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Summary

The identification and analysis of 21 wood samples from Papcastle is described. No dating, relative or absolute was obtained for the six alder samples but the oak timbers produced several precise felling dates ranging from AD97/8 to AD106/7. A site chronology was produced for the period 143BC-AD106.

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Tree-ring analysis of Roman timbers from Papcastle, Cumbria, 1984

The excavation of the *vicus* immediately to the south of Papcastle Fort (NY 110315) was carried out in 1984 in advance of housing development. The work which was undertaken by the Cumbria and Lancashire Archaeology Unit under the direction of Adrian Olivier, revealed several contexts containing waterlogged wood. All but one of these contexts were sealed by a clay foundation for mid-late 2nd century and later structures, and were thought to be late 1st/early-mid 2nd century in date. Context 192, which contained timbers arranged around a possible well-shaft, was not sealed by the platform but seemed to be associated with the pre-platform phases. These phases represented industrial activity which was possibly analogous to that at Walton-le-Dale, a site from which timbers had already been examined and dated (Groves 1987). Many of the Papcastle timbers sampled for dendrochronology were planks, including those from context 149 which were the remains of a wooden door (Fig 1; Table 1). Others were stakes such as that from context 144 which was an upright stake from a wattle fence. The timbers were examined at Sheffield in 1988 in order to establish a firm dating framework for the site.

Methods

The samples were deep frozen for at least 48 hours before being surfaced with a surform plane, which left a cross-section with clearly defined annual growth rings. The ring widths were measured using a travelling stage attached to an Apple II microcomputer (Hillam 1985, Fig 4). This equipment allows the widths to be measured accurately whilst being automatically transmitted to the computer for further analysis. Much of the crossmatching and dating are now done by computer but the ring widths are plotted graphically by hand to enable the dendrochronologist to become familiar with the ring pattern.

Normally only one set of measurements are made per oak sample but some of the

Papcastle samples were a diffuse-porous species rather than the ring-porous oak (for more details of wood anatomy, see Wilson & White 1986, 105). Measurements were made along two radii of these samples because their ring patterns are less reliable than those of oak. The ring boundaries are less well defined and there are problems with missing rings (Groves & Hillam 1988). Two sets of measurements were also made on oak samples 1, 2 and 3 because their rings were narrow and difficult to measure. In all cases the two sets of ring widths were averaged to give a single ring sequence.

The oak and non-oak samples were treated as two separate groups. The absolute dating of Roman oak timbers is now well established but little work has been done on non-oak species (Groves & Hillam 1988). No absolute dating has been obtained for diffuse-porous species, although the absolute dating of elm from an archaeological site has been established (Groves 1988). In the present study it was hoped that the ring patterns from the non-oak might provide relative dating or even match with the oak sequences.

The ring sequences of the oak samples were compared with each other and also with dated reference chronologies. This was done visually by looking at the graphs, and by computer. The crossmatching program (Baillie & Pilcher 1973) measures the amount of correlation between two ring sequences by calculating the correlation coefficient for each position of overlap. The significance of the correlation is then tested using the Student's t-test, where a value of 3.5 or above generally indicates a match provided that the visual match is acceptable (Baillie 1982, 82-5).

If a tree-ring sample has bark or bark edge, the date of the outer ring is also the date of felling. Where the sample is incomplete but retains some sapwood, the felling date is estimated using the sapwood estimate of 10-55 rings (Hillam *et al* 1987). This estimate indicates that 19 out of 20 British

trees over 30 years old are unlikely to have less than 10 or more than 55 sapwood rings. In the complete absence of sapwood, allowance is made for the minimum number of missing sapwood rings by adding 10 to the date of the last measured ring, but the actual felling date could be much later depending on the amount of heartwood removed.

Results

The non-oak samples

The non-oak samples were all identified as alder (*Alnus glutinosa* (L) Gaertn). With the exception of a beam from context 155 (sample 5), the alder came from context 149 where three alder planks were found with two oak timbers as part of a wooden door (Fig 1; Table 1). Sample 5 from context 155 had only a few unclear rings and was rejected. The three timbers from context 149 (11/12, 13/14, 16) had 101-115 rings (Table 2). The two measured radii from sample 11 were found to match each other and with one of the radii from sample 12, a second sample from the same timber. 14A and 14B also matched each other, but there was no match with sample 13 from the same timber, nor did 13A and B or 16A and B match each other. This confirms results from an earlier study (Groves & Hillam 1988) which suggested that in order to trace the locally missing rings that are so common in alder, it is necessary to have a complete section of tree-trunk.

None of the alder sequences appeared to match the oak sequences, and it was noticeable that the year-to-year variation (the mean sensitivity) was much greater in the alder than in the oak.

The oak samples

The samples of oak (*Quercus* spp) had 25 to 148 growth rings (Table 2). Sample 8 from context 145 was rejected because it is not possible to date a sequence with as few as 25 rings. All the other samples were measured, although the

chances of dating sample 6 (118H) with 44 rings or sample 20 (166A) with 41 rings were not considered high. Sample 10 was difficult to measure because of narrow rings. Since it was from the same timber as sample 9, the latter ring sequence was used instead.

Some relative dating was found amongst the oak samples. Samples 4 and 5 from context 118, for example, matched each other, as did samples 9 and 15 from context 149. No match was found between these two pairs, so the ring sequences were next tested against dated chronologies. High t values were obtained for several of the sequences, particularly with chronologies from Carlisle and Belfast (Table 3). The Papcastle ring sequences cover a relatively long period of time with no overlap between 4/5 and 9/15 (Fig 2). Three other samples (17, 18, 21) were also dated.

A site master curve was constructed using the seven sequences listed above (Table 4). The chronology spans the period 143BC-AD106, and matches extremely well with chronologies from Belfast and Carlisle (t = 10.6 and 11.3 respectively). It also matches Roman chronologies from other areas of Britain, such as Droitwich or London, but the t values are not so high (Table 5). The match between Papcastle and the chronology from nearby Walton-le-Dale (Groves 1987) also gives a relatively low t value (4.0), suggesting that the timber for the two sites came from two very different sources.

The unmatched Papcastle sequences were tested against the site master. No reliable dating was found for the short sequences 6 and 20, but good visual matches and t values over 3.5 were obtained for samples 1, 3 and 7. Sample 2 from context 118 gave a t value of 3.8 with the Papcastle chronology when its outer ring dated to AD112, but the visual match was not very good nor did the sequence match other chronologies at this position. The tentative match was therefore not accepted. (Since sample 3, also from context 118, ends at AD111,

it is probable that the tentative match is correct but, since this cannot be proved solely from the tree-rings, the match must be ignored.) The sequences from samples 1, 3 and 7 were not added to the master chronology since the level of correlation between them and other reference chronologies was poor.

Interpretation of the tree-ring dates

The date spans of each ring sequence are set out in Table 6 and illustrated in Figure 2. Since bark edge (see Baillie 1982, Plate 1d) was present on some of the dated timbers, it is possible to give precise felling dates for some contexts.

Context 105. The rings of the single sample (1) from this context dated to AD21-116. Bark edge was present so that the timber was felled either in AD116 or in the early part of AD117.

Context 118. Three samples (3, 4, 5) were dated. Sample 3 had bark edge and was felled in AD111/2. Samples 4 and 5 had no sapwood and their outer rings dated to 65BC and 54BC respectively. Examination of the cross-sections (Table 2) indicates that these timbers were cut from the inner portion of a tree trunk whilst sample 3 was from the outer part.

Context 144. Sample 7 also had bark edge but the outer sapwood rings were very narrow and could not be measured accurately. The measured ring sequence dates to AD5-79, and approximately 25 extra rings were counted. The timber was therefore felled in approximately AD104. (An error term of ± 2 probably covers possible counting errors.)

From a tree-ring point of view, sample 7 was interesting because the number of sapwood rings was very variable. At one point on the circumference, the heartwood rings continued to the bark (compare Baillie 1982, Plate 1e) whilst

at another point there were 41 rings of sapwood. This extreme variation in sapwood width was probably due to the presence of a knot near to the point of sampling.

Context 149. The two oak timbers from the door (samples 9, 15) both had sub-bark rings dating to AD106. This outer ring was complete on sample 9 indicating that the timber was felled either in late AD106 or early AD107. (An incomplete outer ring would indicate felling in late spring or summer.)

Context 154. Sample 17 had bark edge, and its outer ring was complete. It was therefore felled in the winter or early spring of AD97/8.

Context 155. The rings of sample 18 dated to 80BC-AD18, but there was no sapwood. It was felled some time after AD28, and could be broadly contemporary with the other dated timbers.

Context 192. Sample 21 also had no sapwood. Its rings dated to 70BC-AD41, giving an estimated felling date some time after AD51. However the date of its outer ring is similar to the date of the heartwood-sapwood transition on sample 17, and it is therefore likely that the timbers from context 192, which was not sealed by the clay platform, are broadly contemporary with contexts which were.

There is therefore a range of felling dates for timbers from the pre-platform contexts at Papcastle (Fig 2). The timber from context 154 was felled first in AD97/8, followed by one from context 144 in AD104±2. This context could be contemporary with context 149 since the two oak door timbers were fellled in AD106/7. Finally timbers from context 118 and 105 were felled in AD 111/2 and AD116/7 respectively. Whether this range of felling dates represents a variation in the date of timber use, or whether the timber was used at the same time from stockpiled or re-used timber, cannot be determined from the

tree-rings.

Conclusion

Tree-ring analysis of the 21 samples from 18 timbers at Papcastle showed that both oak and alder were used in the structures. The alder samples were not dated because of problems associated with missing rings, but eleven of the oak timbers were dated producing a tree-ring chronology for the period 143BC-AD106. This chronology is very similar to those from Carlisle and Belfast, but it matches less well with the chronology from nearby Walton-le-Dale.

Precise felling dats in the period AD97/8 to AD116/7 were obtained for several contexts from the pre-platform levels. Context 192 which was not sealed by the platform could be contemporary with the other contexts.

Acknowledgements

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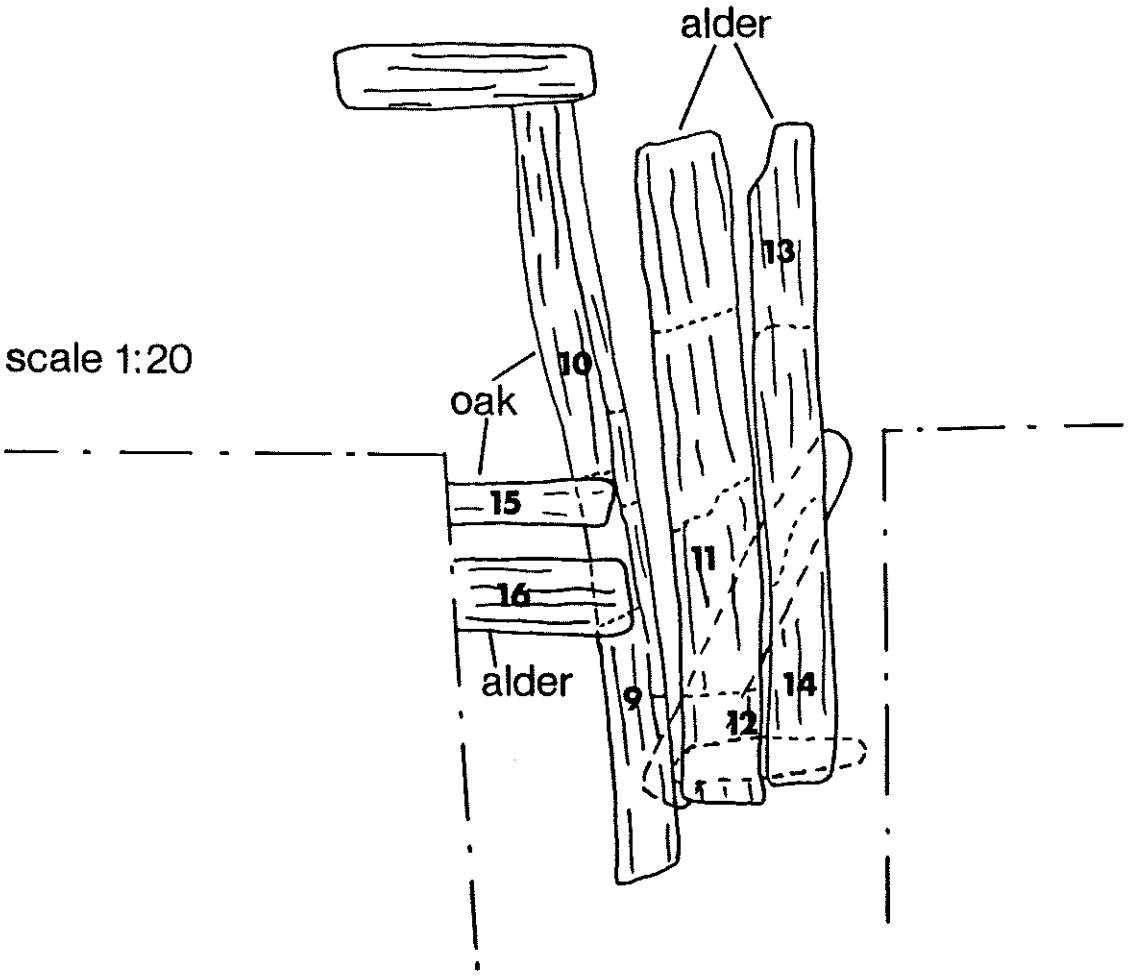
Fig 1: Plan showing *in situ* positions of timbers from context 149. Samples taken for tree-ring analysis are indicated by their dendro numbers. (Original plan: C.L.A.U.)



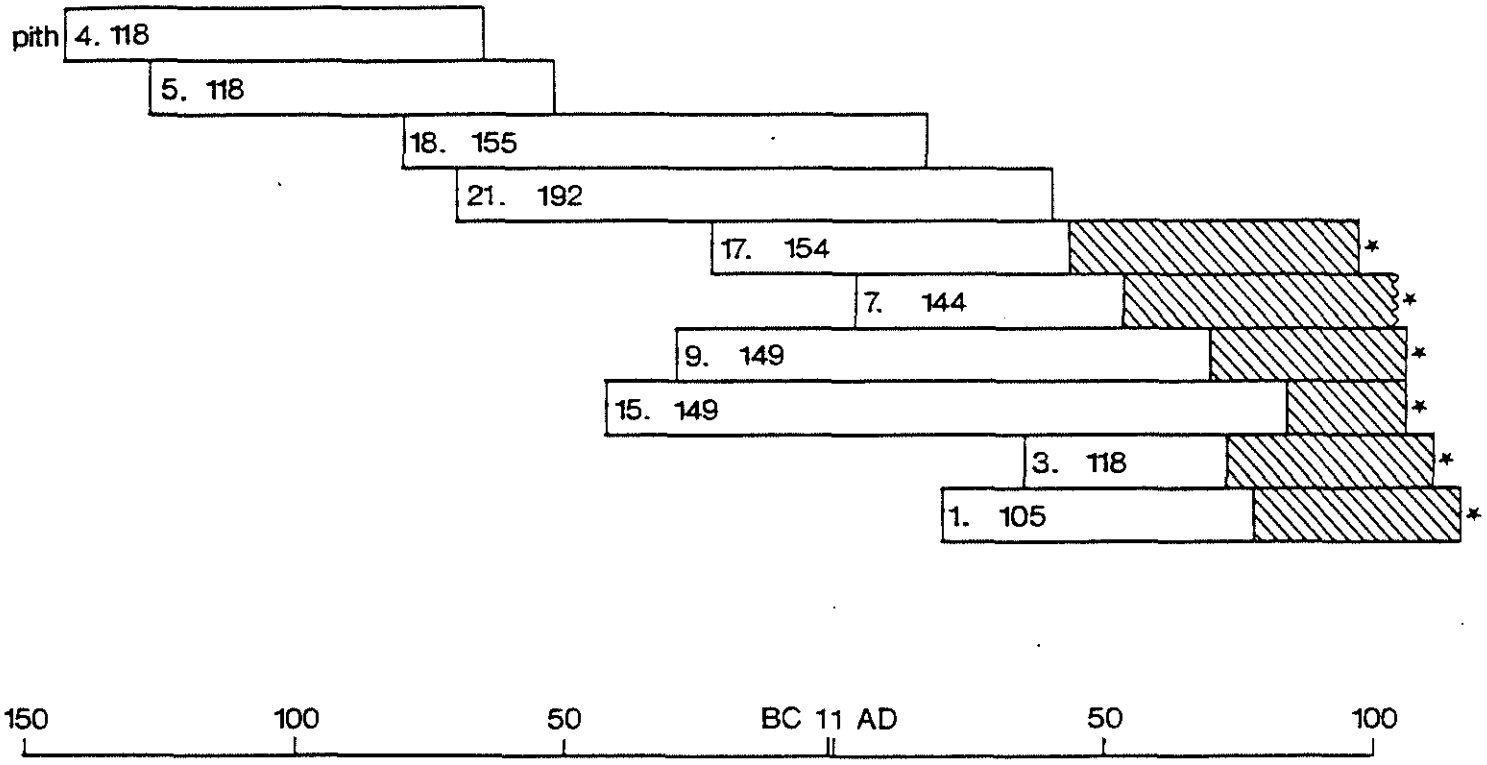


Fig 2: Bar diagram showing the relative positions of the Papcastle ring sequences. White bars - heartwood rings; hatching - sapwood. Bark edge is indicated by an asterisk. The date of the bark edge on sample 7 is approximate.

Table 1: Tree-ring samples and their contexts. The dendro numbers were given at Sheffield.

Context	Timber	Dendro	Species	Timber function
105	-	1	oak	plank?
118	-	2	oak	waste/firewood? from abandonment horizon
	E	3	oak	plank from abandonment horizon
	F	4	oak	"
	G	5	oak	"
	H	6	oak	"
144	D	7	oak	upright stake from wattle fencing
145	C	8	oak	plank
149	B1/B3	9/10	oak	doorsill?
	C3/C4	11/12	alder	plank from door
	D1/D3	13/14	alder	"
	E	15	oak	"
	F	16	alder	"
154	-	17	oak	beam
155	E	18	oak	plank - structural?
	F	19	alder	beam
166	A	20	oak	stake/post
192	A	21	oak	plank - well timber?

Table 2: Details of samples. Sketches are not to scale; shading indicates sapwood. + - unmeasured rings present. Samples are oak unless otherwise stated.

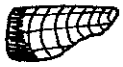
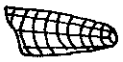
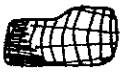
Dendro no	No of rings	Sapwood rings	Average ring width (mm)	Sketch	Dimensions (mm)	Comment
1	96	39	0.99		115x50	2 radii; bark
2	80	29	0.83		90x80	2 radii; pith; bark
3	76	39	2.24		175x60	bark edge
4	79	-	1.73		180x60	pith
5	74	-	1.58		130x55	
6	44	-	2.34		130x30	
7	75+	0-41	0.74		125x125	c 25 rings to bark
8	25	3	-		95x35	rejected
9	+135	37	0.65		145x135	felled winter
10	+84	34	0.59		190x90	bark edge; same as 9
11	115	-	0.81		265x45	alder
12	100	-	0.82		260x50	same as 11
13	69	-	0.85		175x40	alder
14	101	-	0.84		185x45	same as 13
15	148	31	0.66		105x55	

Table 2/cont

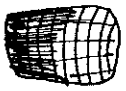
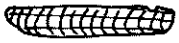
Dendro no	No of rings	Sapwood rings	Average ring width (mm)	Sketch	Dimensions (mm)	Comment
16	113	-	0.89		220x50	alder
17	119	54	0.76		100x85	felled winter
18	98	-	1.34		150x35	
19	-	-	-		145x85	rejected; alder
20	41	31	0.71		70x65	felled summer; pith
21	111	-	1.59		190x20	

Table 3: Dating the Papcastle oak samples. Comparisons giving t values less than 3.0 are indicated by an asterisk. Full details of reference chronologies are given in Table 5.

		t values			
Dendro no	context	Carlisle	Belfast	Walton	Papcastle
1	105A	3.1	5.3	*	4.2
3	118E	*	3.4	*	3.7
4	118F	4.0	4.5	*	-
5	118G	7.4	5.8	*	-
7	144D	*	*	*	4.6
9	149B1	4.4	4.3	*	-
15	149E	5.7	4.8	3.3	-
17	154	7.0	4.1	3.5	-
18	155E	6.7	6.2	4.8	-
21	192A	4.9	4.7	3.2	-

Table 4: Papcastle tree-ring chronology, 143BC-AD106.

Date	Ring widths (0.02mm)									
143BC								117	70	67
	69	60	72	91	76	109	43	86	108	130
	96	142	150	138	144	87	63	93	120	97
	137	114	101	110	80	59	31	70	83	122
	96	67	96	82	70	45	74	69	134	124
100BC	140	128	156	101	65	32	22	51	68	87
	95	82	121	104	84	110	43	76	62	99
	79	90	77	72	76	91	99	74	80	71
	81	79	64	51	74	74	62	62	43	49
	54	34	51	72	81	64	43	65	104	87
50BC	60	51	39	70	71	53	91	73	65	52
	53	42	40	49	63	60	57	63	63	79
	53	30	35	45	48	53	43	55	63	38
	55	45	55	48	50	44	67	57	51	31
	41	50	45	44	54	54	63	55	32	31
AD1	55	47	36	36	38	41	43	30	42	48
	41	48	34	46	45	40	48	59	40	42
	47	45	46	46	56	41	51	50	46	35
	49	45	46	46	51	45	51	48	47	43
	49	35	32	49	41	33	31	23	28	34
AD51	31	28	25	33	52	49	40	44	53	34
	54	53	45	51	53	39	62	62	58	42
	30	29	30	40	27	44	31	41	41	37
	24	44	45	29	23	22	24	24	35	36
	28	39	32	27	26	31	43	41	47	43
AD101	55	47	28	40	62	79				

Table 5: Dating the Papcastle chronology, 143BC-AD106. t values with dated reference chronologies.

chronology	date span	t value with Papcastle
Alcester, Warks (Baillie pers comm)	184BC-AD95	4.1
Belfast (eg Brown *et al* 1986)	5289BC-AD1983	10.6
Caerleon (Hillam 1987)	47BC-AD72	4.2
Carlisle (Baillie pers comm)	247BC-AD90	11.3
Droitwich, Friar St (Hillam 1982)	141BC-AD44	4.3
Droitwich, Old Bowling Green (Crone pers comm)	215BC-AD25	4.4
Droitwich, Upwich (Groves 1988)	256BC-AD61	5.4
London, City/Southwark (Tyers pers comm - data various)	252BC-AD255	4.7
Nantwich (Laxton, Litton & Simpson pers comm)	134BC-AD132	3.8
Walton-le-Dale, Lancs (Groves 1987)	235BC-AD119	4.0

Table 6: Tree-ring results for the oak timbers. The AD date of the heartwood-sapwood transition, if present, is given in brackets.

Dendro no	context	date span	felled	comment
1	105A	AD21-116(78)	AD116/7	
3	118E	AD36-111(73)	AD111/2	?winter felled
4	118F	143-65BC	after 55BC	inner part of tree
5	118G	127-54BC	after 44BC	"
7	144D	AD5-79+	AD104±2	bark present but outer rings narrow.
9	149B1	+29BC-AD106(70)	AD106/7	winter felled
15	149E	42BC-AD106(84)	AD106/7	
17	154	22BC-AD97(44)	AD97/8	winter felled
18	155E	80BC-AD18	after AD28	
21	192A	70BC-AD41	after AD51	