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Summary

The analysis of 43 timbers from five wells is described. Four of the wells were 4th century AD in date; the fifth, which produced five timbers, was from the early Saxon period. The majority of the timbers, all but two of which were oak, had insufficient rings for dating purposes. However a felling date of AD309 was obtained for a timber from one of the wells, and a felling date range of AD316-348 for six timbers from another. At the present time, these are the only 4th century AD timbers in England dated by dendrochronology.

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Introduction

The 1988-91 excavations at Godmanchester near Huntingdon (NGR TL25607140) by the Central Excavation Unit under the directorship of F McAvoy, uncovered remains dating to the prehistoric, Romano-British and Anglo-Saxon periods. These included five wells still containing some of their timber lining. Three of the wells (10400, 10466, 10495) were associated with a high-status building, probably a bath-house. Pottery finds suggested a *terminus post quem* of mid 4th century AD for the wells. A similar date was postulated for a fourth well (10698), excavated in 1990 to the west of the main building complex. The remaining well (1127) was excavated in 1991 and was Early Saxon in date.

The wells and their timbers

Well 10400, a rectangular-shaped well, was lined on its four sides by four rows of timbers. The bottom three layers were held together by lap joints; the upper timbers were unjointed. These produced 16 samples for analysis (Table 1). A further two samples (8158, 8143) were taken from unattached timbers associated with the second and third rows respectively.

Well 10466 produced 12 tree-ring samples from its two rows of timbers. The four timbers in each row were joined together at the corners by tenon joints; those on the bottom row were also supported by corner struts.

Well 10495 produced a single row of timbers held together at the corners by dovetail joints. Each of the four timbers was sampled for analysis.

Well 10698 was uncovered during gravel quarrying operations. The timbers were not *in situ* but had been left as a discrete pile by the quarry excavator. Four timbers were sampled for analysis.

Well 1127 was lined by a rough frame of timbers around an inner circular wattle. Five samples were taken from the frame timbers.

Methods

The samples were prepared by freezing them for at least 48 hours and then cleaning their cross-sections with a surform plane (Hillam 1985). When the samples had thawed, a note was made of their cross-sectional dimensions and the orientation of the annual rings (Table 1). A note was also made of timbers which might have come from the same tree and whether they were oak or non-oak. Oak is easily recognisable by its distinct annual growth rings and wide medullary rays which run radially from pith to bark (Wilson & White 1986). Any non-oak species were identified by taking thin sections and identifying key characteristics as set out in, for example, Schweingruber (1978).

Samples which were unsuitable for dating purposes were rejected at this stage. These include samples with unclear annual rings since they are likely to produce inaccurate data. Samples with less than 50 rings are also usually rejected because short ring sequences may not be unique (Hillam *et al* 1987). However, samples containing 30-50 rings might be measured if there is more than one sample from a context and if they have bark edge.

The ring widths were measured to an accuracy of 0.01mm on a travelling stage built in the Department of Geography, City of London Polytechnic. The stage is connected to an Atari microcomputer which uses a suite of dendrochronology programs written by Ian Tyers (pers comm 1992). The measured ring sequences were plotted as graphs using an Epson HI-80 plotter attached to the Atari. The graphs were then compared with each other on a light box to check for any similarities between the ring patterns which might indicate contemporaneity. The Atari is also used to aid the crossmatching process, although it is the quality of the visual matching which dictates whether or not a match is accepted. The crossmatching routines are based on the Belfast CROS program (Baillie & Pilcher 1973; Munro 1984), and

all the Student's *t* values quoted in this report are identical to those produced by the first CROS program (Baillie & Pilcher 1973). 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). Student's *t* values greater than 10 usually indicate that two timbers originated in the same tree, although this does not necessarily imply that all timbers giving levels of correlation less than 10 are from different trees. Data thought to derive from a single tree are averaged before being included in a site master to avoid bias.

Dating is achieved by crossmatching ring sequences within a site or structure, combining the matching sequences into a site master, and then testing that master for similarity against dated reference chronologies. A site master is used for dating whenever possible because it enhances 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. There are relatively few chronologies covering the late Roman period, particularly compared to the number available for the early Roman or medieval periods. Long chronologies from Ireland (Brown *et al* 1986) and Germany (Becker 1981; Hollstein 1980) span all of the Roman period whilst, more locally, there are short chronologies from London (eg Hillam 1987a; 1990), but these generally end in the mid 3rd century AD. The most recent Roman chronologies are those from Peter's Hill and Sunlight Wharf, but these probably represent different parts of the same structure. These chronologies cover the periods AD191-294 and 225-293 respectively (Hillam 1987b).

Once a sample has been dated, the tree-ring date has to be related to the felling date of the tree before an indication of the construction date can be obtained. If the 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 dormant period in winter or early spring. This is referred to as "winter felled". If the ring is

incomplete, felling took place during the growing season in late spring or summer (referred to as "summer felled"). In the absence of bark edge, felling dates of oak timbers are calculated using the sapwood estimate of 10-55 rings. This is the range of the 95% confidence limits for the number of sapwood rings in British oak trees over 30 years old (Hillam *et al* 1987). Where sapwood is absent, felling dates are given as *termini post quem* by adding 10 years, the minimum number of missing sapwood rings, to the date of the last measured heartwood ring. The actual felling date could be much later depending on how many heartwood rings have been removed.

When the felling date range or *terminus post quem* has been calculated, factors such as seasoning of timber, reuse, stock-piling, or repairs have also to be taken into account. Timbers for a timber lined pit, for example, will not have been seasoned but they may be reused. Thus whilst the tree-ring dates for the measured rings are precise and independent, the interpretation of these dates often requires other archaeological evidence.

Results

Well 10400

There was a marked difference between the oak timbers in the bottom row and those in the top three rows. The latter were tangential planks measuring 25- 55mm in thickness, although 50-55mm was most common (Table 1). Their widths varied from around 300mm for the second row, 325mm for the third, and 140-245mm for the fourth row. The bottom layer of timbers by contrast were squarer in shape with cross-sectional dimensions of approximately 135x110mm.

All the timbers had been cut from fast-growing (and therefore wide-ringed) oak trees, and many contained knots. Sapwood was present on eight of the timbers. Only one sample (8164) contained more than 50 rings. Its rings were measured as were those from the three samples with more than 40 rings, all of which had bark edge (8159, 8165, 8166). The ring patterns of 8164 and 8166 crossmatched (t = 4.9) to give a single sequence of 56 rings.

This did not match any of the other ring sequences from Godmanchester, nor was there any correlation with dated reference chronologies. It is unlikely that this short sequence from well 10400 will ever be reliably dated.

Well 10466

All the timbers were oak. The eight timbers lining the four sides of the well were tangential planks measuring 250-320mm by 50-100mm in cross-section. The corner struts were smaller timbers measuring approximately 50x30mm. The latter had 9-16 annual growth rings and were therefore unsuitable for dating purposes. The larger timbers tended to be knotty and relatively wide-ringed, but six had more than 50 rings. Of the bottom row timbers, only 8162 with 31 rings was rejected; the others had 62-91 rings, and three retained some sapwood rings. In the upper row, 8147 was too knotty for accurate measurement, but the remainder had 66-82 rings including one with 2 rings of sapwood.

When their ring sequences were compared against each other, it became apparent that some of the timbers had come from the same tree. The ring patterns of two of the bottom row timbers (8150, 8163) were almost identical, the match between them giving a *t* value of 13.0, suggesting an origin in the same tree (see above). Three of the upper row timbers (8146, 8148, 8149) are probably from another tree (Table 2). The bottom timber 8145 might also belong to the same tree group as 8146 etc but this is less certain. The ring width data of 8146/8148/8149 were therefore included in the four sample master as a single tree and those from 8145 were added as a separate tree. The combined data from 8150/8163 produced a ring sequence of 91 years in length, whilst 8145 and 8146/8148/8149 produced one of 84 years. There was a weak match between these two sequences (hereafter referred to as S2 and S4) which gave a *t* value of 3.7. The visual match was not considered good enough for the two sets of data to be combined at this stage of the analysis. Instead they were tested separately against reference chronologies covering the Roman period. S2 produced *t* values of 5.0 and 4.0 respectively with chronologies from Peter's Hill, London (Hillam 1987b) and Germany (Hollstein

1980) when its rings spanned the period AD225-315 (Table 3). S4 gave *t* values of 4.6 and 6.5 respectively with Peter's Hill and the Belfast long chronology (Brown *et al* 1986) over the period AD224-307. These results are consistent with the tentative S2/S4 match described above. Since the visual matches with the reference chronologies are also acceptable, the tree-ring dates can be accepted with confidence given the reference data available at present.

Well 10495

The four oak timbers from this well were all tangential planks with cross-sectional dimensions of approximately 320x45mm. The samples contained 25-31 wide rings with some sapwood remaining on three of them. None of them were suitable for dating purposes.

Well 10698

The four oak timbers from 10698 differed from most of those described above in that they showed fewer signs of working and tended to come from almost complete tree trunks (Table 1). Cross-sectional dimensions were 180-230mm by 125-180mm. 8191 was the most complete trunk. It had 28 rings, 6 of which were sapwood, and had been felled in winter. The remainder had been trimmed on at least two sides. They contained 69-95 measurable rings. Complete sapwood was preserved on two sides of 8194, although the outer few rings were too narrow for accurate measurement. The measured ring sequence had 95 rings, and a further 5 complete and 1 incomplete outer rings were counted, indicating that the parent tree was felled in its 101st year.

8192 and 8193 both contained knots but it was apparent that the two ring patterns were very similar. Their ring width data were therefore combined to produce a single sequence of 93 years. This did not match 8194 nor any of the other Godmanchester sequences. Comparison with dated reference chronologies was also unsuccessful and 8192/8193 remains undated.

The 95-year 8194 sequence gave a *t* value of 3.9 when it was compared with S2. Although the visual match was considerably

better than that between S2 and S4, the two sets of data were kept separate. Instead 8194 was tested independently against reference chronologies. *t* values of 4.1 and 4.5 respectively were obtained against two London chronologies, Peter's Hill and Sunlight Wharf (Hillam 1987b) when its ring sequence spanned the period AD209-303. This is consistent with the 8194-S2 match described above.

On the basis of the above results, the data from S2, S4, and 8194 were combined to produce the 107-year master curve, GODMAN, which dates to AD209- 315 (Table 4). However, two points should be noted: first, the level of correlation between the three data sets is relatively low and second, S2 tends to show more similarity with German data whilst S4 is more similar to the Irish data. This may indicate that the timber came from different sources. For this reason it may be more valid to keep the data separate, and therefore they are listed separately in Table 5. This is considered particularly important because the newly dated Godmanchester sequences extend existing Roman tree-ring sequences by 21 years and could form the basis for dating other late Roman timbers. The ring width data of all the individual samples are stored at the Sheffield Dendrochronology Laboratory where they can be consulted.

Well 1127

The only non-Roman timbers to be examined were generally small. 8202-4 were oak; 8205 was identified as *Salix/Populus spp.* and 8201 as a member of the *Pomoideae*. The latter group includes such trees as hawthorn, apple and rowan, but it is not possible to identify them more closely on the basis of their wood anatomy (Schweingruber 1978, 123-31). It was impossible to distinguish the ring boundaries on 8201, whilst 8205 was rejected because it contained only 6 rings. Of the oak samples, 8202 was a small piece of almost complete roundwood with 16 rings, 8 of which were sapwood. 8203 and 8204 had 44 and 45 rings respectively; both had sapwood rings and 8204 may have had bark edge. The ring sequences of 8203 and 8204 were measured. Comparison of their ring patterns (t = 10.8) indicated that they were probably from the same tree, which was 45 years old when felled. Not surprisingly,

considering the shortness of the ring sequence, no match was found between them and dated Saxon reference chronologies.

Interpretation

No tree-ring dates were obtained for wells 10400, 10495, or 1127, and therefore dendrochronology cannot help determine their dates of construction. Well 10466 however produced six dated timbers, whilst 10698 produced one. It is therefore necessary to look at these dates in relation to the completeness of the timbers.

Timber 8194 from 10698, whose last measured ring dates to AD303, had bark edge. Allowing for the unmeasured rings (5 complete, 1 incomplete), a precise felling date of summer AD309 is obtained.

None of the dated timbers from 10466 had bark edge but four of them had sapwood (Fig 1). The dates of their heartwood-sapwood transitions vary between AD294 and AD305. If S2 and S4 are considered separately, felling date ranges of AD316-355 and AD314-348 respectively are obtained. These can be combined to produce a single felling date range for the 10466 well timbers of AD316-348. This suggests that well 10466 was constructed after well 10698, although the possibility that some of the timbers were stockpiled cannot be ruled out.

Discussion

Like all late 3rd/early 4th century AD timbers so far examined dendrochronologically in Britain (eg Hillam 1987a, b), the Godmanchester timbers are from young, relatively small trees and they also tend to be knotty. This contrasts with, for example, the huge 1st-2nd century AD timbers used in the revetments along the Thames waterfront in the City of London (Hillam 1986). It may be that early Roman demands on surrounding woodland had depleted it of larger trees so that by the late 3rd century AD, timber had to be brought from further away. They would then have selected the smallest trees which were large enough to produce timbers of adequate size for the job in hand.

What happened in the later 4th century AD is not known since timbers of this date have not yet been found in England, or at least none have been dated dendrochronologically. The Godmanchester timbers, ending in AD315, are the most recent Roman timbers so far dated. After AD315 there is a break in the tree-ring record until AD404 when the earliest Saxon tree-ring chronology begins. This gap is not apparent in Ireland or Scotland, ie outside the sphere of Roman influence, suggesting that it somehow relates to the with drawal of the Roman Army (Tyers *et al* 1993).

Conclusion

The analysis of the 43 samples from Godmanchester was disappointing in that many were unsuitable for dating purposes. It was, however, worth examining the samples in detail in view of the rarity of 4th century AD timbers in England. Seven timbers in all were actually dated. Six timbers from well 10466 produced a felling date range of AD316-348, whilst 8194 from well 10698 was felled in the late spring/summer of AD309. The tree-ring evidence therefore suggests that well 10466 was constructed after 10698.

Although the Godmanchester timbers were from young trees and therefore produced short ring sequences, the study has provided a new reference chronology for the period AD209-315. This will be useful for future analyses since it extends existing Roman tree-ring chronologies by 21 years towards the present day.

Acknowledgements

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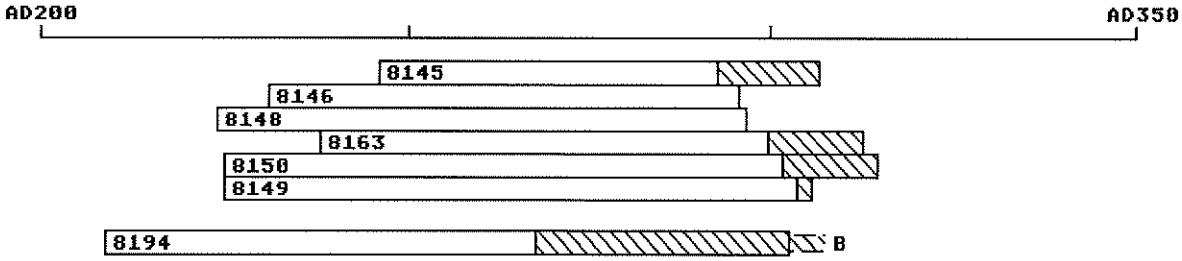
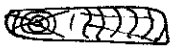
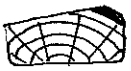
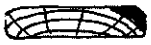


Fig 1: Bar diagram showing the relative positions of the dated ring sequences. 8194 is from well 10698; the remainder are from well 10466. White bars - heartwood rings; hatching - sapwood; broken lines - unmeasured rings; B - bark edge.

Table 1: Details of the tree-ring samples. Sketches of the cross-sections are not to scale; shading on sketches represents sapwood. * - rings widths measured.

sample no	context no	timber location	total no of rings	sapwood rings	average ring width (mm)	sketch	dimensions (mm)	comments
well 10400								
8137	10761	4th row, north	23	1	-		140x40	
8138	10762	4th row, south	?	-	-		245x50	very knotty
8139	10763	4th row, west	22	-	-		165x50	timber incomplete
8140	10764	4th row, east	25	-	-		180x50	knotty
8141	10765	3rd row, north	14	-	-		335x55	wide rings
8142	10766	3rd row, east	33	-	-		330x55	
8143	10767	3rd row, unattached	7	2	-		120x25	incomplete?
8144	10775	3rd row, west	35	-	-		325x55	
8156	10776	3rd row, south	32	-	-		325x50	
8157	10777	2nd row, west	36	15	-		285x50	bark edge
8158	10778	2nd row, unattached	28	7	-		145x35	timber incomplete
8159*	10779	2nd row, north	47	-	3.4		315x55	knotty
8160	10780	2nd row, east	39	12	-		295x50	
8161	10781	2nd row, south	30	-	-		300x50	
8164*	10783	bottom row, west	56	10	1.8		130x100	
8165*	10786	bottom row, east	41	7	2.3		140x85	
8166*	10791	bottom row, north	44	16	2.2		135x105	bark edge
8167	10792	bottom row, south	?	-	-		130x115	knotty

sample no	context no	timber location	total no of rings	sapwood rings	average ring width (mm)	sketch	dimensions (mm)	comments
well 10466								
8145*	10756	bottom row, east	62	14	2.3		300x100	knotty
8146*	10751	upper row, south	66	-	2.2		300x65	knotty
8147	10752	upper row, east	28	-	-		310x60	knotty
8148*	10753	upper row, north	74	-	2.1		320x65	knotty
8149*	10754	upper row, west	82	2	2.1		275x95	
8150*	10755	bottom row, south	91	13	2.6		260x80	
8152	10768	bottom row, corner strut	16	-	-		50x40	
8153	10769	bottom row, corner strut	9	-	-		45x35	
8154	10770	bottom row, corner strut	11	3	-		40x30	woodworm holes
8155	10771	bottom row, corner strut	12	-	-		45x30	
8162	10757	bottom row, north	31	-	-		265x70	
8163*	10758	bottom row, west	76	13	1.2		250x50	
well 10495								
8133	10729	single row	25	7	-		325x40	
8134	10772	single row	31	9	-		320x45	
8135	10773	single row	27	-	-		325x45	
8136	10774	single row	27	4	-		305x45	

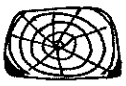
sample no	context no	timber location	total no of rings	sapwood rings	average ring width (mm)	sketch	dimensions (mm)	comments
well 10698								
8191	10693		28	6	-		180x145	felled winter
8192*	10696		84	5	1.6		230x180	
8193*	10697		69+	-	1.4		180x155	very knotty
8194*	10901		95	25	1.1		220x125	
well 1127								
8201	4441		-	-	-		55x30	not oak
8202	4442		16	8	-		95x65	
8203	4443		44	19	1.8		85x50	
8204	4444		45	20	1.6		115x70	bark edge?
8205	4445		6	-	-		35x35	not oak; felled winter

Table 2: *t* value matrix for matching sequences from well 10466. Values less than 3.5 are not printed.

	8145	8146	8148	8149	8150	8163
8145	*	7.2	9.5	6.8		
8146		*	10.2	18.6		
8148			*	10.1		
8149				*	3.8	3.5
8150					*	13.0
8163						*

Table 3: Dating the Godmanchester timbers. *t* values with dated reference chronologies; values less than 3.0 are not printed. BLC - Belfast long chronology; PET - Peter's Hill; SUN - Sunlight Wharf; Germany - Hollstein 1980.

	S2	S4	8194	BLC	PET	SUN	Germany
S2	*	3.7	3.9		5.0		4.0
S4		*		6.5	4.6		
8194			*		4.1	4.5	
GODMAN				5.0	5.4	3.6	3.3

Table 4: The Godmanchester master curve, GODMAN, AD209-315.

date	ring widths (0.01mm)										no of trees									
AD209									216	341									1	1
	122	104	81	53	83	52	74	128	123	101	1	1	1	1	1	1	1	1	1	1
	160	117	330	284	342	303	345	191	273	426	1	1	1	2	3	3	3	3	3	3
	260	264	345	276	292	235	118	197	130	157	3	3	3	3	3	3	3	3	3	3
	265	283	234	244	178	254	275	283	211	226	3	3	3	3	3	4	4	4	4	4
AD251	179	190	174	217	167	252	252	240	261	201	4	4	4	4	4	4	4	4	4	4
	149	209	158	192	143	175	168	153	154	150	4	4	4	4	4	4	4	4	4	4
	128	189	184	238	179	235	232	242	140	145	4	4	4	4	4	4	4	4	4	4
	188	162	155	145	175	144	139	219	247	160	4	4	4	4	4	4	4	4	4	4
	150	170	125	87	126	116	137	102	98	136	4	4	4	4	4	4	4	4	4	4
AD301	127	79	122	122	80	128	91	75	58	88	4	4	4	3	3	3	2	1	1	1
	174	153	220	310	351						1	1	1	1	1					

Table 5: Ring width data from a) S2, b) S4, and c) 8194. Widths are in units of 0.01mm.

a) S2, AD225-315

397	359	475	188	315	548	295	371	472	419
334	303	132	180	95	218	338	346	294	297
224	339	252	321	306	230	210	210	113	265
177	293	284	234	255	153	170	236	148	183
272	185	153	180	182	179	79	125	124	164
118	233	245	252	173	211	178	144	143	200
202	201	95	134	205	71	77	124	95	62
177	148	163	127	116	192	155	109	135	171
117	199	116	74	57	87	173	152	219	309
350									

b) S4, AD224-307

383	500	462	471	309	409	510	366	284	336
288	336	274	163	284	195	155	263	308	270
229	162	204	294	281	208	299	204	233	267
267	171	282	304	265	243	200	147	227	189
237	116	208	185	154	176	168	191	287	279
345	272	314	292	305	162	160	259	216	212
157	209	153	210	345	345	240	241	250	181
113	117	134	159	103	99	110	135	70	120
97	61	92	64						

c) 8194, AD209-303

215	340	121	103	80	52	82	51	73	127
122	100	159	116	329	183	127	87	87	74
94	219	117	135	225	120	203	127	57	126
98	96	191	194	136	205	147	265	256	247
121	72	96	80	46	65	147	147	113	195
299	249	128	143	104	109	64	95	145	121
79	83	49	55	53	95	52	77	97	102
62	47	53	69	51	64	79	66	40	50
89	85	38	55	42	57	89	46	63	73
76	128	81	64	111					