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Mill Lodge Farm, Great Ryburgh, Norfolk

Tree-ring Analysis of Oak Timbers

Ian Tyers

Scientific Dating

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Summary

Dendrochronological analysis of oak coffin timbers excavated in Great Ryburgh, Norfolk was undertaken. The three dated coffins were probably constructed in the first half of the eighth century AD. This report archives the dendrochronological results.

Contributors

Ian Tyers

Acknowledgements

My thanks to James Fairclough, archaeologist MoLA, Matt Champion, archaeologist MJC-associates, Gary Boyce, landowner, and especially Shahina Farid, Historic England, for their invaluable assistance with the site sampling.

Front cover image

A grave from Great Ryburgh under excavation. [© MOLA]

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Introduction

This document is a technical archive report on the tree-ring analysis of oak timbers from Great Ryburgh, Norfolk excavated by Museum of London Archaeology (MOLA) on behalf of the landowner, Mr Gary Boyce, between January and July 2016. 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 on the material.

Great Ryburgh lies *c.* 5 km south-east of Fakenham in Norfolk. A group of middle Saxon burials were located during landscaping works on the edge of the river Wensum (Fig. 1). A total of 88 articulated human skeletons were excavated from a well-ordered cemetery (Fig. 2). The individuals had been placed in wooden coffins some of which survived in the partially waterlogged conditions. The cemetery may have been demarcated by a large ditch, whilst a small rectilinear structure within the cemetery may be a chapel or church.

Samples were collected in June 2016 from 16 coffin boards from five burials, the bases and a few surviving lids from *c.* 60 log coffins, and a handful of structural timbers associated with a small building and a boundary line. The rest of the coffin timbers had either lost their structural integrity or they only survived as staining in the soil. The excavation records used a single sequence of 4-figure numbers for the timbers, the grave cuts, the skeletons and the fills, all within the range *c.* 2000 to *c.* 3200. This report uses the grave numbers, prefixed by G, and the wood numbers, prefixed by W, to clarify the tables, figures and discussions. In Tables 1 and 2, and Figure 3 the grave numbers are used to group together the timbers from each grave.

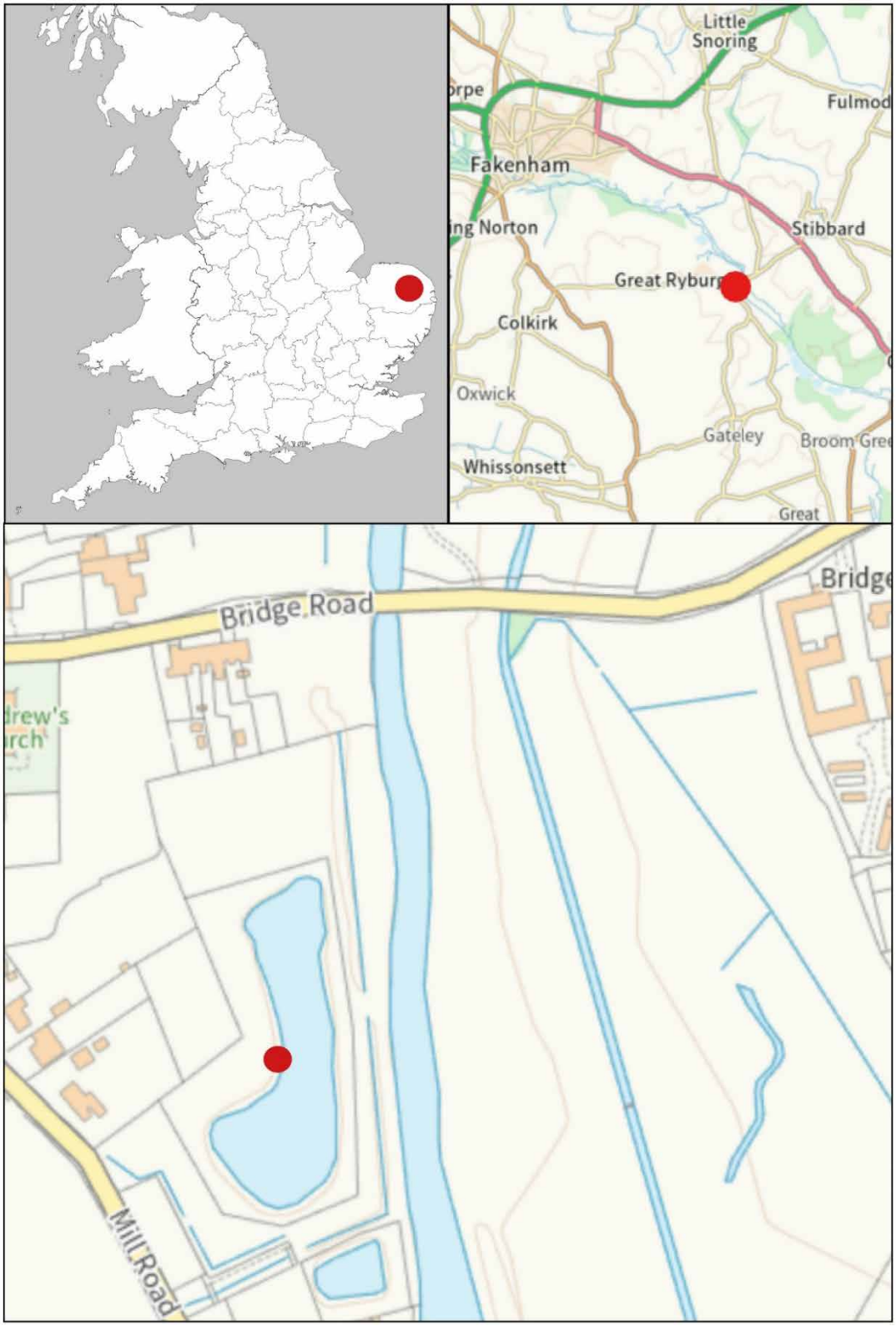

Figure 1: Maps to show the location of Great Ryburgh, Norfolk and the location of the site. Scale: top right 1:150000; bottom 1:3000. [© Crown Copyright and database right 2024. All rights reserved. Ordnance Survey Licence number 100024900]

Figure 2: Plan showing the location of timbers sampled for dendrochronology from Great Ryburgh. [© MoLA]

Methodology

The plank timbers and structural timbers were sampled by the removal of cross-sectional slices by handsaw at locations that provided a combination of the maximum numbers of rings, and/or retained likely original outer surfaces. Each of the log coffin timbers was lifted, and a section cut from its thickest end. These samples were not always complete cross-sections. Due to the excavation timetable and its limited budget this sampling was undertaken by the author with the invaluable assistance of Shahina Farid from Historic England. This sampling may seem relatively *ad hoc* but it can be safely assumed that the best available tree-ring material was recovered from the site. These sections were taken off site, and they were subsequently sub-sampled for the least distorted or knotty radii, apart from those sections being conserved. Each sample was subsequently placed in a deep-freezer for 48 hours in order to consolidate the timber. A surface equivalent to the original horizontal plane of the parent tree was then prepared with a variety of bladed tools. This preparation revealed the width of each successive annual tree ring. Each prepared sample could then be accurately assessed for the number of rings it contained, and at this stage it was also possible to determine whether the sequence of ring widths within it could be reliably resolved.

Tree-ring dating employs the patterns of tree-growth to determine the calendar dates for the period during which the sampled trees were alive. The amount of wood laid down in any one year by most trees is determined by the climate and other environmental factors. Trees over relatively wide geographical areas can exhibit similar patterns of growth, and this enables dendrochronologists to assign dates to some samples by matching the growth pattern with other ring-width sequences that have already been linked together to form reference chronologies.

Timbers intended for dendrochronological analysis need to be free of aberrant anatomical features such as those caused by physical damage to the tree, which may prevent or significantly reduce the chances of successful dating.

Standard dendrochronological analysis methods (*see*, for example, English Heritage 1998) were applied to each suitable sample from each site. Complete or partial sequences of the annual growth rings were measured to an accuracy of 0.01mm using a micro-computer based travelling stage. The sequences of ring widths were then plotted on screen or onto semi-log graph paper to enable visual comparisons to be made between sequences. In addition, cross-correlation algorithms (e.g. Baillie and Pilcher 1973) were employed to search for positions where the ring sequences were highly correlated. Highly correlated positions were checked using the graphs and, if any of these were satisfactory, new

composite sequences were constructed from the synchronised sequences. Any *t*-values reported below were 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 need to have been obtained from a range of independent sequences, and that these positions were supported by satisfactory visual matching.

Not every tree can be correlated by the statistical tools or the visual examination of the graphs. There are thought to be a number of reasons for this: genetic variations; site-specific issues (for example a tree growing in a stream bed will be less responsive to rainfall); or some traumatic experience in the tree's lifetime, such as injury by pollarding, defoliation events by caterpillars, or similar. These could each produce a sequence dominated by a non-climatic signal. Experimental work with modern trees shows that 5–20% of all oak trees, even when enough rings are obtained, cannot be reliably cross-matched.

Converting the date obtained for a tree-ring sequence into a useful date requires a record of the nature of the outermost rings of the sample. If bark or bark-edge survives, a felling date precise to the year or season can be obtained. If no sapwood survives, the date obtained from the sample gives a *terminus post quem* for its use. If some sapwood survives, an estimate for the number of missing rings can be applied to the end-date of the heartwood. This estimate is quite broad and varies by region. This report uses a range of 10–46 rings (95% probability) for the local English material from Great Ryburgh (English Heritage 1998, 11).

Results and Interpretation

All the selected tree-ring samples were oak (*Quercus* spp.). The log coffins with insufficient rings for reliable ring-width dendrochronological analysis were not sampled, and some of the structural timbers associated with a chapel and a boundary also contained insufficient rings for analysis and were not sampled. Sixteen coffin boards, from five burials, 49 coffin logs, from 44 burials, and three structural timbers were sampled, measured, and analysed (Tables 1–3).

Eleven coffin boards cross-matched (Table 4), and the combined sequence was successfully dated (Table 5; Fig. 3). These dated timbers are middle Saxon and match to contemporaneous tree-ring sequences from East Anglia, London and South-eastern England (Table 5). A pair of log timbers (Timbers W2766 and W2769, both from Grave cut G2770) were cross-matched to each other (*t*-value 10.95, where W2769 spans relative years 1–147 and W2766 spans 67–138; Fig. 4) but these could not to be dated conclusively when compared to reference sequences. The remaining ring-width series are all unmatched and undated.

The eleven dated boards were from three plank-built coffins in three different graves, that yielded three, six, and two dated boards each. Three short sequences from two other plank-built coffins in other graves were undated, and two short sequences were also undated from one of the dated coffins. The dated material was quite remarkable: straight-grained, slow-grown, and very long lived. The boards survived as heartwood only and the site yielded a 456-year long tree-ring sequence dated as spanning AD 271–726 which is clearly local in origin (Table 5). It is a unique English tree-ring sequence since it covers the entire fourth century AD, and thus closes the gap between the Roman sequences ending in the later third and early fourth century AD and the Saxon sequences that typically begin in the early fifth century AD.

In the three dated burials the latest heartwood end dates are at AD 707 for grave G2660, at AD 721 for grave G2819 and at AD 727 for grave G2827 (Fig. 3). These give them *terminus post quem* dates after AD 717, AD 731 and AD 737 respectively. There is potentially a same-tree match (W2815 from G2819 and W2826 from G2827, *t*=18.75; Table 4) between two graves which were adjacent on site (Fig. 2). This link suggests both of these burials are from post-AD 737. The two most remarkable timbers were the east and west boards of G2819 (W2855 and W2869) which both contained more than 400 heartwood rings, and were from the same parent tree (*t*=29.18; Table 4). The poor burial conditions may have resulted in the loss of sapwood from all these datable samples. It is uncertain if significant amounts of heartwood were also lost due to fluctuating water tables.

If there has been significant heartwood loss the *terminus post quem* dates may be some decades earlier than the usage dates.

Table 1: Details of the analysed *Quercus* spp. (oak) dendrochronological samples from Great Ryburgh board coffins, sitecode ENF139720. [- no sapwood]

G=grave cut	W=wood	Cross-section (mm)	Rings	Sapwood	Average Growth Rate (mm/year)	Date of measured sequence	Interpreted result
G2576	W2668 east side	135 x 25	93	-	1.44	not dated	-
G2624	W2622 lid fragment a	120 x 10	80	-	1.51	not dated	-
" "	W2622 lid fragment b	100 x 10	48	-	1.94	not dated	-
G2660	W2657 south side	105 x 10	78	-	1.41	AD 440–517	after AD 527
" "	W2658 east side	240 x 30	248	-	0.94	AD 460–707	after AD 717
" "	W2659 base	390 x 10	240	-	1.61	AD 451–690	after AD 700
G2819	W2815 lid	280 x 30	129	-	2.14	AD 551–679	after AD 689
" "	W2818 base	440 x 35	248	-	1.74	AD 474–721	after AD 731
" "	W2853 north side	160 x 10	135	-	1.16	AD 421–555	after AD 565
" "	W2854 south side	260 x 30	151	-	1.59	AD 466–616	after AD 626
" "	W2855 west side	490 x 40	404	-	1.13	AD 290–693	after AD 703
" "	W2869 east side	400 x 30	412	-	0.97	AD 271–682	after AD 692
G2827	W2825 base	380 x 35	358	-	1.05	AD 321–678	after AD 688
" "	W2826 west side	400 x 30	281	-	1.40	AD 446–726	after AD 736
" "	W2837 north side	75 x 20	54	-	1.39	not dated	-
" "	W2838 south side	80 x 15	51	-	1.51	not dated	-

Table 2: Details of the analysed *Quercus* spp. (oak) dendrochronological samples from Great Ryburgh log coffins (bases unless specified). [?H/S possible onset of sapwood; - no sapwood; +40 etc, estimated number of rings in unmeasurable bands in the heartwood]

G=grave cut	W=wood	Rings	Sapwood	Average Growth Rate (mm/year)	Result
G2049	W2048	99	-	1.70	not dated
G2055	W2054 frag a	62	-	1.01	not dated
" "	W2054 frag b	70+40	-	1.07	not dated
G2522	W2521	38	-	3.93	not dated
G2526	W2525	45	-	1.22	not dated
G2529	W2530	75	-	1.34	not dated
G2573	W2572	102	-	0.75	not dated
G2581	W2580=W2577	49	-	2.19	not dated
G2590	W2587	77	?H/S	2.19	not dated
G2603	W2602	53	-	2.69	not dated
G2611	W2610	111	-	0.72	not dated
G2636	W2635	74+20	-	1.20	not dated
G2642	W2641	40+79	-	0.76	not dated
G2646	W2645	106	-	1.06	not dated
G2650	W2649	52	-	1.14	not dated
G2654	W2653	40	-	1.67	not dated
G2681	W2680	74	-	0.94	not dated
G2685	W2683	62	-	1.82	not dated
G2686	W2687	71	-	1.04	not dated
G2720	W2719	60	-	1.43	not dated
G2732	W2731	142	-	1.03	not dated
G2737	W2736	140	?H/S	1.49	not dated
G2744	W2743	5+38	-	2.94	not dated
G2749	W2748	69	19	0.78	not dated
G2765	W2764	98	-	0.76	not dated
G2770	W2766 lid	72	-	0.99	not dated, matches W2769
G2770	W2769 base	147	-	1.20	not dated, matches W2766
G2774	W2773	74	-	1.08	not dated
G2859	W2858	69	-	1.04	not dated
G2866	W2867	38	-	2.13	not dated
G2891	W2890	106	-	0.91	not dated
G2896	W2895	89	-	1.40	not dated
G2915	W2914	53	-	1.96	not dated
G2926	W2925	102	-	1.29	not dated
G2930	W2929	45	-	1.47	not dated
G2959	W2958	104	-	0.93	not dated
G2967	W2966 frag a	105	-	1.47	not dated
G2967	W2966 frag b	55	-	2.87	not dated

G2975	W2974	58	-	1.69	not dated
G2979	W2978	121	-	1.35	not dated
G2984	W2983	33	-	1.59	not dated
G2988	W2987	48+10	-	2.56	not dated
G2992	W2991	58	-	1.67	not dated
G3000	W2999	51	?H/S	1.75	not dated
G3009	W3008	35	-	2.53	not dated
G3014	W3010 lid	58	-	2.12	not dated
G3014	W3013 base	78	-	1.63	not dated
G3019	W3015 lid	64	-	1.13	not dated
G3019	W3018 base	90	-	1.12	not dated

Table 3: Details of the analysed *Quercus* spp. (oak) dendrochronological samples from other timbers from Great Ryburgh. [- no sapwood]

Timber	Item	Rings	Sapwood	Average Growth Rate (mm/year)	Result
W3121	boundary post	110	-	2.13	not dated
W3124	boundary post	31	-	3.11	not dated
W3158	building post	37	-	4.29	not dated

Table 4: Showing *t*-values (Baillie and Pilcher 1973) between the Great Ryburgh individual board sequences. [– *t*-values less than 3.0, \ overlap less than 25 years, bold are pairs of sequences potentially derived from the same tree]

	W2658	W2659	W2815	W2818	W2825	W2826	W2853	W2854	W2855	W2869
W2657	–	5.78	\	4.95	5.50	4.66	6.18	4.44	3.68	3.44
W2658		8.58	4.77	7.97	8.06	7.58	3.40	3.68	5.76	4.99
W2659			4.49	10.21	8.77	7.64	5.37	3.55	5.09	5.79
W2815				7.28	–	**18.75**	\	–	5.56	5.30
W2818					6.42	10.36	4.06	4.44	5.70	6.04
W2825						6.73	7.65	3.95	7.06	7.30
W2826							5.36	4.77	7.51	8.10
W2853								3.35	5.22	5.43
W2854									5.17	4.26
W2855										**29.18**

Table 5: Showing *t*-values (Baillie and Pilcher 1973) between the composite Great Ryburgh sequence and contemporaneous reference data.

	Great Ryburgh AD 271–726
Essex, Slough House Farm Gt Totham (Hillam 1990)	8.28
Berkshire, Old Windsor (Fletcher unpubl data)	7.95
London, Barking Abbey (Tyers 1988)	6.84
Suffolk, Greyfriars Road Ipswich (Hillam 1989)	6.34
Essex, Mersea Strood (Hillam 1981)	6.28
Suffolk, Brandon (Groves and Hillam 1986)	5.98
Site in North Kent (Nayling et al. 2020)	5.98
London, Westminster Jewel Tower Wharf (Brett unpubl data)	5.85
Cumbria, Carlisle Tullie House (Groves and Hillam unpubl data)	5.58
Staffordshire, Uttoxeter Quarry (Tyers 2022)	5.31
London, Cheapside (Tyers 1992)	5.30
Staffordshire, Tamworth 72-74 Bolebridge Street (Baillie 1992)	5.24

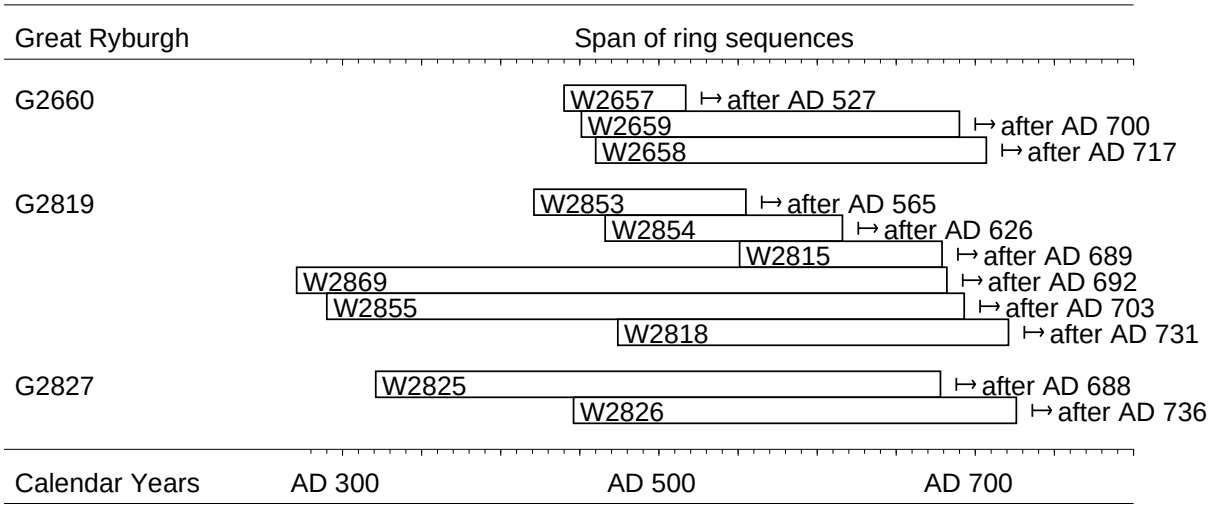

Figure 3: Bar diagram showing the calendar dating positions of the dated tree-ring sequence from three of the plank-built coffins from Great Ryburgh. The interpreted *terminus post quem* dates for their felling is also shown for each sample. [White bars are English oak heartwood]

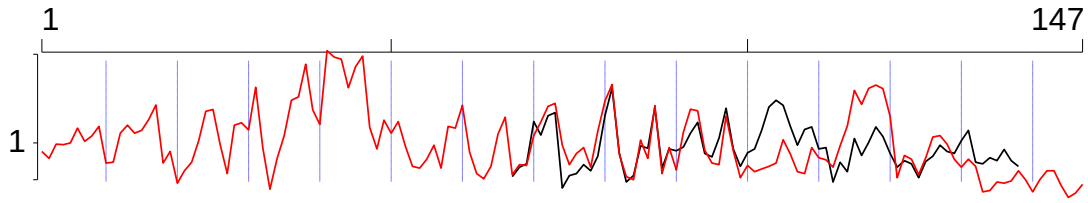

Figure 4: Diagram showing the relative positions of undated tree-ring sequences from W2766 lid (black) and W2769 base (red) from Great Ryburgh, *t*-value 10.95. These are both from grave G2770 and appear likely to be from a single tree.

Discussion

The board coffins were spread amongst the more numerous log coffins, and both groups respect the same alignments (Fig. 2), and so it may be expected that the groups were broadly of the same period. However, the much more numerous log coffins (timbers were analysed from 44 burials, although several others contained unsuitable material and others only retained stains or pulp) used oak timbers of a very different character. These hollowed log timbers were exceptionally knotty, often with both protrusions and holes through them, suggesting the more heavily lignified knots were differentially preserved. The depth of most of the coffins encompassed the waterlogged to non-waterlogged stratigraphic level, and perhaps water-level change over the centuries has affected the timber so that the assemblage is atypical in its preservation. The outer and inner surfaces of the log coffins were badly eroded with no, or very little, tooling surviving. The timbers surviving outer layers may not represent the original outer heartwood or the heartwood/sapwood transition of these logs. There was no sapwood on any of the board timbers and only one of the 49 log coffin timbers that were analysed retained definite sapwood.

The recording and analysis of the tree-ring sequences obtained from these log coffin samples have yielded almost no useful results. There is one pairing that is securely identified by a cross-match (Fig. 4). These two series represent one of only three lid and base pairs from which there were viable samples in both parts. This result strongly suggests that these two are from one tree, lid and base pairs were therefore at least sometimes derived from a single tree. The other two pairs of lids and bases produced shorter sequences and were not matched to each other, though it is possible they represent non-contemporaneous fragments from heavily eroded timbers.

The failure to date any of this material by ring-width dendrochronology is undoubtedly due to the repeated presence of series of distressed growth rings throughout their tree-ring sequences. The lack of synchronisation between the sequences suggests these were not caused by general local environmental factors, like widespread flooding, but are instead events that have impacted individual trees or small groups of trees. A possibility is that this material is coming from a group of over-aged pollard-type material, perhaps stag-headed oaks suffering from crown dieback. Such trees may have partially hollowed branches that would be attractive for making log coffins. Two other potential causes are very small-scale water table changes, only influencing a few trees at a time, or, trimming in different years for animal fodder in bad winters or springs. Perhaps there are two separate processes here, with some taken for new leaf growth in spring, the other for the stems and bark itself

in very bad winters. Livestock will eat smaller woody stems quite happily, even when not starving. There have been a number of studies of ‘tree fodder’ (Charles et al. 1998). The extreme contrast between the knotty and distressed log coffin trees and the straight-grained trees harvested for the board coffins is quite a puzzle.

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Appendix

Data of Measured Samples. Measurements in 0.01mm units

W2048

246	216	126	112	190	198	190	229	308	259
377	272	356	385	260	360	485	352	195	142
90	106	126	147	171	197	219	162	140	125
114	208	224	302	382	128	79	89	137	243
230	284	177	156	162	209	182	130	100	110
213	183	180	241	199	168	122	186	98	128
97	88	133	196	186	207	187	192	112	97
130	111	148	137	104	136	86	104	111	155
140	104	93	70	92	96	76	116	68	131
118	112	77	101	176	122	131	98	84	

W2054a

195	121	121	92	153	145	134	134	436	292
155	108	74	151	128	56	43	57	66	73
97	93	79	111	94	41	40	83	99	104
113	130	101	96	81	92	221	87	45	39
43	40	51	68	62	105	105	100	96	89
64	78	74	77	143	100	54	66	68	58
61	84								

W2054b

65	47	84	114	164	125	180	193	184	202
195	240	148	154	226	299	187	100	70	63
66	73	128	95	109	150	128	135	162	106
104	52	45	60	63	101	100	114	96	72
46	89	94	118	113	135	97	128	128	201
109	75	43	68	61	53	57	64	63	120
98	101	75	63	53	50	55	41	33	35

W2521

430	631	681	820	612	666	555	685	565	351
469	558	500	220	241	285	260	251	271	449
285	528	423	574	535	625	747	486	301	87
69	61	82	78	99	143	158	142		

W2525

272	354	323	180	232	225	189	186	162	168
176	120	96	96	210	155	131	113	120	91
85	68	65	79	51	58	54	68	59	51
63	45	47	68	56	65	52	79	56	115
115	110	110	165	90					

W2530

133	91	112	156	154	127	139	70	39	51
78	102	100	128	192	273	481	403	192	250
288	141	289	354	143	346	304	101	42	50

86 117 120 182 51 100 104 107 47 67
84 102 111 122 106 43 43 96 129 156
90 131 73 70 67 48 82 65 104 153
307 353 342 126 110 86 79 43 40 45
56 53 67 77 76

W2572
300 312 250 168 37 30 37 39 67 78
76 82 76 101 117 95 125 58 48 38
74 62 76 91 96 69 45 43 91 103
131 128 102 105 127 36 33 45 41 52
47 27 41 61 98 67 75 88 59 48
47 66 122 129 90 88 44 80 35 20
26 40 32 33 35 35 28 32 34 34
56 58 78 66 42 58 70 79 67 91
89 34 24 23 43 64 42 67 94 103
77 119 102 111 93 100 106 95 53 55
52 96

W2580
378 380 422 448 375 270 368 277 182 215
146 303 367 270 316 194 102 206 299 163
215 201 233 257 206 203 199 184 137 213
186 167 124 140 96 110 178 144 139 149
209 182 212 132 162 218 148 120 182

W2587
442 300 354 327 329 520 446 447 516 395
444 467 493 547 617 610 407 360 426 324
169 237 265 354 342 206 106 134 141 106
83 79 58 62 57 50 55 70 87 98
104 91 107 104 83 92 102 83 75 75
68 77 92 101 128 125 192 254 237 173
205 200 133 138 143 111 118 138 185 198
177 204 315 229 169 133 163

W2602
336 415 499 456 449 387 383 183 130 142
241 332 453 527 650 505 389 364 397 310
166 110 232 248 198 133 183 233 298 267
281 155 152 130 204 221 231 222 218 241
129 135 188 265 303 289 299 280 217 143
108 98 156

W2610
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128

W2622a
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102 147 178 149 193 178 167 185 205 192
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81 80 139 175 224 210 178 122 49 71
108 162 162 172 179 166 127 148 188 121
164 179 173 77 53 93 111 120 160 182
102 70 71 121 154 155 170 236 167 176

W2622b
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197 123 70 79 107 97 119 160 219 133
227 223 94 63 125 153 145 166 220 290
323 230 150 145 229 236 135 232 248 245
295 304 311 311 275 261 188 384

W2635
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80 131 112 115

W2641
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46 74 55 99 94 78 73 112 66 64
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112 118 112 63 69 75 73 71 67 109
89 87 58 59 65 50 38 29 42 49
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W2645
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110 72 46 41 81 74 102 145 170 186
226 205 82 65 53 82 72 138 57 58
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93 48 41 61 52 54 56 79 107 123

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154 137 208 129 89 56 72 52 39 33
48 52 59 56 73 81

W2649
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108 187 135 131 152 199 216 267 115 87
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104 145 147 157 165 64 52 45 53 62
80 107 93 68 52 65 70 58 71 92
64 63

W2653
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294 221 216 317 342 236 169 129 170 129
109 95 112 71 68 107 119 70 92 77
91 72 67 93 93 67 76 102 71 106

W2657
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211 188 176 135 121 143 180 139 146 194
115 95 84 133 99 211 139 141 117 150
135 95 160 144 163 133 111 155 146 128
99 89 131 109 127 150 258 93 107 194
157 159 184 90 89 82 114 172 167 145
163 147 145 100 94 94 127 176

W2658
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144 91 78 100 86 102 104 101 155 114
77 87 79 82 87 93 77 69 85 77
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104 71 94 81 66 74 111 114 91 80
85 87 79 79 108 82 79 127 87 95
120 140 102 131 120 129 146 167 91 85
94 67 81 91 113 129 137 143 107 133
153 113 139 130 129 149 87 77 99 109
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126 89 93 67 82 61 58 84 91 108
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63 76 120 109 62 58 50 55 64 67
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131 82 121 72 93 104 98 116 101 131

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89 82 69 103 128 93 118 106

W2659
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151 113 114 86 108 137 153 147 142 150

W2668
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89 110 144 124 47 46 53 75 113 96
174 168 158 215 86 83 94 100 85 60
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212 132 129

W2680
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52 35 69 59 83 62 128 108 104 107
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57 60 80 79 76 68 63 100 59 80
57 81 98 103

W2683
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138 259 144 258 287 269 392 322 320 163
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257 252 264 233 171 109 149 97 134 144
237 174 181 164 120 178 153 203 229 189
301 217

W2687
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104 129 108 93 164 163 136 115 54 63
54 60 102 107 137 132 117 125 137 155
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84 74 98 104 92 46 75 55 89 107
74 55 102 114 112 97 94 114 81 67
88 86 116 118 119 83 99 103 86 111
81

W2719
116 119 107 227 323 263 143 227 185 129
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91 121 116 104 168 180 193 213 147 291
166 162 244 230 170 129 129 137 134 155
120 101 109 106 90 67 67 90 59 66
71 61 74 85 69 89 93 105 100 115

W2731
46 37 39 68 68 70 55 54 63 74
97 115 152 133 153 59 55 68 78 67
63 89 122 151 196 69 45 64 62 49
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91 87 65 120 191 125 115 95 90 113
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59 69 95 110 133 144 137 112 89 69
92 109 119 121 136 104 105 77 150 72
128 197 200 102 107 55 66 82 105 160
126 84 69 100 124 177 220 120 115 158
159 85 76 65 80 87 104 83 100 125
163 83 59 53 40 49 46 60 81 69
60 93 79 59 52 77 126 99 156 145
106 81 92 170 163 240 143 159 206 290
246 171

W2736
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161 168 179 227 320 168 200 86 80 74
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160 181 69 56 72 131 178 154 170 199
157 149 145 190 146 284 207 315 127 72
89 101 137 143 148 244 176 166 161 205
208 156 93 40 60 49 67 93 137 165
82 72 103 102 182 132 197 131 135 149
258 180 122 112 122 279 167 144 232 81
59 60 97 103 142 176 123 129 133 139
161 148 180 119 35 35 42 72 57 53
76 121 104 84 116 80 86 107 106 70
68 75 73 128 96 108 96 72 55 43

W2743
39 90 128 240 238 369 443 461 433 482
243 81 46 72 75 149 194 268 75 124
140 316 516 293 269 292 469 425 258 195
297 400 478 619 582 785 299 297

W2748
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77 58 56 74 95 78 78 79 73

W2764
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57 85 78 88 90 70 65 43 60 74
91 84 67 93 97 79 67 81 72 93
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101 95 94 73 49 65 62 60 59 71
74 81 62 74 81 63 60 59

W2766
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68 61 79 162 265 84 50 56 95 91
187 64 90 87 93 119 144 83 78 109
185 90 66 84 90 126 189 213 195 134
96 127 133 90 92 50 71 60 108 80
101 133 112 83 65 73 69 54 72 79
96 86 83 104 125 71 69 77 73 89
73 66

W2769
86 76 98 97 100 130 103 113 134 70

71	119	137	119	125	152	196	70	86	49
61	71	104	175	181	98	58	137	143	126
268	91	44	76	114	213	226	404	180	139
514	459	442	266	387	466	132	90	150	119
146	94	66	64	75	96	64	134	130	195
85	58	53	66	117	158	57	68	67	114
145	191	202	96	68	83	92	65	123	210
282	82	55	52	105	76	194	58	92	62
121	182	177	88	70	68	161	87	54	67
60	63	66	70	106	82	60	58	92	77
74	65	95	135	254	198	263	279	262	160
54	80	75	57	77	111	114	98	75	65
75	66	42	43	50	49	51	61	52	42
52	61	61	47	38	41	48			

W2773

74	61	75	78	88	117	125	183	121	65
88	86	98	148	178	132	241	229	308	130
57	47	80	87	92	67	61	75	87	120
145	213	81	54	69	89	69	106	68	131
136	82	51	93	75	88	87	143	142	92
88	92	53	50	55	79	112	87	106	157
158	120	126	201	118	70	66	54	74	93
117	181	178	146						

W2815

307	390	248	244	209	205	192	215	347	317
258	240	266	243	194	230	254	215	204	341
250	231	176	185	179	249	201	112	146	196
178	167	159	180	202	238	222	211	225	208
178	283	306	225	206	202	322	266	202	228
247	337	272	193	245	240	169	181	120	250
161	214	228	389	246	216	213	251	206	148
265	223	178	78	158	119	139	249	205	191
201	256	194	140	116	146	355	168	166	187
166	169	276	232	226	215	262	200	244	156
78	70	128	143	175	226	242	184	174	219
293	283	304	182	207	144	247	326	362	230
89	120	211	284	196	182	158	184	171	

W2818

297	413	451	422	366	351	158	87	167	218
365	270	326	170	306	284	152	159	255	215
279	277	352	207	194	319	352	241	283	147
78	88	98	214	202	245	213	185	149	145
94	121	185	338	307	228	223	179	218	123
253	167	184	206	219	249	228	354	240	209
278	180	234	354	233	139	121	164	85	41
25	30	94	91	64	170	178	118	177	168
145	123	118	74	114	213	180	216	189	173
158	107	121	143	177	210	238	116	120	67

77	51	75	64	40	71	67	64	64	108
111	103	134	116	75	82	72	104	100	142
132	106	164	286	251	146	128	227	259	321
174	159	118	84	83	82	130	112	110	97
127	105	153	221	228	176	179	230	162	291
177	265	115	63	123	94	91	102	183	158
161	180	218	409	265	137	226	240	187	125
105	121	114	136	154	117	92	67	68	76
120	143	129	155	159	205	156	184	191	133
46	39	42	56	73	135	118	66	74	110
180	175	186	192	204	229	220	187	144	252
241	237	310	183	216	191	192	227	207	149
198	257	362	214	227	145	217	136	120	149
270	278	266	163	168	252	100	252	171	194
253	165	168	130	189	132	156	168		

W2825

84	64	77	78	102	90	115	119	163	124
75	82	57	80	100	79	85	79	85	134
148	151	196	193	198	152	105	126	163	201
106	107	115	85	116	130	103	91	94	77
102	89	84	88	68	56	72	68	67	87
79	62	75	108	105	135	167	168	213	100
91	96	120	106	113	113	126	121	137	115
125	131	109	86	76	82	72	76	83	89
135	116	134	133	81	106	134	101	121	157
185	164	151	151	157	133	138	197	258	201
156	165	154	171	207	173	203	239	225	234
144	127	103	136	173	188	142	145	130	132
148	120	121	163	158	211	174	162	155	165
136	122	112	100	124	154	144	160	150	136
137	117	103	109	84	128	120	96	126	109
100	98	142	100	123	126	129	128	121	90
73	83	99	94	90	78	65	75	73	55
71	81	110	99	112	137	88	76	102	121
109	121	107	75	48	55	63	57	82	96
76	83	68	58	74	75	91	109	101	110
101	91	79	70	63	55	55	47	58	60
75	76	86	99	85	88	79	72	59	61
56	60	78	72	86	83	85	77	103	110
74	121	123	140	119	108	93	104	105	123
129	137	158	118	81	113	115	118	125	115
116	118	89	80	60	67	83	101	110	93
103	100	88	98	126	132	149	119	112	108
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80	114	115	73	82	84	72	84	92	126
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66	83	89	90	91	94	78	85	61	53
61	76	66	63	73	76	78	98	77	80
85	72	68	52	47	61	78	79	74	87
123	111	120	89	92	81	90	99	86	75

109 108 113 95 100 91 98 76 74 61
50 55 61 88 91 58 52 67

W2826
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137 163 117 102 103 129 138 165 164 148
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140 153 99 109 126 108 113 123 126 112
138 138 123 143 156 111 154 224 165 132
136 183 175 134 115 168 171 179 163 147
137 109 85 63 138 116 147 156 244 176
164 167 186 169 132 146 173 133 63 117
99 115 163 166 161 147 188 140 108 85
111 195 121 108 136 161 141 191 156 168
190 192 202 210 129 59 63 79 90 126
175 199 151 149 194 212 213 218 199 176
136 173 228 200 166 58 88 127 186 151
139 113 167 180 179 163 110 124 147 122
166 154 163 176 133 151 122 160 137 217
219 125 117 102 80 82 67 81 145 140
182 104 87 71 57 104 118 117 113 76
85 88 114 125 114 79 141 145 109 184
158

W2828
156 176 181 150 146 184 166 119 176 150
149 175 264 175 163 166 191 179 128 133
159 199 193 168 191 148 101 93 117 106
133 133 130 116 150 131 101 95 78 113
117 103 102 113 122 174 219 156 167 213
212

W2837
186 228 139 137 132 143 122 178 192 153
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125 61 141 137 137 119 97 174 141 113
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119 129 114 99 142 150 172 133 155 126
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W2853

172 226 171 241 208 177 147 168 266 190
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72 121 137 174 127 104 69 100 96 73
78 70 84 87 122 177 91 91 139 155
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104 93 94 100 92 77 95 88 131 123
123 133 147 152 146 110 175 107 100 87
63 72 80 119 119 108 144 116 116 171
110 154 129 131 128

W2854
166 171 208 216 198 141 149 170 194 232
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136 152 162 181 146 160 180 166 183 117
180 162 139 158 170 227 246 175 130 118
147 206 245 214 244 220 204 181 195 168
194 231 209 187 217 194 161 149 180 183
141 123 141 157 160 181 179 192 209 163
228 217 210 203 231 243 243 207 266 223
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94 96 135 164 144 159 151 157 136 128
154 146 145 209 141 120 107 87 106 92
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105 109 96 139 139 129 102 101 76 93
85 137 138 158 120 116 128 113 121 123
122 148 119 99 139 138 133 190 202 137
139

W2855
183 274 130 147 116 89 118 88 105 109
158 209 119 133 111 107 129 195 129 106
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113 97 101 87 88 89 99 100 105 124
99 154 104 85 97 121 104 96 119 138
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92 105 111 81 79 75 85 89 98 125
107 100 88 89 117 115 115 165 123 151
95 99 116 135 135 130 126 146 102 174
105 88 93 87 143 86 80 78 110 82
78 129 95 96 81 73 44 99 51 58
94 82 101 86 99 102 84 73 98 83
82 65 125 75 102 87 59 94 82 91
88 52 62 65 67 115 93 69 58 50
48 78 68 66 88 82 72 71 81 77
78 64 64 74 73 89 95 104 118 108

103	74	63	62	49	45	60	61	76	87
65	76	65	101	49	63	73	78	90	79
45	56	72	79	107	94	80	56	81	80
69	107	93	73	95	74	115	78	96	100
133	160	137	69	60	56	93	115	112	90
100	95	95	94	76	68	113	181	135	116
102	90	77	71	88	62	79	80	94	107
119	121	129	135	138	114	95	113	82	69
68	96	113	105	180	132	105	117	101	128
163	150	197	135	113	142	135	100	171	178
155	128	130	141	124	109	125	214	146	176
144	140	143	82	97	117	83	53	54	80
125	122	138	146	144	151	167	185	179	187
173	147	176	209	192	108	77	119	132	184
194	176	214	187	167	164	173	184	204	155
163	175	167	203	256	221	214	206	207	207
199	224	154	117	98	153	130	140	190	154
142	147	150	138	130	124	91	104	102	93
154	132	129	139	145	155	155	159	143	132
137	173	146	126	69	59	52	81	73	84
109	118	114	129	87	84	66	91	112	125
106	65	83	97	133	94	89	93	145	127
121	156	120	117	95	85	107	93	104	89
91	98	88	85						

W2858

112	60	47	37	58	81	84	70	81	112
106	75	134	162	145	143	76	110	93	69
85	103	81	63	40	35	28	28	34	45
69	60	44	38	43	38	34	49	72	67
95	67	78	87	89	99	127	88	152	127
81	69	92	87	275	286	430	460	227	289
167	126	114	84	97	111	127	83	82	

W2867

311	239	275	393	386	352	329	221	244	248
279	281	282	223	287	293	143	69	60	88
77	146	186	229	190	165	189	229	214	231
228	151	118	138	159	119	168	162		

W2869

167	161	169	211	171	168	75	59	74	110
147	88	92	104	195	156	61	121	106	123
192	90	105	93	56	78	50	62	83	100
148	69	86	74	66	87	144	95	72	88
76	42	51	62	74	97	105	89	91	63
51	47	50	52	62	67	76	82	106	87
99	84	66	64	88	77	75	85	109	93
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72	79	75	116	67	76	75	92	71	73
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82	87	61	63	70	88	58	75	99	92
118	101	64	50	52	76	98	83	84	74
81	89	82	71	51	92	130	92	97	71
68	64	63	83	62	79	80	94	107	119
121	129	125	114	94	88	87	71	58	58
77	89	95	128	98	99	95	70	107	139
123	163	110	83	87	81	78	103	132	114
105	103	100	93	83	91	131	121	137	128
103	103	66	85	88	65	63	52	71	99
114	110	144	153	126	132	139	127	153	143
127	149	144	135	85	66	90	95	137	143
134	189	153	139	106	113	135	144	129	171
152	147	153	155	171	193	160	181	147	159
168	137	108	76	90	97	101	145	159	139
123	114	127	123	102	111	105	102	102	152
139	120	122	140	147	142	174	153	145	143
163	156	121	84	65	67	92	96	91	116
142	120	143	141	121	95	118	162	147	92
70	70	112	130	103	122	102	114	129	148
127	136								

W2890

151	201	239	251	258	201	149	189	267	145
110	53	75	76	91	105	128	170	114	36
32	45	55	59	63	44	30	37	74	69
77	111	106	66	49	35	51	59	73	100
108	104	200	196	71	63	58	37	59	44
37	31	45	56	53	74	42	39	57	52
85	146	181	198	97	71	62	44	55	86
143	97	109	102	50	59	48	75	82	78
61	105	62	52	68	65	99	113	124	184
151	154	136	124	66	58	37	42	36	45
59	56	45	51	53	48				

W2895

153	202	122	121	141	191	177	173	194	230
87	60	71	105	139	142	123	144	148	209
150	76	92	71	67	126	127	214	78	51
75	114	76	72	86	133	138	128	121	131

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153 133 130 129 169 195 201 248 236 200
140 242 234 194 157 167 128 151 132 133
141 189 140 107 111 112 84 112 105

W2914
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211 190 270 203 118 218 232 176 168 145
191 158 155 122 179 139 198 236 185 127
179 107 101 148 157 130 104 151 118 192
194 218 223

W2925
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117 64 93 97 109 66 49 38 53 82
83 96 110 116 130 142 132 101 148 154
156 201 89 60 84 128 84 70 64 70
73 92 56 80 72 187 96 165 204 173
223 187

W2929
260 248 188 278 278 234 200 154 139 80
115 121 91 97 189 208 316 201 247 175
150 317 332 160 67 50 48 53 70 95
151 104 87 87 72 75 53 71 105 109
117 111 104 109 106

W2958
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255 174 196 94 46 60 51 61 146 118
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62 43 50 49 43 58 50 80 139 125
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116 89 106 77

W2966a
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190 159 116 107 110 123 134 136 119 115
104 130 168 90 116 135 59 56 52 70

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126 159 159 143 115 109 106 156 146 167
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219 183 218 243 224 263 178 167 294 192
268 299 286 330 105 51 41 46 40 43
55 79 84 82 83 88 105 126 93 90
98 82 88 77 95 128 157 142 126 111
98 155 157 146 171

W2966b
233 277 247 348 420 457 547 308 581 288
327 410 412 216 191 259 286 248 279 370
325 359 396 267 207 248 392 339 288 224
382 392 200 136 410 246 251 191 119 107
189 108 188 171 208 172 155 179 149 356
283 464 449 299 228

W2974
220 354 253 258 336 231 257 310 405 288
357 425 303 282 295 307 177 78 51 54
112 124 218 143 243 132 88 107 129 92
106 140 165 147 127 47 44 48 63 96
100 74 100 59 55 53 87 133 171 162
151 143 116 118 144 145 195 185

W2978
233 133 221 647 655 378 350 231 306 272
191 761 260 67 59 97 119 80 82 90
58 49 53 112 87 78 97 109 89 51
55 46 71 82 141 166 44 61 77 98
59 62 118 190 123 100 187 324 398 313
288 195 237 146 131 149 221 252 105 43
46 52 75 85 80 91 94 59 67 64
56 83 98 113 69 58 50 56 50 42
50 52 59 73 64 68 99 122 175 95
52 54 48 60 80 99 84 85 89 72
56 73 96 154 160 215 177 183 150 135
138 154 195 277 233 140 76 52 72 69
87

W2983
352 198 164 130 118 184 260 180 88 103
166 222 159 127 133 181 264 270 181 206
162 190 106 68 81 73 89 114 190 187
126 86 77

W2987
217 176 257 351 328 302 315 434 154 103
121 105 137 136 168 232 271 215 301 359
325 321 268 255 292 241 386 344 396 536
586 442 324 320 274 218 145 107 182 111

98 126 175 174 161 274 345 176

W2991
197 150 139 107 138 100 87 114 75 70
66 99 63 61 51 60 104 72 140 233
237 134 118 226 355 353 191 219 223 125
89 145 182 204 274 148 71 59 45 57
46 78 106 134 195 207 183 82 119 222
352 456 373 479 266 293 349 180

W2999
463 494 751 634 465 491 562 506 161 87
128 108 89 78 99 89 104 108 106 80
68 48 79 73 96 101 113 85 80 84
109 152 163 103 142 138 143 75 69 89
150 122 147 124 109 97 77 128 135 118
110

W3008
149 114 227 253 403 351 309 205 340 82
127 219 445 470 391 265 381 426 255 243
263 226 164 81 85 86 107 121 309 282
320 223 389 307 224

W3010
707 698 407 151 68 66 80 165 329 299
537 203 62 59 88 242 167 228 171 186
176 130 229 291 221 146 88 50 41 66
62 87 121 267 241 205 124 57 55 66
134 149 187 233 390 211 92 65 119 336
396 386 496 321 175 302 330 364

W3013
427 359 309 263 302 244 297 334 281 234
324 419 105 37 35 86 79 75 60 116
127 108 159 197 187 156 198 257 207 183
82 62 48 48 51 64 79 104 139 168
148 162 120 142 246 230 229 197 210 289
184 165 216 231 149 144 101 94 118 97
70 114 110 126 142 121 69 93 132 132
164 177 103 167 163 95 106 161

W3015
306 166 101 109 145 187 123 142 272 234
127 130 76 120 85 45 41 42 58 96
59 117 108 79 78 85 73 72 69 56
81 83 101 131 127 173 145 217 160 144
86 92 82 81 102 102 125 156 100 134
140 144 147 86 127 86 62 57 69 79
82 117 130 107

W3018

297	339	328	192	265	171	167	216	71	43
57	60	70	59	102	122	83	82	98	84
98	67	42	50	45	57	41	55	82	102
85	69	77	79	91	129	133	145	107	195
182	142	66	58	61	101	125	143	133	103
73	57	61	66	97	98	48	52	55	62
68	103	89	132	112	71	56	43	66	91
104	129	142	152	218	206	163	210	102	112
87	62	83	172	128	155	138	153	130	130

W3121

414	272	193	363	501	581	509	619	200	114
82	125	105	132	134	158	198	211	196	93
132	235	331	207	258	400	363	280	234	246
181	131	68	67	67	138	154	168	157	236
213	201	248	250	226	108	135	155	79	131
162	185	178	164	188	144	123	124	148	215
132	167	145	124	151	147	150	172	160	290
261	262	257	235	189	214	173	273	231	197
206	204	183	199	290	377	279	312	343	289
348	260	179	197	144	95	151	166	177	210
168	171	175	304	225	163	237	274	305	250

W3124

502	332	248	403	428	281	355	288	268	164
67	72	92	112	112	106	170	188	313	495
599	529	484	325	411	425	224	342	329	463
517									

W3158

725	293	425	660	201	115	216	297	436	342
523	484	724	532	847	815	691	789	659	391
158	125	125	142	243	425	394	588	505	581
135	348	289	232	295	478	654			

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