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Summary

During AD 2000 a series of timbers was revealed during excavations at Swalecliffe Waste Water Treatment Works, Near Whitstable, Kent. The timbers were associated with archaeological features of late Bronze Age and/or early Iron Age date. Analysis of the entire assemblage, part-funded by English Heritage and part-funded by RPS Consultants Ltd, has provided absolute dates for some of the material in the twelfth and eleventh centuries BC. In addition a further group of timbers have been found to cross-match but no absolute dating has been obtained from this material. As well as providing data for the archaeological interpretation the material provides a rare opportunity to help strengthen the national network of prehistoric tree-ring chronologies.

Keywords

Dendrochronology

Author's address
Sheffield Dendrochronology Laboratory, Archaeology & Archaeological Science Research School, Department of Archaeology & Prehistory, University of Sheffield, West Court, 2 Mappin Street, Sheffield, S1 4DT

Introduction

During AD 2000 a series of timbers was revealed during excavations at Swalecliffe Waste Water Treatment Works, near Whitstable in Kent (NGR TR 134 672), being undertaken by RPS Consultants Ltd, on behalf of Southern Water (sitecode R4047B). The timbers were associated with archaeological features of late Bronze Age and early Iron Age date. Tree-ring analysis with a view to providing archaeological spot-dates of some parts of the assemblage was undertaken in AD 2000. This dated some timbers to the end of the second millennium BC. In AD 2001 the analysis of additional timbers, funded by English Heritage, was undertaken. It was hoped analysis of these timbers would help date some of the features undated in the original analysis, provide additional evidence for the period of occupation on the site, and help refine the national prehistoric tree-ring database.

Methodology

The general methodology and working practises used at the Sheffield Dendrochronology Laboratory are described in English Heritage (1998). The methodology used for this assemblage was as follows.

The samples were waterlogged when delivered to the laboratory. All the samples were placed in a deep-freeze until they were frozen. Once solid the surfaces were cleaned using a surform plane and scalpels. After the samples had thawed, the ring sequence from each sample was assessed for its suitability for dendrochronological analysis. Unsuitable samples are usually those with either unclear ring sequences or fewer than 50 rings.

The complete sequence of growth rings in the samples that were selected for dating purposes were measured to an accuracy of 0.01mm using a micro-computer based travelling stage (Tyers 1999a). The ring sequences were plotted onto semi-log graph paper to enable visual comparisons to be made between sequences. In addition a cross-correlation algorithm (Baillie and Pilcher 1973) was employed to search for positions where the ring sequences were highly correlated. These positions were checked using the graphs and, where these were satisfactory, new mean sequences were constructed from the synchronised sequences. The *t*-values reported below are derived from the original CROS algorithm (Baillie and Pilcher 1973). 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.

All the measured sequences from this assemblage were compared with each other, and with the previously obtained data from the site. Any that were found to cross-match were

combined to form a series of site master curves. These master curves and the remaining unmatched ring sequences were then tested against a range of reference chronologies, using the same matching criteria: high *t*-values, replicated values against a range of chronologies at the same position, and satisfactory visual matching. Where such positions are found these provide calendar dates for the ring-sequence.

These tree-ring dates can initially only date the rings present in the timber. Their interpretation relies upon the nature of the final rings in the sequence. 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 applied through-out this report 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 or deposit from which they are derived. It is necessary to incorporate other specialist evidence concerning the re-use 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 archaeological sequence.

Note that the BC scale used by dendrochronologists, and as used in this report, has no year zero, the year 1 BC immediately precedes the year AD 1.

The samples

There was a total of 29 samples supplied from timbers from the site. This figure is not representative of the total assemblage of archaeological timbers available since material assessed as either of no dendrochronological value, or as too fragile to sample was not supplied for analysis (Masefield and Goodburn pers comm).

Results

A total of 24 of the selected timbers were found after preparation to contain measurable ring sequences (Table 1). Twelve timbers from four of the archaeological features were found to cross-match with each other (Table 2). Two pairs of samples (5057/8.1/5057/8.2 and

5083/5086), with each pair apparently derived from the same parent log, were initially combined and then these and the remaining eight sequences were combined to form a single 348-year mean chronology named **SWALCLF1**. This was compared with absolutely dated reference chronologies and a single well replicated correlation found that dates the sequence to 1432-1085 BC inclusive (Table 3; Fig 1). This sequence is listed in Table 4. Seven of the remaining twelve series also cross-match with each other (Table 5; Fig 2). These are from three other features. Here one pair of samples derived from the same parent log (5124.1/5124.2) were initially combined before this and the remaining five series were combined into a 163-year mean chronology named **SWALCLF2** (Table 6). Comparison with absolutely dated reference chronologies failed to locate a replicated correlation for this sequence and hence this series has no absolute dating at present. It does provide some relative dating of value to the site interpretation, discussed below. The other five series from the site fail to match any of the other material from the site, each other, or with local, British Isles, or northern European reference data and are undated by the analyses reported here. Four of these undated samples are from archaeological features from which other samples either date or cross-match. One sample is from yet another feature. In total the analysed samples are derived from eight different archaeological features which are discussed below.

Pit 5013. Four samples were analysed from this group. These are described as 'loose cleft oak fragments in the pit fill' (Goodburn pers comm). Two are derived from a single parent log, and all four are dated. Only one retains sapwood, but this appears to retain full sapwood and to have been felled in the winter of 1102/1 BC. The other three dated samples have no sapwood and were felled sometime after 1154 BC.

Pit 5015? Three samples from the machining of this area of the site, possibly derived from broken fragments in the primary fill, were found to cross-match with material from structures *5015* and *5033*. Only one of these retains any sapwood, but in combination the three suggest felling between years 162-186 of the arbitrary relative scale used for the SWALCLF2 group. This may mean that they are broadly contemporary with the matched fragments in *5015* and *5033*. Two of these fragments are derived from a single parent log.

Pit 5015. Four samples were analysed from this group. Three are described as 'cleft oak stakes in well lining' (Goodburn pers comm). The fourth piece is a broken 'step end'. Two are exceptionally slowly grown (< 0.5mm/year average) and one of these and the other two more 'normal' samples were successfully cross-matched with material from *5015?* and *5033*. Two retain no sapwood and are felled after year 152 of the arbitrary relative scale used for the SWALCLF2 group, but the third matched timber was felled in the winter of year 130/31 of

the same arbitrary scale. This result indicates this sample is earlier than all the other SWALCLF2 material.

Pit 5025. A single timber, another 'step' was supplied from this feature. The sample could not be matched either to any other timber from the site or to reference data.

Pit 5033. A single timber found loose in this feature matches with material from features *5015?* and *5015.* This sample retains full sapwood and bark-edge and was felled in year 163 of the arbitrary relative scale used for the SWALCLF2 group. Except for 5054F in *5015* all the other SWALCLF2 material could be contemporary with this date, or could be within a few years of this date.

Pit 5045. This is the most confusing of the dated groups. All the samples are well lining stakes and five of the eight supplied samples were found to date. None are definitely derived from the same parent log, although 5081L which ends much earlier than the rest may be the inner half of an originally wider plank. The other four all end at bark-edge or possible bark-edge, although these edges are spread over the period 1098 BC to 1085 BC, a period of thirteen years. Two of these appear to be particularly convincing edges, and these were both independently checked in Sheffield by Cathy Groves, and were also independently assessed during their sampling as 'complete sap' by Damian Goodburn (pers comm). This appears to indicate that this feature either had a relatively long usage period and had been repaired during that period, or that it was built with stockpiled or re-used material, either of which would be an unusual finding in a prehistoric context. Stratigraphic, finds, environmental, or timber technological records should usefully contribute to a discussion of this feature when each is complete.

Pit 5047. A clearly reused 'step plank' was provided from this feature. The long sequence obtained from it indicates the tree was felled after 1242 BC. Hence if this was re-used at the same time as the rest of the dated material this timber could have be up to 150 years old at that time, although the lack of sapwood on it obviously prevents a precise first use period from being determined.

Pit 5082. Two fairly slow growing timbers were supplied from this feature, described as from a 'lining or fence collapsed into the pit fill' (Goodburn pers comm). Both retain full sapwood and bark-edge and both were felled in the same period – summer 1164 BC. They appear to be derived from the same parent log.

Conclusion

Eleven dated sequences yield archaeologically useful information for three features. All these features contain timbers felled between 1164 BC and 1085 BC (Fig 1). An earlier date from a single timber in a fourth feature probably supports the interpretation that this timber was re-used. The dates are earlier than had been initially anticipated from some of the finds information (Masefield pers comm). An undated sequence of seven timbers from three other features is constructed from a number of apparently different trees. This implies that it is a useful series that may eventually prove datable either when the local tree-ring chronology is strengthened or extended. The archaeological interpretation of these timbers needs to be carefully reviewed to identify whether these features may be later than those with the absolutely dated timbers. Carefully targeted radiocarbon assays may help with the dating of this sequence. The dated tree-ring chronology obtained from the site provides an excellent parallel for part of the sequence obtained from the Flag Fen / Fengate area excavations and as such is a valuable addition to the national tree-ring data bank since there is almost no other replicated data for this period from the south-east of England.

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Robert Masefield from RPS Consultants Ltd kindly provided sample details, numbering updates, context information, draft reports, plans, and figures as well as useful feedback on the results. RPS Consultants Ltd funded the initial spot-dating of one third of the assemblage. English Heritage provided funding for the analysis of the remainder of the assemblage, and this report. Damian Goodburn and Nick Branch supplied various of the samples following technology assessments and environmental processing. Alex Bayliss kindly discussed the radiocarbon implications of the material with respect to the Flag Fen results and discussed other aspects of the assemblage. Cathy Groves kindly discussed the results and offered her views on the presence of bark-edge on both some specific samples and on prehistoric material generally.

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Table 1 List of samples analysed from Swalecliffe Waste Water Treatment Works, nr Whitstable, Kent

Sample No	Pit No	Sample size (mm)	Species	Total rings	Sapwood rings	ARW mm/year	Date of tree-ring sequence	Period of felling of the tree
5057/8.1 <31>	5013	80 x 45	Oak	69	-	1.11	1233 BC-1165 BC	after 1155 BC
5057/8.2 <31>	5013	75 x 65	Oak	70	-	1.13	1233 BC-1164 BC	after 1154 BC
5057/8.3 <31>	5013	95 x 40	Oak	126	34+Bw	0.75	1227 BC-1102 BC	1102/1 BC winter
5057/8 D <31>	5013	180 x 40	Oak	181	-	0.99	1354 BC-1174 BC	after 1164 BC
5124.1 <3>	5015?	155 x 125	Oak	149	H/S?	0.98	Rel 1-149	159-95?
5124.2 <3>	5015?	0 x 0 XX	Oak	117	H/S?	0.85	Rel 36-152	162-98?
5124.3 <3>	5015?	145 x 80	Oak	86	4	0.86	Rel 59-144	150-86
5053A	5015	60 x 50	Oak	74	12	0.49	undated	-
5053B	5015	45 x 30	Oak	57	-	0.48	Rel 86-142	after 152
5053H	5015	50 x 35	Oak	74	-	0.70	Rel 47-120	after 130
5054F	5015	180 x 80	Oak	117	26+Bw	1.51	Rel 14-130	130/131 winter
5030A <34>	5025	145 x 55	Oak	87	-	1.58	undated	-
5125 <63>	5033	105 x 40	Oak	69	28+B	0.60	Rel 95-163	163
5081A <44>	5045	80 x 55	Oak	100	38+½Bs	0.81	1194 BC-1095 BC	1094 BC spring
5081C <44>	5045	95 x 25	Oak	112	-	0.84	undated	-
5081H <44>	5045	60 x 40	Oak	54	-	1.12	undated	-
5081K <44>	5045	80 x 40	Oak	82	32+Bs	0.97	1166 BC-1085 BC	1085 BC summer
5081L <44>	5045	65 x 45	Oak	64	-	0.70	1235 BC-1172 BC	after 1162 BC
5081M <44>	5045	70 x 30	Oak	71	41+?B	1.01	1163 BC-1093 BC	1093 BC?
5081P <44>	5045	125 x 30	Oak	132	-	0.97	undated	-
5081R <44>	5045	140 x 45	Oak	184	41+?B	0.74	1281 BC-1098 BC	1098 BC?
5079A <41> *	5047	250 x 50	Oak	181	-	1.37	1432 BC-1252 BC	after 1242 BC
5083 <48>	5082	120 x 65	Oak	87	35+½Bs	0.75	1251 BC-1165 BC	1164 BC summer
5086 <46>	5082	80 x 20	Oak	97	36+Bs	0.75	1260 BC-1164 BC	1164 BC summer

Key: Sapwood rings; H/S? series ends at possible heartwood/sapwood boundary, ?B series ends at possible bark-edge, Bs series ends at an incomplete ring indicating spring or summer felling, Bw series ends at a complete ring indicating winter felling. ARW = Average ring width in mm/year. * = definitely re-used timber

Table 2 Correlation *t*-values between the samples forming the chronology SWALCLF1

	5057/8.2	5057/8.3	5057/8D	5079A	5081A	5081K	5081L	5081M	5081R	5083	5086C
5057/8.1	12.38	4.02	4.82	\	3.19	\	5.65	\	5.12	5.55	4.88
5057/8.2		3.51	4.52	\	3.70	\	5.56	\	5.69	5.57	4.71
5057/8.3			-	\	7.24	5.10	-	3.51	4.76	-	4.78
5057/8D				4.38	-	\	5.79	\	5.33	5.59	4.58
5079A					\	\	\	\	-	\	\
5081A						6.78	-	3.99	6.17	-	3.19
5081K							\	7.46	5.60	\	\
5081L								\	5.70	5.08	4.41
5081M									3.24	\	\
5081R										3.80	4.46
5083											10.26

Table 3 Correlation *t*-values between SWALCLF1 at the position 1432-1085 BC inclusive and external reference chronologies, note the 'English Prehistoric' master sequence is not independent of some of the individual site series

Details of reference series	**SWALCLF1**
English Prehistoric - 14 chronology mean (Hillam pers comm)	9.50
Cambridgeshire Flag Fen / Fengate (Neve 1999)	7.67
Cambridgeshire Flag Fen NTY99 (Tyers 1999b)	5.16
Essex Rook Hall Farm (Hillam pers comm)	4.97
Lancashire Leyland (Brown and Baillie 1992)	6.54
Lancashire Croston Moss (Brown and Baillie 1992)	3.57
Somerset Harters Hill (Hillam pers comm)	4.14
Humberside Hasholme bog oak (Hillam 1987)	4.17
Ireland/Belfast Long Chronology (Baillie *et al* 1983)	4.48
Wales Goldcliff boat (Hillam pers comm)	3.38
Germany (Becker 1993)	4.76
Netherlands bog oaks (Jansma 1995)	4.55

Table 4 Ring width data for the SWALCLF1 sequence

Years	Ring widths (0.01mm)										No of trees									
1432 BC									170	187									1	1
	234	180	121	90	112	240	212	244	181	247	1	1	1	1	1	1	1	1	1	1
	222	244	265	145	160	166	169	99	172	147	1	1	1	1	1	1	1	1	1	1
	147	180	240	193	221	190	200	197	153	90	1	1	1	1	1	1	1	1	1	1
1400 BC	62	71	153	103	146	149	204	189	271	263	1	1	1	1	1	1	1	1	1	1
	180	205	224	203	215	162	194	223	131	162	1	1	1	1	1	1	1	1	1	1
	196	175	188	154	219	166	195	207	182	198	1	1	1	1	1	1	1	1	1	1
	208	172	132	102	106	169	131	112	101	157	1	1	1	1	1	1	1	1	1	1
	106	121	120	151	129	201	147	126	121	120	1	1	1	1	1	1	2	2	2	2
1350 BC	114	123	79	96	128	172	151	148	127	146	2	2	2	2	2	2	2	2	2	2
	112	163	182	189	151	136	141	150	101	108	2	2	2	2	2	2	2	2	2	2
	127	161	84	140	179	133	116	116	132	149	2	2	2	2	2	2	2	2	2	2
	157	152	130	138	121	113	85	103	96	78	2	2	2	2	2	2	2	2	2	2
	88	137	96	113	114	108	86	95	103	116	2	2	2	2	2	2	2	2	2	2
1300 BC	97	99	100	88	80	70	99	111	106	76	2	2	2	2	2	2	2	2	2	2
	73	99	99	118	111	74	59	80	104	84	2	2	2	2	2	2	2	2	2	3
	97	85	103	104	112	119	95	100	100	102	3	3	3	3	3	3	3	3	3	3
	101	72	69	85	91	63	83	84	74	78	3	3	3	3	3	3	3	3	3	3
	76	106	98	91	73	64	74	74	81	92	4	4	4	4	4	4	4	4	4	3
1250 BC	105	89	83	86	80	79	85	106	107	123	3	3	3	3	3	3	3	3	3	3
	94	82	101	89	89	99	135	109	100	89	3	3	3	3	3	4	4	5	5	5
	101	114	116	77	85	117	99	89	91	90	5	5	5	6	6	6	6	6	6	6
	91	83	102	81	79	110	111	75	77	77	6	6	6	6	6	6	6	6	6	6
	86	89	90	80	67	61	62	73	93	109	6	6	6	6	6	6	6	6	6	6
1200 BC	100	74	90	102	95	70	113	106	102	107	6	6	6	6	6	6	7	7	7	7
	115	120	89	72	70	92	94	96	78	76	7	7	7	7	7	7	7	7	7	7
	71	78	67	49	57	60	79	80	79	90	7	7	7	7	7	7	7	6	6	5
	68	54	77	79	67	79	74	83	103	75	5	5	5	5	6	6	6	5	5	5
	72	107	101	86	100	109	110	119	99	81	5	5	5	5	5	5	5	5	5	5
1150 BC	73	69	91	90	82	107	93	116	112	93	5	5	5	5	5	5	5	5	5	5
	91	91	62	64	85	107	99	71	78	84	5	5	5	5	5	5	5	5	5	5
	73	66	65	57	55	62	62	59	100	82	5	5	5	5	5	5	5	5	5	5
	56	49	62	63	68	72	76	71	69	77	5	5	5	5	5	5	5	5	5	5
	75	69	55	48	60	73	58	58	70	68	5	5	5	5	5	5	5	5	5	4
1100 BC	59	50	52	76	63	72	41	38	49	48	4	4	4	3	3	3	2	2	1	1
	56	82	80	85	78	51					1	1	1	1	1	1				

Table 5 Correlation *t*-values between the samples forming the chronology SWALCLF2

	5053H	5054F	5124.1	5124.2	5124.3	5125
5053B	-	-	6.92	6.48	3.38	3.02
5053H		4.12	8.64	9.13	5.13	4.03
5054F			4.67	3.70	5.13	-
5124.1				17.03	5.95	6.92
5124.2					6.70	6.91
5124.3						5.06

Table 6 Ring width data for the undated SWALCLF2 sequence, the date scale is arbitrary

Years	**Ring widths (0.01mm)**										**No of trees**									
1	165	154	138	132	131	189	154	137	135	123	1	1	1	1	1	1	1	1	1	1
	95	130	142	301	319	260	220	179	191	222	1	1	1	2	2	2	2	2	2	2
	179	185	209	256	167	140	165	202	176	189	2	2	2	2	2	2	2	2	2	2
	168	130	155	111	89	101	127	148	105	132	2	2	2	2	2	2	2	2	2	2
	109	94	74	108	124	156	106	72	70	84	2	2	2	2	2	2	3	3	3	3
51	107	82	65	65	101	97	146	168	126	89	3	3	3	3	3	3	3	3	4	4
	98	137	133	103	171	118	144	134	106	72	4	4	4	4	4	4	4	4	4	4
	92	82	65	67	142	109	95	106	114	92	4	4	4	4	4	4	4	4	4	4
	113	154	145	109	103	69	55	80	85	106	4	4	4	4	4	5	5	5	5	5
	106	81	49	44	53	62	87	76	89	78	5	5	5	5	6	6	6	6	6	6
101	59	45	74	74	71	84	92	67	48	60	6	6	6	6	6	6	6	6	6	6
	90	80	109	73	61	50	46	43	57	82	6	6	6	6	6	6	6	6	6	6
	80	81	81	66	65	63	68	97	103	103	5	5	5	5	5	5	5	5	5	5
	68	46	67	83	79	61	51	57	64	64	4	4	4	4	4	4	4	4	4	4
	70	57	68	68	52	34	47	59	69	77	4	4	3	3	2	2	2	2	2	2
151	93	65	59	55	57	62	59	55	35	30	2	2	1	1	1	1	1	1	1	1
	24	24	38								1	1	1							

Figure 1 Bar diagram showing the relative positions of the matched and dated samples from Swalecliffe, sorted by feature number. White bars are heartwood, hatched bars are sapwood, the interpreted felling dates are also shown

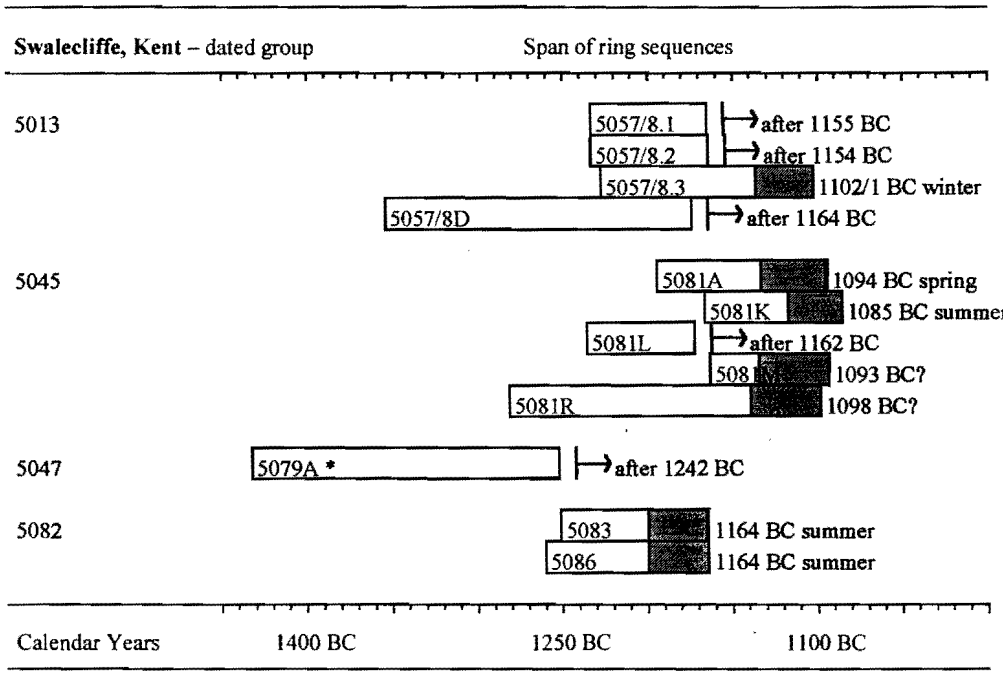

Figure 2 Bar diagram showing the relative positions of the matched but undated samples from Swalecliffe, sorted by feature number. White bars are heartwood, hatched bars are sapwood, the interpreted felling dates are also shown. The relative date scale is arbitrary