-85. 1008 (WDE 10) was complete, but the outer few rings were impossible to measure accurately due to crushing of the sapwood; so it has a relative felling date range of *c* 63-66. The remainder of the crossdated samples were felled in relative year 65 or 66. Most were felled after growth had stopped in the autumn/winter of relative year 65/66, but three from trench C were felled before growth was completed for the relative year 65. The difference between the timbers felled in summer relative year 65 and those felled in winter relative year 65/66 might be only a matter of a few weeks (Baillie 1982; Varley and Gradwell 1962). Since there is no apparent structural difference between the timbers felled in summer

and winter (Fig 3), it seems likely that the trackway was constructed using timber felled at slightly different times and that it was built some time in the winter of year relative year 65/66.

Timbers 1034 (WDE 29) and 1063 (WDE 16), which are found next to 1033 (WDE 15) and 1071 (WDE 30) respectively, remain undated. It is therefore not possible to determine when they were added to the trackway, and whether or not they are repairs.

Shinewater

At Shinewater, the tree-ring samples are fewer and are spread over a greater area than Willingdon. The results therefore are less conclusive. The Area D posts are in a similar alignment to, and could be part of, the Willingdon trackway. The fact that one of the Area D timbers, 1247 (SPE 3), was felled in winter of relative year 65/66 supports, but does not prove, this hypothesis. Other timbers from the Area D alignment were felled in winter relative year 68/69 and summer relative year 75 (Fig 3).

Also felled in relative year 65/66 is horizontal timber 1311 (SPE 16), the only timber to be crossdated from Area B. The two dated Area C timbers, 1309 and 1310 (SPE 13, SPE 14) were felled in the spring of relative year 66, probably about April or May, just before leaf burst. The crossdated timbers from the Area A platform were all felled at different times, the first in winter of relative year 66/67 and the last in relative year 72/73, also probably winter (Fig 3).

DISCUSSION

Building activity at Willingdon seems to have been restricted to one or two years with the exception of 1023 (WDE 17), but there is evidence of construction and repair over at least 10 years at Shinewater. The earliest timbers were those from the south-west end of the Willingdon excavation, which were felled in the summer of relative year 65. Although these could have been stockpiled until the winter of relative year 65/66 when the remainder were felled, it may indicate that construction began at the south-west end of the trackway. The tree-ring results also tend to indicate that the trackway was constructed before work commenced on the platform areas at Shinewater.

The oak timbers are likely to have been obtained from nearby dry land. The trees were probably all under 70 years old when felled. It is impossible to be exact about age at felling because the number of rings decreases up the tree trunk, and the position of the tree-ring sample in relation to the trunk is unknown. Relatively good crossmatching between all the ring sequences suggests that the same area of woodland was exploited for all the oak timbers. There is evidence that trees were felled in spring, summer, and autumn/winter which suggests there was human activity in the area throughout the year.

Lack of absolute dating is disappointing but not surprising. The combined Shinewater/Willingdon master curve with only 75 rings is short and at the moment there are relatively few tree-ring chronologies covering the late Bronze Age/Iron Age periods (Hillam 1992) in the relevant region. However, as more prehistoric chronologies are produced, in the future it may be possible to obtain absolute dates for the sites.

CONCLUSION

The analysis resulted in the production of a 75-year tree-ring chronology. Although it has not yet been possible to assign calendar dates to this chronology, the relative dating is precise because of the presence of bark edge on many of the samples. Most of the Willingdon trackway timbers were felled in relative year 65 or 66. Timbers of this date were also found in Areas B and D at Shinewater. Other Shinewater timbers were felled at various times between relative year 66 and summer of relative year 75. Young oak trees, probably from a single area of woodland, were felled for construction at various times of the year.

ACKNOWLEDGEMENTS

Analysis of the Eastbourne timbers was undertaken as part of an English Heritage-funded research project to construct a prehistoric tree-ring chronology. I am also grateful to Chris Greaterex and his team for information about the site, and to Ian Tyers for carrying out an advisory and assessment visit to the site. Mike Baillie and Dave Brown provided unpublished tree-ring chronologies; further data were made available through the EU Environmental Research Programme, contracts EV5V-CT94-0500 and ENV5-CT95-0127.

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Figure 1: Location of Shinewater Park and Willingdon Drove, adapted from a drawing by South Eastern Archaeological Services

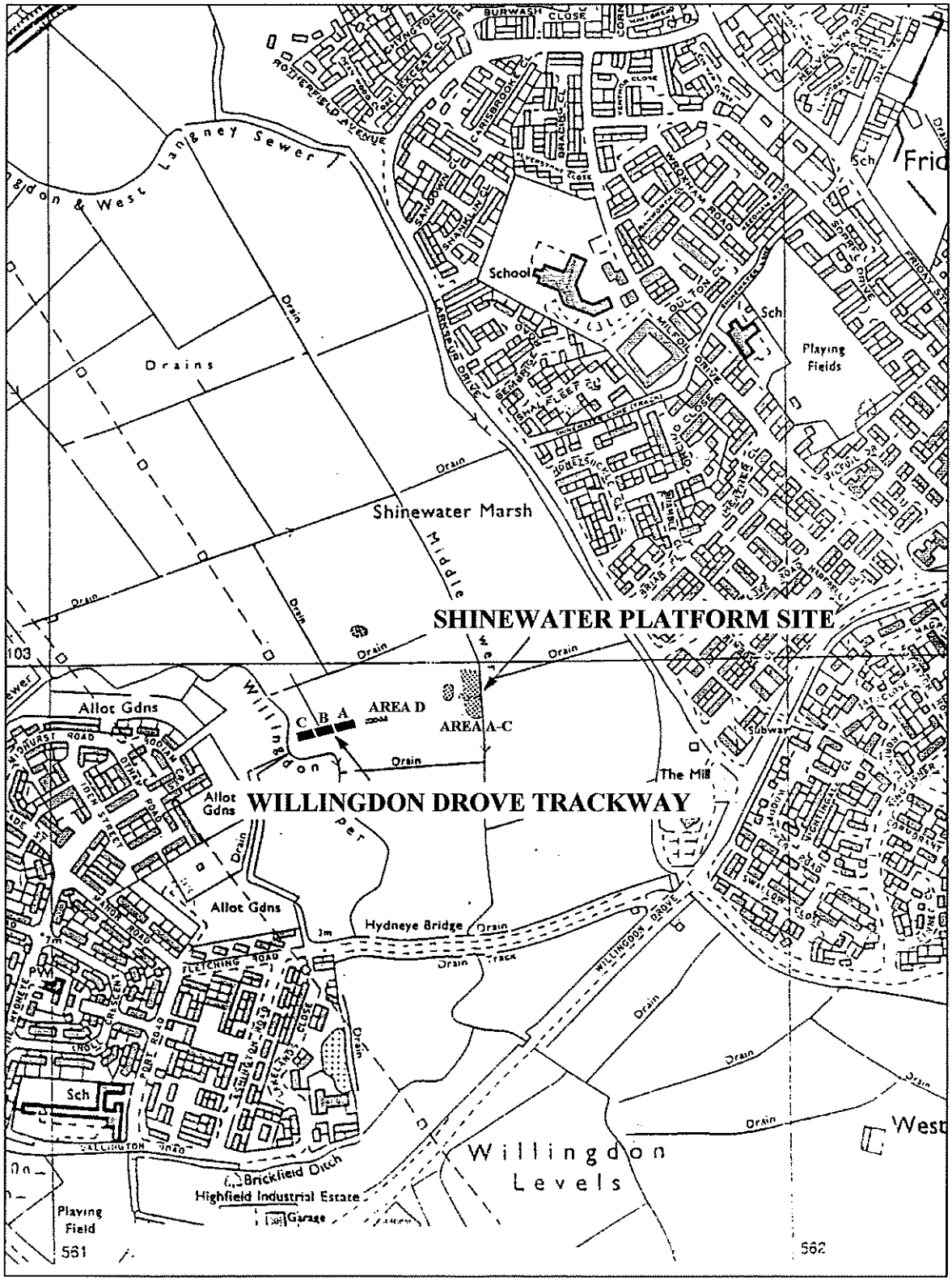

Figure 2: Sketch plan of the three trenches at Willingdon Drove showing the location of the tree-ring samples (after a drawing provided by South Eastern Archaeological Services). Sample numbers in square boxes indicate timbers felled in relative year 65/66; those underlined were felled in the summer of relative year 65

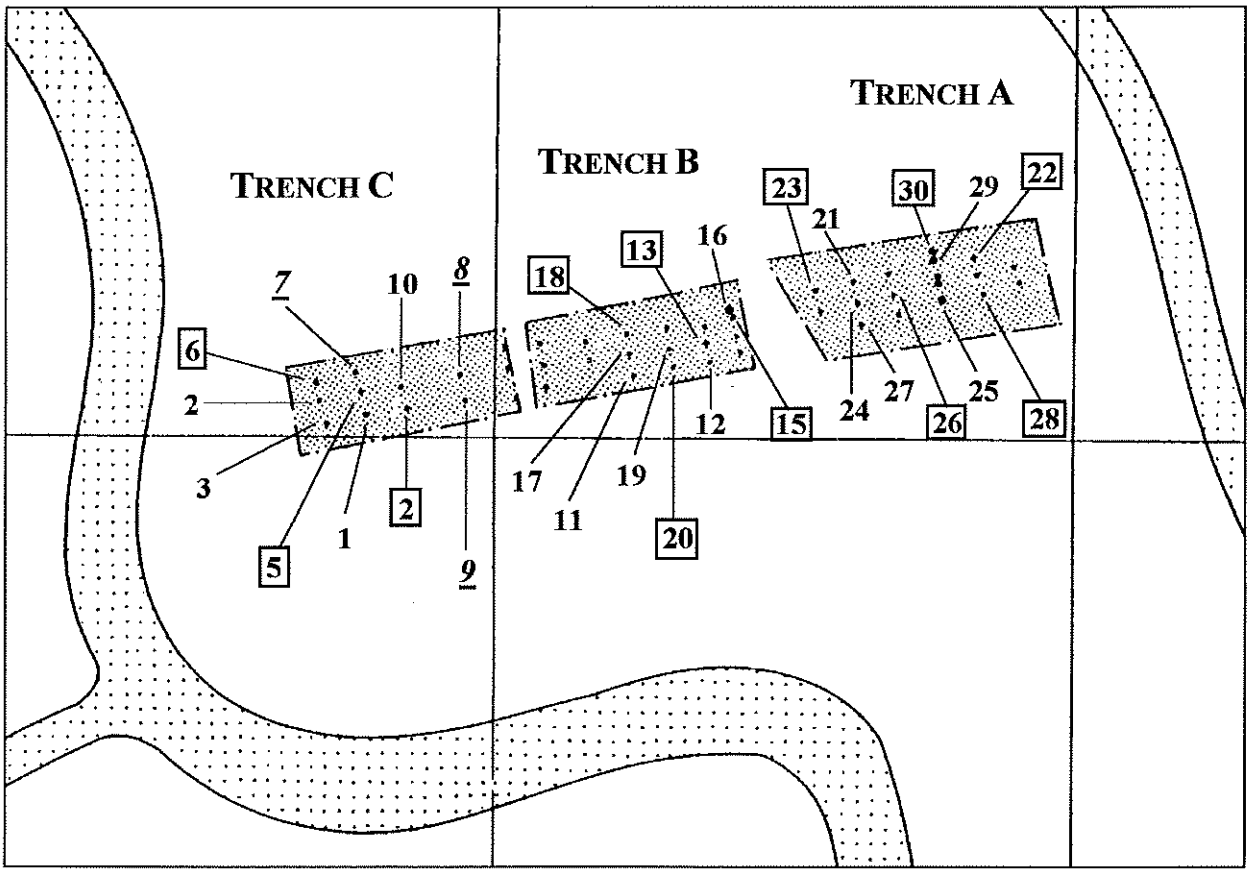

Figure 3: Bar diagram showing the relative positions of the matching ring sequences from Shinewater and Willingdon arranged by site. White bars - heartwood rings; hatching - sapwood; narrow bars - unmeasured rings; C - pith present; V - within 5 rings of pith

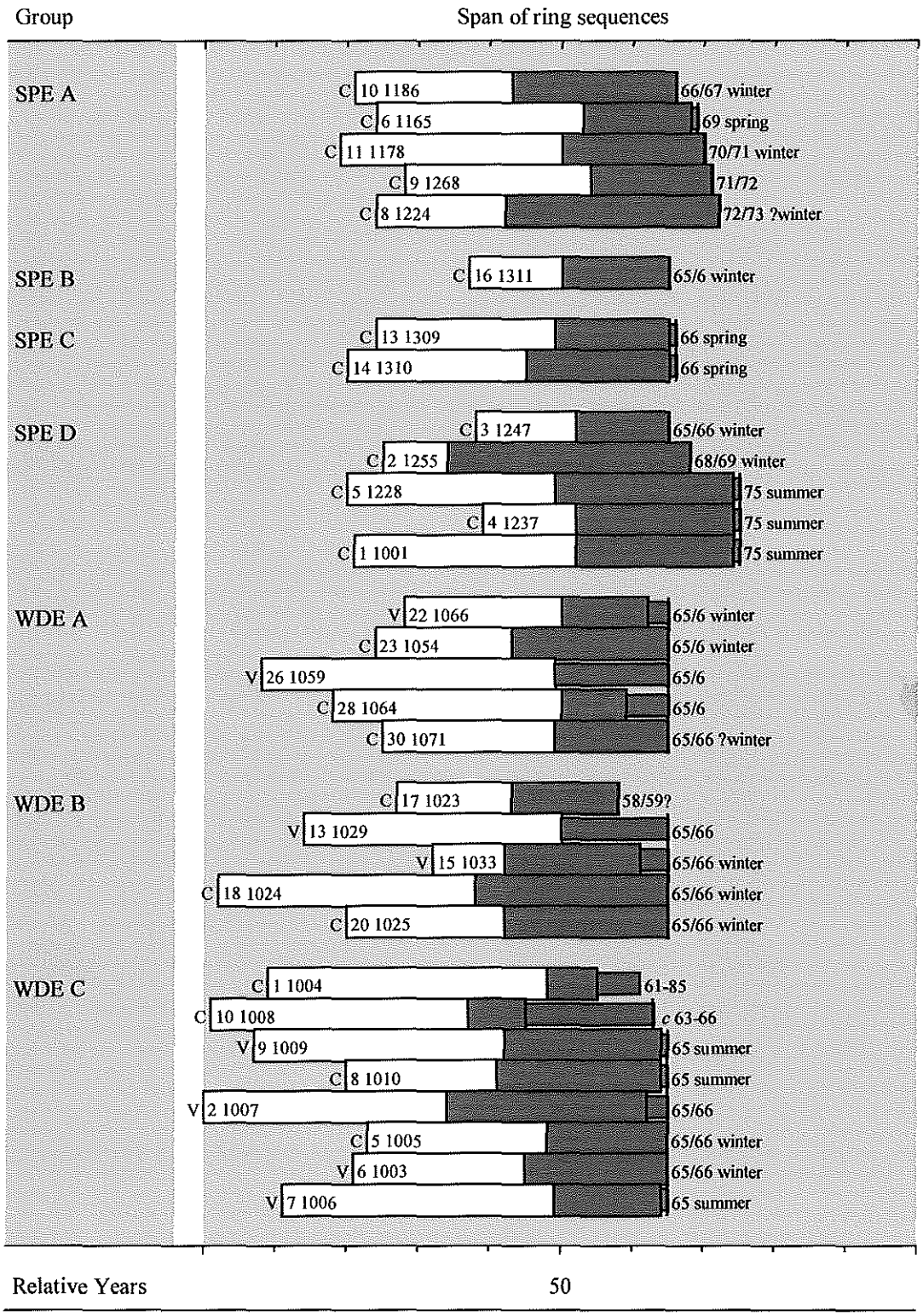

Table 1: Details of the tree-ring samples and results. Note that complete outer rings are measured, incomplete ones are not. ARW - average ring width; HS - heartwood-sapwood boundary

Sample no	Timber no	Area or Trench	Total no of rings	Sapwood rings	Outer ring	ARW (mm)	Dimensions (mm)	Relative dating	Relative felling date
SPE95									
1	1001	D	54	22	incomplete	1.85	175x170	21-74	75 summer
2	1255	D	44	34	complete	0.95	90x85	25-68	68/69 winter
3	1247	D	28	13	complete	2.06	120x110	38-65	65/66 winter
4	1237	D	36	22	incomplete	2.16	180x160	39-74	75 summer
5	1228	D	55	25	incomplete	1.43	170x160	20-74	75 summer
6	1165	A	45	15	spring vessels just forming	1.11	120x110	24-68	69 spring
7	1210	A	*c*32	-	-	-		rejected	-
8	1224	A	49	30	complete?	1.35	140x130	24-72	72/73 ?winter
9	1268	A	44	17	season unknown	1.57	150x130	28-71	71/72
10	1186	A	46	23	complete?	1.97	200x200	21-66	66/67 ?winter
11	1178	A	52	20	complete	1.44	155x145	19-70	70/71 winter
12	1265	B	27	19	complete?	2.06	125x125	undated	?winter
13	1309	C	42	16	spring vessels just forming	1.66	145x140	24-65	66 spring
14	1310	C	46	20	spring vessels just forming	1.48	145x140	20-65	66 spring
15	1272	B	24	13	complete?	1.88	110x85	undated	?winter
16	1311	B	29	15	complete	2.29	135x115	37-65	65/66 winter
WDE96									
1	1004	C	47	7	not present; plus at least 6 sapwood rings	1.64	155x120	9-55	after 61
2	1007	C	63	28	+3-4 sapwood rings to bark edge; season unknown	1.02	160x145	0-62	65/66
3	1001	C	-	-	-	-	-	rejected	-
4	1002	C	38	18	season unknown	1.94	140x135	1-38	-
5	1005	C	43	17	complete	1.51	155x130	23-65	65/66 winter
6	1003	C	45	20	complete	1.80	170x155	21-65	65/66 winter
7	1006	C	54	15	incomplete	1.32	160x150	11-64	65 summer
8	1010	C	45	23	incomplete	1.46	130x115	20-64	65 summer
9	1009	C	58	22	incomplete	1.19	150x140	7-64	65 summer
10	1008	C	45	8	not known; +18-20 sapwood rings	1.04	120x120	1-45	c 63-66
11	1022	B	41	HS?	sapwood unmeasurable	1.45	150x130	undated	-
12	1028	B	30	HS	sapwood unmeasurable	2.39	150x130	undated	-
13	1029	B	37	-	not known; +15 sapwood rings	1.85	150x150	14-50	65/66
14	1030	B	20+	?	-	-	145x110	rejected	-
15	1033	B	30	19	complete; +4 sapwood rings	1.49	130x105	32-61	65/66 winter
16	1034	B	31	16	complete?	2.22	160x150	undated	?winter
17	1023	B	32	15	bark edge?	1.64	125x115	27-58	?58/59
18	1024	B	64	27	complete	1.21	140x130	2-65	65/66 winter
19	1026	B	23	14	spring vessels just forming?	-	rejected	rejected	?spring
20	1025	B	46	23	complete	0.97	120x110	20-65	65/66 winter
21	1057	A	26	14	incomplete?	2.76	160x130	undated	?summer
22	1066	A	35	12	season unknown; +3 sapwood rings	1.83	165x135	28-62	65/66 winter
23	1054	A	42	22	complete	1.57	150x130	24-65	65/66 winter
24	1056	A	26	17	incomplete	2.09	115x105	undated	summer
25	1061	A	20+	-	-	-	130x120	rejected	-
26	1059	A	42	-	season unknown; +16 sapwood rings	1.13	110x100	8-49	65/66
27	1055	A	36	14	incomplete	2.84	170x160	undated	summer
28	1064	A	42	9	season unknown; +6 sapwood rings	1.57	170x150	18-59	65/66
29	1063	A	30	4	not present	1.70	140x125	undated	-
30	1071	A	41	16	complete?	2.00	140x120	25-65	65/66 ?winter

Table 2: *t* value matrix showing the agreement between the matching ring sequences. Values less than 3.0 are not given

a) Shinewater matrix

		01	**02**	**03**	**04**	**05**	**06**	**08**	**09**	**10**	**11**	**13**	**14**	**16**
	date span	*21-74*	*25-68*	*38-65*	*39-74*	*20-74*	*24-68*	*24-72*	*28-71*	*21-66*	*19-70*	*24-65*	*20-65*	*37-65*
01	*21-74*	*	-	5.9	3.4	3.4	3.5	-	4.5	6.5	3.7	5.1	5.1	5.4
02	*25-68*	*	*	3.8	4.3	4.2	5.2	6.4	3.5	6.1	3. 5	5.9	8.0	5.3
03	*38-65*	*	*	*	4.4	5.2	6.4	4.1	3.8	7.3	3.3	4.8	6.2	5.7
04	*39-74*	*	*	*	*	5.1	4.8	6.0	3.5	4.1	4.2	4.4	4.3	5.3
05	*20-74*	*	*	*	*	*	8.2	5.4	4.1	5.8	4.7	5.3	4.8	4.5
06	*24-68*	*	*	*	*	*	*	8.4	-	11.0	4.5	7.8	8.4	5.1
08	*24-72*	*	*	*	*	*	*	*	-	7.2	4.5	6.1	7.3	5.7
09	*28-71*	*	*	*	*	*	*	*	*	3.2	3.7	3.3	3.9	3.1
10	*21-66*	*	*	*	*	*	*	*	*	*	4.4	9.2	9.7	7.1
11	*19-70*	*	*	*	*	*	*	*	*	*	*	4.6	4.8	3.4
13	*24-65*	*	*	*	*	*	*	*	*	*	*	*	8. 8	8.2
14	*20-65*	*	*	*	*	*	*	*	*	*	*	*	*	7.6
16	*37-65*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 2/cont

b) Willingdon matrix

		01	**02**	**05**	**06**	**07**	**08**	**09**	**10**	**13**	**15**	**17**	**18**	**20**	**22**	**23**	**26**	**28**	**30**
	date span	*9-55*	*0-62*	*23-65*	*21-65*	*11-64*	*20-64*	*7-64*	*1-45*	*14-50*	*32-61*	*27-58*	*2-65*	*20-65*	*28-62*	*24-65*	*8-49*	*18-59*	*25-65*
01	*9-55*	*	5.4	4.6	4.5	3.7	-	5.4	-	6.4	3.2	4.0	4.7	4.4	-	-	4.3	3.9	-
02	*0-62*	*	*	6.3	3.4	3.6	3.2	3.8	3.7	5.4	3.9	-	4.8	-	3.7	3.9	4.8	3.3	3.5
05	*23-65*	*	*	*	4.4	4.3	3.7	4.1	3.8	4.2	4.9	6.3	6.2	4.0	5.1	4.1	-	3.6	4.5
06	*21-65*	*	*	*	*	4.2	-	-	-	3.5	-	-	3.1	3.2	-	-	-	-	-
07	*11-64*	*	*	*	*	*	-	-	-	3.9	-	-	3.6	3.2	3.2	3.2	-	3.1	3.5
08	*20-64*	*	*	*	*	*	*	4.0	3.5	4.2	4.1	-	3.4	-	3.5	-	-	3.4	3.9
09	*7-64*	*	*	*	*	*	*	*	3.9	5.2	4.2	-	6.0	3.8	-	4.2	4.4	5.3	-
10	*1-45*	*	*	*	*	*	*	*	*	3.6	\	-	4.7	-	-	5.3	-	-	-
13	*14-50*	*	*	*	*	*	*	*	*	*	3.2	-	4.3	5.5	3.2	4.2	-	3.9	-
15	*32-61*	*	*	*	*	*	*	*	*	*	*	-	4.1	3.4	3.2	-	-	-	-
17	*27-58*	*	*	*	*	*	*	*	*	*	*	*	5.0	3.6	-	3.1	-	4.5	3.9
18	*2-65*	*	*	*	*	*	*	*	*	*	*	*	*	5.3	-	-	-	5.3	3.8
20	*20-65*	*	*	*	*	*	*	*	*	*	*	*	*	*	-	-	-	-	-
22	*28-62*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	-	-	-	3.9
23	*24-65*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	-	4.6	5.5
26	*8-49*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	4.4	-
28	*18-59*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	3.4
30	*25-65*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 2/cont

c) Shinewater compared to Willingdon

SPE	WDE *date span*	01 *9-55*	02 *0-62*	05 *23-65*	06 *21-65*	07 *11-64*	08 *20-64*	09 *7-64*	10 *1-45*	13 *14-50*	15 *32-61*	17 *27-58*	18 *2-65*	20 *20-65*	22 *28-62*	23 *24-65*	26 *8-49*	28 *18-59*	30 *25-65*
01	*21-74*	6.1	3.6	-	-	-	-	3.9	3.0	3.1	-	3.5	3.4	-	-	-	-	4.2	3.3
02	*25-68*	4.9	-	4.6	4.6	3.5	-	-	-	3.1	-	3.4	5.4	4.0	-	-	-	-	3.2
03	*38-65*	-	4.0	4.0	-	-	-	4.5	\	\	3.8	3.3	4.5	-	3.2	4.2	\	3.5	5.8
04	*39-74*	-	-	-	-	-	-	3.9	\	\	-	-	6.0	3.6	-	-	\	-	3.1
05	*20-74*	3.4	-	6.0	-	-	-	3.2	-	3.5	4.8	4.5	4.0	4.7	3.8	3.4	-	-	3.1
06	*24-68*	4.0	4.6	7.8	3.2	5.6	4.0	4.1	-	4.3	4.3	5.0	6.2	3.6	4.9	4.4	-	5.2	6.2
08	*24-72*	4.7	3.4	6.5	3.4	3.8	-	4.7	3.2	3.7	4.6	4.8	8.3	5.6	-	3.2	-	3.5	3.2
09	*28-71*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	*21-66*	6.4	5.5	7.4	4.4	5.1	3.5	4.7	3.1	4.9	4.6	5.5	6.4	4.5	4.7	3.8	-	5.9	4.6
11	*19-70*	-	-	3.1	-	-	-	-	3.4	-	-	4.9	-	-	-	3.9	-	-	4.2
13	*24-65*	5.3	5.6	5.9	-	3.1	3.3	3.6	3.2	3.9	4.0	5.2	5.7	3.3	3.0	4.0	-	4.6	3.7
14	*20-65*	3.9	3.8	5.1	3.5	4.2	-	-	-	-	3.9	3.5	5.1	-	3.6	-	-	3.2	3.7
16	*37-65*	4.8	3.2	3.5	-	-	-	5.3	\	\	4.9	-	4.9	3.6	-	-	\	-	-

Table 3: The undated Shinewater/Willingdon chronology

ring widths (0.01mm)										no of samples									
162	131	171	149	243	252	152	163	198	172	1	2	3	3	3	3	3	4	5	6
239	181	194	160	172	183	146	131	211	175	6	7	7	7	8	8	8	8	9	10
196	205	233	265	179	233	217	261	293	253	14	17	17	18	22	24	24	25	26	26
165	152	181	173	130	153	118	120	140	190	26	26	27	27	27	27	27	28	29	30
126	150	197	159	121	86	140	130	156	120	30	30	30	30	30	30	29	29	29	29
156	133	122	121	114	85	119	110	141	122	28	27	27	27	27	27	26	26	26	25
114	92	62	66	100	100	82	98	94	65	24	24	23	22	22	19	9	8	8	6
69	72	85	70	78						6	5	4	3	3					

Table 4: *t*-values between measurements from the same sample

sample no	*t*-value between radii
SPE2	8.7
SPE4	6.0
SPE5	10.0
SPE6	9.0
SPE8	10.2
SPE9	7.7
SPE10	11.8
SPE11	6.9
SPE13	7.4
SPE14	12.6
WDE2	9.5