Ancient Monuments Laboratory
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Summary

During AD 1998-9 a series of timbers was revealed during gravel extraction operations at the ARC Shardlow site, which is located to the north of the river Trent, at a point where it defines the junction of the counties of Derbyshire and Leicestershire, some 15km south-west of the city of Nottingham. The timbers included naturally deposited oaks, a log-boat, and a number of timbers associated with enigmatic archaeological features. Analysis of the entire assemblage, part-funded by English Heritage and part-funded by the University of Sheffield, has provided absolute dates for some of the naturally deposited timbers in the third millennium BC, but has yielded only a single dated timber from the archaeological deposits. This latter timber appears to be a fragment of a naturally deposited oak of the same period, re-used or otherwise intrusive in an archaeological context and of little interpretive value to the site. The large number of undated sequences from the site have been compared with prehistoric, Roman, and medieval reference chronologies from throughout the UK and northern Europe without successfully obtaining reliable cross-dating.

Author's address :-

I Tyers
SHEFFIELD DENDROCHRONOLOGY LABORATORY
Archaeology Research School
University of Sheffield West Ct 2 Mappin St
Sheffield
S1 4DT

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Introduction

During AD 1998-9 a series of timbers was revealed during gravel extraction operations at the ARC Shardlow gravel extraction site, which is located immediately to the north of the river Trent, at a point where it defines the boundary of the counties of Derbyshire and Leicestershire. The site lies between the villages of Aston-on-Trent and Shardlow, both in Derbyshire, and Cavendish Bridge, Hemington, and Castle Donington, all in Leicestershire (Fig 1), and is centred around NGR SK4329. The timbers included naturally deposited oaks, a log-boat, and a number of timbers associated with enigmatic archaeological features.

The site is one of many in the Trent valley which have been examined by Dr Chris Salisbury as part of his long term study of the development of the Trent river system. Dendrochronological analysis of samples from other Trent gravel sites over the last 20 years have yielded a series of discontinuous chronologies covering the fifth and third millennia BC (Morgan *et al* 1987; Baillie and Brown 1988; Hillam 1998).

The sampling and analysis of the material from Shardlow has a somewhat chequered history. An initial series of samples was taken by Chris Salisbury and Robert Howard of the Nottingham University Tree-ring Dating Laboratory. Seven of these were analysed but all failed to date. In the spring of AD 1998 a log boat was identified on the site. Over the next year English Heritage supported excavations by Trent and Peak Archaeological Trust in the vicinity of the find. Further tree-ring sampling, of both archaeological timbers and naturally deposited tree-trunks, was undertaken by staff at the University of Sheffield on five separate occasions during this period. Most samples were cross-sections obtained using a chainsaw, although additionally cores and sections were removed from the boat.

The dendrochronology was funded by a variety of sources. English Heritage funded the analysis of the boat and associated archaeological material. This forms the subject of this report. The University of Sheffield funded the analysis of the naturally deposited oaks, this work is reported elsewhere (Tyers 1999a). The Nottingham work was either unfunded or supported by Chris Salisbury. Logistical assistance was provided by ARC, now part of the Hanson Group.

Analysis of the archaeological material was partially completed by Jennifer Hillam, before she retired through ill health. The naturally deposited oaks were partially analysed by an MSc

student, who unfortunately abandoned his course before the work could be completed. Consequently material from both projects has been worked on by a number of different people and some aspects of the analysis have been taken up by the author at an advanced stage.

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 various timbers were usually sampled on site by cutting a complete or partial cross-section by petrol driven chainsaw. Some of the log-boat samples were obtained by using a hand powered foresters increment borer, and some of the archaeological samples were cut by hand saws or electric alligator saws. The material was found to be in two quite different states of preservation, most of the archaeological samples were waterlogged and quite soft, whilst the naturally accumulated material was usually quite dry and hard. These two groups were processed quite differently. All the recovered sections were trimmed into more manageable sections using a band-saw and the state of preservation was assessed at this point. The softer material was 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 unclear ring sequences or fewer than 50 rings. The drier and more mineralised bog oak timbers were air-dried and the surfaces were cleaned using scalpels.

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 1999b). 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 those 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, the repairs of structures, and the taphonomic processes occurring in the river systems before the dendrochronological dates given here can be reliably interpreted as reflecting the construction date of phases within the archaeological structures or of particular events in the development of the river.

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. Dendrochronologists conventionally, but inaccurately, refer to oak timbers recovered in bogs, or in submerged forests, or in gravel accumulations under the generic term 'bog oaks'. In reality the taphonomic, environmental, and geological processes occurring are different in each case but the convention has been followed with this report. Several sections were taken from some of the archaeological material in an attempt to recover the complete ring sequence. The most extreme example is the log-boat from which six samples were taken.

The samples

There are a total of 65 measured oak (*Quercus* spp) timbers from the site (Table 1 lists the 21 archaeological timbers; Tyers 1999a reports on the remainder of the material). This figure under-represents the total number of archaeological timbers examined since material unsuitable for analysis through either the absence of sufficient rings or because the timber was of an unusable species types was not selected for sampling on site. The number of samples quoted also under-represents the total amount of measuring and analysis undertaken since many of these timbers had more than one sample taken or more than one measured radii.

The samples were recovered during a whole series of sampling trips, for a variety of purposes, and so have no overall numbering series. The extended period of sampling, the long gestation period of the analysis, the lack of coherent numbering schemes, and the large number of personnel involved may have had a negative effect on the surviving quality of the samples and hence the quality of the final interpretation. An identified sample numbering problem exists with BDG and BDH where the labels within the bags are transposed with the writing on the outside of the bags. In addition the ES numbers for samples in the BAN-BDK series did not initially tally with a list compiled by the excavators, although this was subsequently resolved. In the end however, although these problems should not be ignored, they probably do not have much effect on the final interpretation. The bog oak group and the archaeological group are sufficiently distinctive in terms of waterlogging and mineralisation that they were clearly separable during the analysis.

Results

A total of eighteen timbers were cross-matched with both other material from the site and with absolutely dated reference chronologies to produce two absolutely dated sequences occupying parts of the third millennium BC (named Shardlow chronologies 1 and 2), a further three samples were linked into a sequence of unknown date (named Shardlow chronology 3). These tree-ring results relate principally to the naturally accumulated material and are discussed in Tyers (1999a). Discussed below are the single archaeological timber in the Shardlow 2 sequence, the eight archaeological samples which formed two other sequences (Shardlow chronologies 4 and 5; Fig 3a, b), and a fourth undated composite sequence created from five separate samples of the log-boat (Shardlow chronology 6; Fig 3c). The numbers given to the chronologies do not indicate their relative dating, which is currently unknown.

The archaeological samples were divided into five groups by Daryl Garton in a letter of April 1999. The rest of this section follows these groupings.

1. The log-boat. There were two cores, a detached fragment, and three cut sections obtained from this vessel. Five of these samples were usable (one of the cores was not) and these were found to cross-match (Fig 2c, Table 2). The tree-ring series obtained from each were then combined to form a single sequence 152 years long (Table 3). The centre of the tree was not far from the innermost end of one of the samples (ES30) and although no sapwood was present on any sample the outermost edge of the outermost section (ES32) was thought to be the heartwood/sapwood boundary of the tree. Hence assuming normal amounts of sapwood was originally present, a tree of around 200 years growth appears to have been used for the construction of the vessel. Unfortunately since there is no cross-dating with any other sample on the site, nor with any other Trent valley sequence, nor with any of the available prehistoric reference chronologies, the date of the series cannot be identified by dendrochronological techniques at this time. After analysis the samples were despatched to the conservation facility in York.

2. Logs from the same context as the boat. Six timbers were present in this group, several were sampled more than once. Note that this group contains several of the longest series obtained from the site. None included any surviving sapwood. Unfortunately none of this material has cross-matched successfully either with other samples from the group, or with anything else. The date of these series thus cannot be identified by dendrochronological techniques at this time.

3. Logs above the brushwood mattress. This group is comprised of a series of short stubby lengths of oak logs. The seven series obtained included four that were cross-matched (Fig 2b; Table 4). ES63 and 64 correlate sufficiently well that they are undoubtedly sections of the same parent log, whilst ES62 and 65 are identified as contemporary rather than definitely derived from the same tree. These series form a single composite sequence of 217-years length (named Shardlow 5; Table 5). Unfortunately this sequence and the un-matched series from this group have neither cross-matched successfully with other samples from the site, or with anything else, and hence the date of these series cannot be identified by dendrochronological techniques at this time.

4. Logs near the brushwood mattress. There is only one measured sample from this group, this sequence has neither cross-matched successfully with other samples from the site, or with anything else, and thus the date of this series cannot be identified by dendrochronological techniques at this time.

5. Ex-situ stakes from the causeway. There are six samples from this group. Three are cross-matched together (Fig 2a; Table 6), these three samples (ES23, 25, and 28) are probably derived from a single original tree. The resulting 142-year sequence (Shardlow 4; Table 7) and two of the other timbers from this group have neither cross-matched successfully with other samples from the site, or with anything else, and thus the date of these series cannot be identified by dendrochronological techniques at this time. Surprisingly the sixth member of the group ES27 was found to closely resemble the material that was matched together to form the later of the two bog oak series from the site (Shardlow 2; Table 8a and b, and see Tyers 1999a). Since Shardlow 2 is a dated sequence this sample is dated to 2401-2325 BC inclusive (Fig 3; Table 9), the timber may retain its original heartwood/sapwood boundary and thus may have died or possibly been felled between 2315 and 2279 BC. However I remain uncertain as to the validity of the identification of this sample as being derived from ES27. It seems not impossible that this sample is a mis-labelled section of a bog oak since the sample exhibits the high mineral component common to the bog oaks and uncommon in the rest of the archaeological material.

Conclusion

Analysis of the entire assemblage from the Shardlow site, part-funded by English Heritage and part-funded by the University of Sheffield, has provided absolute dates for some of the naturally deposited timbers in the third millennium BC, but has yielded only a single dated timber which may be from the archaeological deposits. This latter timber appears to be a fragment of a naturally deposited oak of the same period, re-used or otherwise intrusive in an archaeological context and of little interpretative value to the site. The large number of undated sequences from the site have been compared with prehistoric, Roman, and medieval reference chronologies from throughout the UK and northern Europe without successfully obtaining reliable cross-dating.

From the archaeological material, the results are more than a little disappointing. Five samples from the log-boat were combined to form a single 152-year sequence, this appears to represent the entire surviving sequence of rings present in the vessel, but it has not been dated against reference chronologies. Two other groups of archaeological timbers were combined into two other undated sequences; four of the short lengths of log produced a 217-year sequence, whilst a further three timbers from the *ex-situ* causeway stakes were combined to form a 142-year sequence, probably derived from a single tree. A large number of other archaeological timbers neither matched these nor matched with reference chronologies.

There is however one dated archaeological timber, but with the various potential problems of sample origin this is not necessarily what it claims to be. It is not like the rest of the archaeological material which tended to be humified and preserved through anaerobic conditions, instead it is a mineralised fragment much more like the bog oak material. I believe this could be a transposed sample number, or it could be a piece of bog oak incorporated into the archaeology, though we are unlikely to ever know. Note that this sample has so few rings that it would probably not have been dated if the bog oak material had not been analysed.

Acknowledgements

ARC, the operators of the Shardlow pit, provided permission to work on the site and continuous support and encouragement. Daryl Garton and other staff of TPAT were endlessly supportive and helpful. Chris Salisbury was always enthusiastic and always understanding of our personnel problems. Nigel Nayling (now at the University of Wales, Lampeter Dendrochronology Laboratory) provided practical help on our visits to the site, and much useful subsequent discussions. Jennifer Hillam undertook some of the initial analyses reported here. Robert Howard kindly supplied the data from the initial naturally deposited samples from the site. James Rackham, Cathy Groves (Sheffield Dendrochronology Laboratory) and Alex Bayliss (EH, Ancient Monuments Laboratory) provided useful discussion of the results. The latter kindly suggested improvements to the first draft of this report.

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Figure 1 Location map showing the Shardlow site

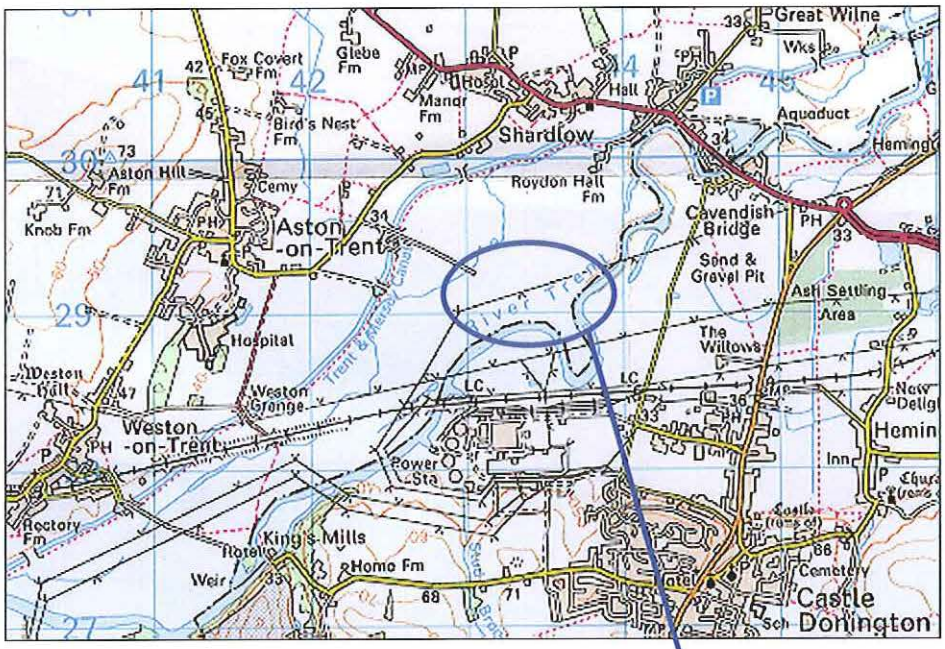

Figure 2 Bar diagram showing the relative positions of the samples forming Shardlow chronologies 4, 5, and 6. White bars are heartwood, hatching represents sapwood, narrow bars are unmeasured groups of rings. The relative year scale is arbitrary and there is no link between the three chronologies.

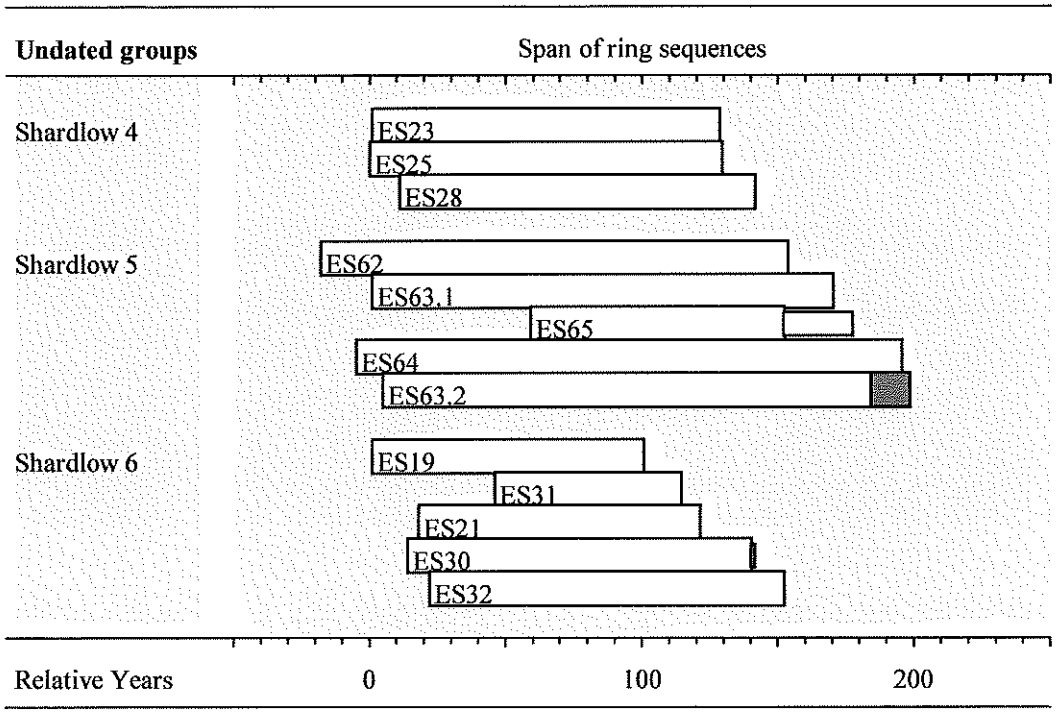

Figure 3 Bar diagram showing the chronological position of the dated archaeological timber. White bars are heartwood. The estimated date of death or felling period of the tree is also shown

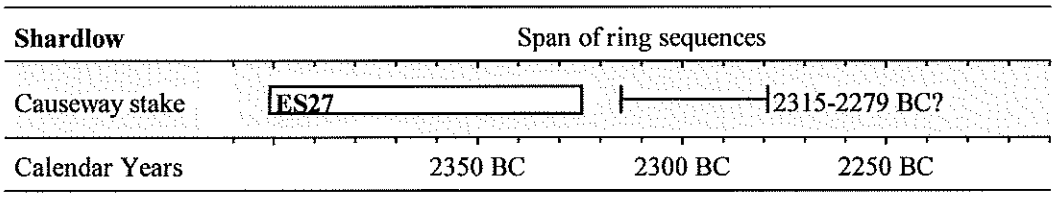

Table 1 List of archaeological samples from Shardlow

Unique number/code	Other details	Total rings	Sapwood rings	ARW mm/year	Sequence linked with other undated samples	Date of tree-ring sequence	Period of felling or death of the tree
ES22	BBI	240	-	1.02	-	Undated	-
ES23	Ex-situ stake	128	-	0.94	ES23, 25, 28	Undated	-
ES24	BAZ 2 samples	164	-	1.08	-	Undated	-
ES25	Stake T21	130	-	1.03	ES23, 25, 28	Undated	-
ES26	Stake T24	79	43+Bw	1.33	-	Undated	-
ES27	Stake T25	77	?H/S	2.73	-	2401 BC-2325 BC	2315-2279 BC?
ES28	Stake T26	131	-	1.25	ES23, 25, 28	Undated	-
ES29	Stake T32	57	12	1.87	-	Undated	-
ES55a	BAZ Same as ES24	138	-	1.10	-	Undated	-
ES56	BAN	127+30h	-	1.00	-	Undated	-
ES57	BBH 2 samples	160	-	1.49	-	Undated	-
ES58	BBI Same as ES22	257	-	0.96	-	Undated	-
ES59	BBJ	119	?H/S	2.12	-	Undated	-
ES60	BDA	162	-	1.18	-	Undated	-
ES62	BDC	172	?H/S	1.45	ES62, 63, 64, 65	Undated	-
ES63	BDE 3 samples	198	14+?B	1.45	ES62, 63, 64, 65	Undated	-
ES64	BDF	201	?H/S	1.42	ES62, 63, 64, 65	Undated	-
ES65	BDG	94+25h	-	1.83	ES62, 63, 64, 65	Undated	-
ES66	BDH	76	?H/S	2.74	-	Undated	-
ES70	BDE	230	-	1.65	-	Undated	-
Log-boat	Composite of 5 samples	152	H/S	1.43	ES19, 21, 30-32	Undated	-

Key: Total rings; where a second value follows a + sign this indicates that there are unmeasurable rings after the end of the measured series.
Sapwood rings; ?H/S = series possibly ending at the heartwood/sapwood boundary, H/S = definite heartwood/sapwood boundary, ?B = possible bark-edge present, +Bw = last ring complete to bark-edge – winter felled. ARW = Average ring width in mm/year

Table 2 Correlation *t*-values between the samples of the log-boat forming the Shardlow 6 sequence.

	ES21	ES30	ES31	ES32
ES19	4.62	7.82	6.02	7.56
ES21		6.57	5.49	5.36
ES30			9.86	5.80
ES31				6.59

Table 3 Ring width data for the undated Shardlow 6 log-boat sequence, the relative date scale is arbitrary

Years	**Ring widths (0.01mm)**									
1	112	90	109	90	119	138	186	187	112	92
	159	248	217	166	146	125	166	162	237	255
	204	200	238	268	251	168	137	96	83	99
	117	126	119	146	176	166	174	227	126	140
	138	194	166	190	176	243	166	219	242	346
51	321	103	94	75	77	104	96	94	103	122
	123	112	127	113	156	179	200	157	173	169
	100	61	61	69	93	84	93	102	127	131
	166	156	133	96	85	71	74	91	99	107
	109	107	106	162	145	149	168	182	151	215
101	157	159	142	129	92	99	131	116	143	120
	125	151	136	151	156	175	121	146	128	149
	127	156	163	164	150	199	169	196	172	208
	130	127	114	131	91	142	125	115	146	129
	147	153	124	124	119	131	122	103	105	177
151	160	96								

Table 4 Correlation *t*-values between the samples forming the Shardlow 5 sequence, - = *t*-value less than 3.0

	ES63.I	ES63.II	ES64	ES65
ES62	4.33	-	3.38	5.51
ES63.I		9.57	10.59	6.05
ES63.II			15.49	5.21
ES64				5.12

Table 5 Ring width data for the undated Shardlow 5 chronology, the relative date scale is arbitrary

Years	**Ring widths (0.01mm)**										**No of samples**									
-3							580	522	444	460							1	1	1	1
1	473	302	503	305	300	285	282	351	91	165	1	1	1	1	1	1	1	1	1	2
	149	177	221	179	188	219	312	301	425	326	2	2	2	2	2	3	3	3	3	4
	345	264	253	256	289	257	395	334	304	112	4	4	4	4	4	4	4	4	4	4
	105	122	108	137	167	204	247	311	268	322	4	4	4	4	4	4	4	4	4	4
	253	354	235	214	261	304	209	273	286	301	4	4	4	4	4	4	4	4	4	4
51	108	79	92	106	115	148	87	88	109	101	4	4	4	4	4	4	4	4	4	4
	147	90	100	91	114	91	101	77	80	96	4	4	4	4	4	4	4	4	4	4
	80	80	93	145	162	104	88	88	117	78	4	4	4	5	5	5	5	5	5	5
	71	105	104	91	73	98	135	112	87	78	5	5	5	5	5	5	5	5	5	5
	80	85	96	131	124	125	141	116	72	84	5	5	5	5	5	5	5	5	5	5
101	92	106	124	129	107	71	76	86	96	106	5	5	5	5	5	5	5	5	5	5
	113	107	104	135	115	174	89	95	68	108	5	5	5	5	5	5	5	5	5	5
	106	90	143	140	110	150	149	124	128	110	5	5	5	5	5	5	5	5	5	5
	103	133	120	166	128	180	191	139	140	152	5	5	5	5	5	5	5	5	5	5
	115	148	178	149	134	185	128	135	147	176	5	5	5	5	5	5	5	5	5	5
151	172	208	170	187	183	247	207	187	229	172	5	5	5	5	5	5	5	5	5	5
	139	169	168	230	213	225	261	197	206	212	5	5	5	5	5	5	5	4	3	3
	149	200	279	228	136	96	71	87	64	72	3	3	3	3	3	3	3	3	3	3
	83	86	90	87	100	134	85	73	96	100	3	3	3	3	3	2	2	2	2	2
	72	59	53	61	69	74	71	89	95	84	2	2	2	2	2	2	2	2	2	2
201	76	73	73	62	61	56	51	53	62	65	2	2	2	2	2	2	2	2	2	2
	42	60	40								1	1	1							

Table 6 Correlation *t*-values between the samples forming the Shardlow 4 sequence

	ES25	ES28
ES23	15.36	6.52
ES25		8.01

Table 7 Ring width data for the undated Shardlow 4 chronology, the relative date scale is arbitrary

Years	**Ring widths (0.01mm)**										**No of samples**									
0										401										1
1	416	355	314	236	175	271	142	79	63	138	2	2	2	2	2	2	2	2	2	2
	133	108	110	84	110	121	126	120	154	142	3	3	3	3	3	3	3	3	3	3
	138	93	111	76	99	94	95	158	160	152	3	3	3	3	3	3	3	3	3	3
	109	111	113	84	123	117	79	103	90	78	3	3	3	3	3	3	3	3	3	3
	96	78	106	92	74	77	79	76	118	109	3	3	3	3	3	3	3	3	3	3
51	89	72	71	53	51	72	72	83	85	84	3	3	3	3	3	3	3	3	3	3
	136	144	135	117	137	110	98	83	68	69	3	3	3	3	3	3	3	3	3	3
	98	123	112	114	116	114	115	114	116	87	3	3	3	3	3	3	3	3	3	3
	92	94	103	79	100	74	122	101	104	112	3	3	3	3	3	3	3	3	3	3
	112	98	127	85	92	100	85	101	87	125	3	3	3	3	3	3	3	3	3	3
101	116	105	107	94	130	95	82	88	79	90	3	3	3	3	3	3	3	3	3	3
	112	112	84	80	84	76	97	117	81	73	3	3	3	3	3	3	3	3	3	3
	68	89	88	84	102	104	110	91	86	83	3	3	3	3	3	3	3	3	2	1
	103	112	95	102	88	98	72	63	67	87	1	1	1	1	1	1	1	1	1	1
	114										1									

Table 8a Correlation *t*-values between the dated bog oak elements of the Shardlow 2 sequence and **ES27**.

	ES27
ASQ.1.3	4.79
ASQ.1.4	6.03
ASQ.7.2	5.09
ASQ2.2	3.35
ASQ2.3	3.73
ASQ2.5	5.44

Table 8b Correlation *t*-values between **ES27**, and the Shardlow 2 sequence (of which **ES27** is a component part) and external reference chronologies, note that the English prehistoric chronology is not independent of the other reference chronologies quoted.

Region or County	Details of reference series	**ES27** 2401-2325 BC	Shardlow 2 2508-2272 BC
England	England prehistoric chronology (Hillam pers comm)	6.40	9.99
Cambridgeshire	Holme Fen (Brown pers comm)	3.98	6.26
Nottinghamshire	Langford chronology 3 (Hillam 1998)	6.60	7.45
Nottinghamshire	Para Trent chronology 1 (Brown pers comm)	6.34	11.41

Table 9 The ring width data for the **ES27** sequence, dated 2401-2325 BC inclusive

Date	**Ring widths (0.01mm)**									
2401 BC										325
2400 BC	559	221	354	294	553	362	425	333	178	216
	304	215	296	316	262	242	287	163	280	352
	371	323	223	190	215	224	172	202	293	366
	353	546	197	152	138	217	316	168	344	282
	415	384	403	378	339	348	206	179	265	372
2350 BC	317	161	253	164	178	327	237	239	159	169
	150	133	154	163	346	245	268	392	470	376
	200	158	177	160	191	119				