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Summary

Tree-ring dates are reported here for 24 of the 40 timbers sampled at Acton Court, Avon (ST 676842) from 1987 to 1990. The sixteenth century building work there is shown to be circumscribed by the felling of the East range timber in the spring of AD1535 and the cutting of timbers for the stair turret treads in the spring of AD1576. The North range timbers have felling date ranges (95% confidence) spanning AD1519-1564, but by including information from detached sapwood pieces from two tibers, this could be narrowed to about 1530 to 1545. The felling date range of the fifteenth century arch-braced roof re-erected on the North range at the same time is AD1486-1531.

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by D Haddon-Reece and Daniel W H Miles

1. Introduction and objectives

Acton Court is a large multi-period house standing at Iron Acton, Avon (ST 676842). The present building (see Fig 1) consists of eastern and northern ranges, both of two storeys, with an semi-octagonal stair turret set in the angle between them, all of the sixteenth century. An arch-braced collar-truss roof, thought to be of fifteenth century date, was re-erected on the North range in the sixteenth century, although the eastern range roof is contemporary with the other timbers in the eastern wing. Archaeological excavation has revealed extensive traces of previous buildings on the site, as well as a now filled-in moat.

The main purpose of the tree-ring dating, or dendrochronology, was to produce dates for the separate building phases. It was hoped that if no absolute dates could be obtained, then the dendrochronology would at least provide a chronological framework for the relative dating of the separate building phases.

The elements regarded as separate phases for which tree-ring dating was possible were, in chronological order:

1. the (re-used) arch-braced North range roof;
2. the East range;
3. the North range including two roof timbers contemporary with the joining of the arch-braced roof to the East range roof;
4. the stair turret.

Tree-ring dates for the East range and the stair turret have been reported in Vernacular Architecture, 21, (Haddon-Reece et al 1990), and dates for the North range in Vernacular Architecture, 23, (Haddon-Reece and Miles 1992).

A short explanation of the principles of dendrochronology is given in Appendix A.

2. Methods of sample collection

A summary of the timbers sampled and their eventual dating is shown in Table 1.

The usual practice of tree-ring sample collection offers a choice of three possible methods: measurements in situ on a well-polished beam end (normally by sanding); cores drilled with a hollow auger; or slices cut from the timbers. At Acton Court, cores and slices were collected between 1987 and 1990. As coring involves the inevitable risk that a core will not run at right angles to the ring boundaries, or that it will meet a hidden area of distortion, most timbers were sampled with more than one core. All timbers sampled were of oak, Quercus sp.

Table 1: ACTON COURT: SUMMARY OF TREE-RING DATING

Sample number	timber & position	dates AD spanning	H/S bdry	sap-wood	no of rings	mean width mm	std devn mm	mean sens
East Range								
* a01a s	bridging beam	1364-1511			148	1.79	0.59	0.186
* a02a s	trimmer T6-7	1328-1472			145	1.16	0.80	0.289
a03 s	lintel				80	2.53	1.56	0.252
* a04 s	wall pad	1376-1530	1504	27	155	1.46	1.13	0.209
* a05 s	transverse beam	1345-1534	1512	22¼	190	1.93	1.58	0.225
* a06 s	transverse beam	1348-1528	1503	25	181	1.93	1.02	0.186
* a07 s	joist?	1469-1534	1514	20¼	66	1.28	0.30	0.180
* a08 s	transverse beam	1367-1508			142	2.45	1.19	0.209
a09 s	beam				68	3.62	2.10	0.323
a10 s	bridg. beam T4-5				66	3.60	1.37	0.233
a11 s	bridg. beam T2-3				63	3.18	1.15	0.150
* a12 c	transverse beam	1354-1511	1504	7	158	1.37	0.39	0.166
* a13 c	transverse beam	1350-1463			114	2.02	0.89	0.121
a14 c	transverse beam	1365-1446			82	1.81	0.59	0.153
* = "East" sub-master		1328-1534			207	1.85	0.87	0.153
North Range								
a15 c	transverse beam				72	2.78	0.97	0.204
a16 c	transverse beam				56	3.47	2.20	0.298
a17 c	transverse beam				70	3.50	2.04	0.349
a18 c/s	transverse beam			20¼	92	2.59	0.88	0.209
a19 c	transverse beam				59	2.90	1.34	0.279
* a20 c	first floor joist	1409-1523			115	0.86	0.33	0.171
a21 s	timber from moat				91	2.15	1.34	0.262
* a27 s	unprov. block	1393-1510	1510	H/S	118	1.36	0.41	0.217
a28 c/s	first floor joist			13C	62	2.63	1.45	0.271
* a31 c/s	lintel S10f	1413-1511	1506	5	99	1.48	0.38	0.229
a32 c	lintel S10d				12	5.11	1.88	0.349
* a33 c/s	S upper purlin T1	1417-1510	1510	H/S	94	1.72	0.78	0.225
a34 c	S princ rafter T1			3	55	1.59	0.71	0.220
* = "N16th" sub-master		1393-1523			131	1.36	0.39	0.175
North Range Roof								
* a36 c	N lwr purlin T4-5	1430-1468			39	2.39	0.67	0.197
a37 c	tiebeam T2				45	2.38	0.81	0.256
* a39 c	N princ rafter T7	1432-1482			51	1.75	0.68	0.212
a41 c	S princ rafter T7				90	0.89	0.53	0.277
a42 c	N princ rafter T5				50	2.43	1.24	0.255
* a44 c	S princ rafter T6	1417-1479	1476	3	63	3.12	1.08	0.195
* a46 c	tiebeam T6	1417-1477			61	2.14	0.84	0.229
a48 c	tiebeam T4				48	3.51	1.28	0.218
* = "N15th" sub-master		1417-1482			66	2.40	0.68	0.163
Stair Turret								
* a22 s	stair tread 30	1376-1549	1544	5	174	1.54	0.49	0.175
* a23 s	stair tread 33	1387-1575	1561	14¼	189	1.43	0.66	0.261
* a24 s	stair tread 34	1422-1575	1561	14C	154	1.61	0.76	0.259
* a25 s	stair tread 48	1455-1575	1560	15¼	121	1.48	0.75	0.283
* a26 s	stair tread 49	1387-1540			154	1.38	0.66	0.246
* = "Stairs" sub-master		1376-1575			200	1.52	0.55	0.205
"Acton" site master		1328-1575			248	1.84	0.80	0.163

* = sample inc. in sub-master; c,s = core, slice;
¼,C = spring, winter felling (bark edge present: partial or complete ring)
H/S = heartwood/sapwood boundary; mean sens = mean sensitivity

3. Timbers sampled and particular problems

The Acton Court tree-ring samples are designated as a01, a02 etc. Figures 2 and 3 are building plans giving the location of timbers sampled in situ. Some samples were cut or sampled ex situ: these are drawn in Figures 4 and 5.

3a. North range roof (a33 - a48)

Cores were drilled from this roof with a 16mm auger. The timbers themselves were of slender scantling compared with the transverse timbers in both East and North ranges; although many had sapwood complete to the bark edge, i.e. a waney edge, it was everywhere too badly worm-eaten for collection or measurement. Despite an outward appearance of solidity to the sapwood, the insect larvae had been so prolifically active in the innermost rings of sapwood against the heartwood that only a compacted mass of frass (droppings) remained. It is probably significant that the North range was derelict in the nineteenth century and hence very damp: this would have made conditions more favourable for insect life and would therefore have increased such activity.

3b. East range (a01a - a14)

The samples from the East range were taken both as 7/8" (22mm) diameter cores drilled from timbers in situ and as slices cut by chain-saw from timber ends which had been removed during restoration work and stored in the works area. It should be noted that not all of these loose timbers can be ascribed a provenance with absolute certainty.

Some of the cores showed a tendency to snap during drilling, which was later found to be due to a band of very narrow, and consequently weak, tree rings. A few of these cores were clearly unusable, but wherever possible, the pieces were carefully laid in order and secured by glue and splints for eventual comparison with the slices.

3c. North range (a15 - a19; a27 - a33)

The samples from the North range were taken mostly as cores drilled from timbers in situ with a 16mm auger. One sample (a27) was a section taken from a block of timber found on the North range long gallery window sill, presumably removed or found during demolition works, although its original location could not be precisely identified. In addition, several sapwood slices were cut from the timbers adjacent to the coring positions.

A slice was cut by the excavator, Mr R Bell, from a large waterlogged timber which he had found in the excavation of the moat.

Very few of the timbers had sapwood, which emphasised the importance for dating of those that did. Of particular relevance were a primary lintel in the south wall (a31) and the purlin (a33) added to connect the re-erected arch-braced roof to the East range roof. The sapwood of these timbers was also crumbly, though not quite so impossible as that in the arch-braced section. Despite extensive larval depredation in the sapwood of both timbers, it was still possible to take samples: the sapwood on the lintel was first consolidated by injections of dilute PVA (Resin W wood glue) through a 0.5mm syringe and by painting its outer surface sevberal times with Ronseal Wood Hardener resin. In the case of the purlin, the larvae had eaten much of the spring and summer components of the axial elements in the wood, but had avoided the thick medullary rays (oak contains both thick and thin-type rays) to such an extent that the sapwood sample taken was seen to consist very largely of rays bound in a matrix of frass. Fortunately, the ring boundaries are repeated in the rays and could be discerned as bands in the laminae remaining there (i.e. in the radial longitudinal section).

3d. Stair treads (a22 - a26)

Slices were cut from several of the stair treads while they were awaiting repair at the Gloucester Blackfriars English Heritage works depot. By gluing a stiffening sheet of hardboard to each tread end with masonry epoxy glue, it was possible to cut from it a very thin slice on a bandsaw. In addition, sections were cut from the newel end of some treads whose ends would in any case be removed for repair. The work was done with the guidance and assistance of the works depot staff.

4. Sample preparation and measurement

All timbers except the moat timber were dry, and were therefore sanded on a linisher through several grades of abrasive paper ranging from 60 grit to 1200 grit. This prepared a sufficiently clean view of the transverse section of the wood for the ring boundaries to be distinguished and the ring-widths to be measured. The moat timber was air-dried and then treated in the same manner as the other timbers.

Once polished, all samples were measured under a x10/x30 microscope using a travelling stage electronically displaying displacement to a precision of 0.001mm. Some ring patterns were found to contain bands of exceptionally narrow rings, which made measurement very difficult - and sometimes impossible. In most instances each sample was measured at least twice, and in the case of the sapwood pieces a31sap and a33sap from the North range, 5 and 9 times respectively in order to obtain a representative average. Where they contained breaks, cores were measured in sections for eventual alignment against other samples.

The moat timber sample was blackened through waterlogging, which had also obscured the wood vessels. After "clearing" the wood with a hypochlorite bleach, the ring pattern up to ring 50 could be measured, but this was followed by a series of rings so distorted, narrow and lacking in late (ie summer) wood that their boundaries could not be distinguished with certainty. Beyond that, measurements could be read to about ring 91. This 91-ring series was recorded in the hope that at least the first 50-ring sequence could be dated and then have an approximate number added to it in order to provide an approximate felling date.

5. Cross-matching procedure

After measurement, the ring-width series for each sample was drawn out in the usual fashion as a graph of width against year on log-linear graph paper. This paper is translucent so that graphs ("curves") can be visually compared by overlay.

All ring-width series were also recorded on a computer for statistical cross-matching using a variant of the Baillie and Pilcher (1973) CROS program (see Appendix A). Some of the work was done on the Torch Sequent computer at the Ancient Monuments Laboratory, some on an A M Lab Toshiba T1200 computer, and the remainder on an Amstrad PC2386 belonging to one of the authors (DWHM). In the final stage of the work, all cross-matching was repeated and checked on the Amstrad using a CROS version in BASIC and other programs written by DH-R.

6. Dating results and analysis

Table 1 gives a summary of dating results for individual timbers as well as for the sub-master curves assembled for each phase/building element. See Section 8 for an extended discussion of the sapwood estimation at Acton Court.

6a. East range (see Table 2)

After measurement (and remeasurement to avoid possible error from the band of narrow rings) samples a01a, a02a, and a04 to a08 were melded into a preliminary mean curve (site sub-master). This initial sub-master curve produced a date of AD1534 when matched against master curves (see Table 8); since the outermost timbers had complete sapwood ending in a complete ring, this indicated **felling in the spring of AD1535.** Although sample a14 matched very highly with a01a, a05 and to a lesser extent with a06, its inclusion in the initial sub-master curve actually lowered the matching of that mean curve with reference curves; it was therefore regarded as securely dated but was omitted from the sub-master curve.

Samples a03 and a09 to a13 from this phase did not date at first, and samples a12 and a13 were dated only after the site curve had been reinforced with samples from other phases. Sample number a11 was unsuitable for measurement.

	a02a	a04	a05	a06	a07	a08	a09	a10	a12	a13	a14
	1472	1530	1534	1528	1534	1508	1502	1535	1511	1463	1446
a01a	5.35	4.18	7.52	7.05	4.20	10.29	2.02	1.52	3.20	3.31	5.90
	109	136	148	148	43	142	68	42	148	100	82
a02a		4.16	3.74	3.32	0.00	2.76	0.00	0.00	2.05	2.62	2.24
		97	128	125	125	106	38	0	119	114	82
a04			3.08	2.78	1.42	2.00	1.72	2.84	3.56	4.49	2.94
			155	153	62	133	68	61	136	88	71
a05				6.79	4.88	7.07	1.38	2.43	4.17	4.20	6.25
				181	66	142	68	65	158	114	82
a06					2.42	5.67	0.75	0.48	3.41	6.50	9.67
					60	142	68	59	158	114	82
a07						2.47	1.73	2.38	4.05	0.00	0.00
						40	34	65	43	0	0
a08							1.86	0.55	2.68	1.66	3.95
							68	39	142	97	80
a09								1.90	2.20	0.00	1.73
								33	68	29	12
a10									0.91	0.00	0.00
									42	0	0
a12										2.87	3.36
										110	82
a13											3.88
											82

Table 2. East range: matrix of t-values and overlaps

6b. North range (sixteenth century elements) (see Tables 3 & 6)

The timber from the moat failed to produce any convincing date.

The main transverse timbers from the long gallery on the first floor of the North range failed to date unambiguously (since they offered so many possible dates). Most curves showed a repeated heavy stress on the timber which had caused the tree's growth to falter badly for a few years before gradually regaining normal behaviour. These regular and repeated bands of narrow rings are often taken as a sign of pollarding (Ruth Morgan, Oliver Rackham, pers comm): deprived of so much of its branches and leaves, the tree takes several years to restore its photosynthetic resources. In this instance, however, the timbers were of a length far greater than would be expected for a pollard tree, and a more convincing explanation is that of snedding (lopping) the side branches, possibly to encourage tall and straight growth.

After an extensive search, only three timbers with complete sapwood had been found in the North range: transverse beam 4 (a18); a lintel (a31 = s10f) in the S wall of the room (room 13/14) beneath the long gallery, and the short purlin (a33) connecting truss 1 and the western slope of the East range roof. The transverse beam sample (a18) failed to match conclusively at any date.

As related in Section 3c, cores could not be taken from a31 and a33 with sapwood attached owing to its crumbly nature. As these timbers were built into a wall, it was not possible to measure the sapwood in situ. Pieces of sapwood were therefore removed separately in the hope of measurement and subsequent alignment with other curves, given some clue from the dating of the parent cores to which the sapwood belonged. These pieces, which had been measured in replicate several times, were compared with as many sub-masters and reference chronologies as possible in the hope that, despite their short extent, they might provide the vital terminus postquem quidcunque for the erection of the North range. They were cross-matched individually and in several combinations, visually and by statistics, but without success.

	a27 1510	a31 1511	a33 1510
a20	3.87 102	1.77 99	3.30 94
a27		3.25 98	4.23 94
a31			3.54 94

Table 3. North range (sixteenth century): t-values and overlaps

Sample a31 had 5 sapwood rings attached that showed no striking visual correlation with the inner rings of its separate sapwood piece, although there may be an overlap of one or two rings. The best that can be said is that by adding the known sapwood of 5 rings (attached) + 26 rings (detached) to the actual latest heartwood date of AD1506, the timber must have been felled later than about AD1536. Architectural evidence also precludes any date prior to AD1535, simply because the North range post-dates the East range, unless its timbers are re-used. The H/S boundary of a33 lies at AD1510, and since its 21-ring sapwood is at least one ring short of the bark edge, its felling date must be after AD1531.

Most of the North range samples were particularly troublesome. It was necessary to test each sample against each other, against the site sub-masters and against external reference chronologies,

and then again in combination, before any acceptable positions could be found. As with all the other samples, visual matching was essential. Wherever a match could be seen, its strength was tested statistically and vice versa; the sample was combined with other samples, or with a sub-master, and the resultant mean curve was then tested for improvement in matching. Statistics alone would have failed to date several of the samples.

6c. Stair treads (see Table 4)

With the exception of sample a22 (tread 30), the five stair treads showed a strong inter-correlation. The t-values were so high (see Table 4) that it would seem probable that, with the exception of a22, all the treads sampled derive from only one or two trees.

Also, the outer ring of samples a23 and a25 revealed that they were felled in the spring or early summer, that is, after the formation of the spring vessels but before a complete ring had formed. Sample a24 had a complete outer ring which indicated a felling in the winter months. This would then suggest that the group consists of at least two and possibly three trees; no sapwood remained on a26 for this to be explored further.

All the tread curves are highly similar in ring pattern, however, and their strong correlation also is due in part to their length. All five curves were therefore averaged, and the mean curve (including complete sapwood) produced a latest felling date of **AD1576 (spring felling).**

	a23 1575	a24 1575	a25 1575	a26 1540
a22	5.76 163	6.53 128	5.11 95	5.27 154
a23		12.16 154	14.22 121	10.01 154
a24			12.79 121	7.91 119
a25				13.27 86

Table 4. Stairs: t-values and overlaps

As earliest and latest phases respectively, the East range and stair turret therefore circumscribe the sixteenth century building work as AD1535 to AD1576.

6d. North range (fifteenth century roof) (see Tables 5 and 6)

The samples here again proved very difficult and ambiguous, offering several alternative positions. Only four samples of the eight collected could be dated positively, and one of those (a37, principal rafter) had to be omitted from the North range roof sub-master curve as it badly reduced the match of that curve with reference curves. None of the dates in Table 5 is a felling date. Only sample a44 has (incomplete) sapwood, and then only three rings.

	a39 1482	a44 1479	a46 1477
a36	2.49 37	1.80 39	3.76 39
a39		3.21 48	1.99 46
a44			4.30 61

Table 5. North range (fifteenth century): t-values and overlaps

6e. North range (fifteenth century and sixteenth century)

The entire matrix of cross-matchings for all the North range elements is shown in Table 6.

	a27 1510	a31 1511	a33 1510	a36 1468	a39 1482	a44 1479	a46 1477
a20	3.87 102	1.77 99	3.30 94	0.98 39	1.85 51	3.49 63	1.43 61
a27		3.25 98	4.23 94	0.21 39	1.36 51	4.32 63	2.11 61
a31			3.54 94	1.05 39	0.88 51	1.62 63	1.20 61
a33				3.24 39	2.50 51	2.56 63	3.27 61
a36					2.49 37	1.80 39	3.76 39
a39						3.21 48	1.99 46
a44							4.30 61

Table 6. North range (fifteenth century & sixteenth century): t-values and overlaps

6f. Unprovenanced block from the North range

The unprovenanced block a27 has a H/S boundary of AD1510, which endorses the dating of the lintel a31 and the purlin a33 but adds little to the understanding of either the transverse beams or the joist. Block a27 may in fact have been removed from the East range, which it matches well statistically and with a consistent H/S boundary.

6g. Inter-comparison of all phases

	N15th 1482	N16th 1523	North 1523	Stairs 1575
East	3.48 66	8.08 131	7.60 131	6.79 159
N15th		5.01 66	-	4.27 66
N16th			-	4.35 131
North				4.57 131

Table 7. Comparison of site sub-master curves: t-values and overlaps

7. Assembly and dating of site sub-masters and master curve

The inter-comparison of the site masters has been presented in Table 7, Section 6g. The sample curves were aligned according to these results, see Figure 6, and melded into a site master curve ("Acton"). This was matched with a large number of reference curves and the highest results are shown in Table 8.

8. Sapwood estimation and felling dates/ranges

As well as the two sapwood pieces a31sap and a33sap, sapwood was recorded in fourteen instances, giving the following numbers of sapwood rings:

	complete	incomplete
East range:	23(a05), 21(a07)	27(a04) 25(a06) 7(a12)
North range:	21(a18), 13(a28)	5+?+26(a31), 3+21(a31) 3(a44)
Stairs:	15(a23) 14(a24) 15(a25) [a23 may = a25]	5(a22)

	east	n15th	n16th	north	treads	ACTON
	1534	1482	1523	1523	1575	1575
ALTON:	7.45	3.17	5.36	5.25	3.25	7.44
(J Hillam)	157	66	112	112	129	157
WALES-ENGLAND:	6.09	5.20	6.40	7.24	5.04	7.40
(V Giertz)	194	66	131	131	200	235
COWFOLD:	7.53	4.92	4.23	4.26	4.74	6.98
(I G Tyers)	158	66	131	131	159	159
OXFORD MEAN:	6.56	2.26	6.03	5.30	4.10	6.97
(DHR, DWHM)	192	66	131	131	200	233
YORKSHIRE 2:	4.73	4.71	4.64	5.43	4.27	6.49
(J Hillam)	207	66	131	131	200	248
ENGLAND:	5.65	4.77	4.18	5.54	3.16	6.45
(MGLB/JP)	176	66	111	111	128	176
MARTIN:	4.31	4.43	3.78	4.11	4.34	5.75
(M C Bridge)	156	66	131	131	156	156
EAST MIDLANDS:	5.32	3.35	4.92	5.41	3.56	5.64
(Nottm Univ)	173	66	108	108	125	173
SCOTLAND:	3.00	1.99	3.15	3.35	4.75	5.63
(M Baillie)	134	66	123	123	175	175
FROCESTER:	4.06	5.07	6.77	7.50	2.73	5.49
(J Fletcher)	134	66	121	121	134	134
EXETER MEDVL:	4.64	6.76	5.36	6.06	4.64	5.44
(C M Mills)	168	66	131	131	200	209
KENT88:	4.47	4.38	3.83	4.41	4.22	5.28
(Nottm Univ)	207	66	131	131	165	213
HOLLSTEIN:	3.53	3.37	2.12	1.54	2.79	3.91
(E Hollstein)	207	66	131	131	200	248

Table 8. Cross-matching of Acton Court building phases: t-values and overlaps

If the known felling dates of the East range timbers apply to a04, a06 and a12, then these would all have a full complement of 31, 32 and 31 sapwood rings respectively. Likewise, the stairs timber a22 would have a full complement of 31. Without logarithmic transformation to correct for skewness, this would offer a mean value of 21.5+/-7.50, or in round terms, a 95% confidence interval of 7 to 36 rings. For the six known values of sapwood (if a23 is taken to be the same timber as a25), this would be 17.5+/-4.10, or 9 to 26 rings. It is obviously impossible to infer any real difference between the two phases.

As a statistical sample, these figures are more comparable with the Oxfordshire estimate of 10 to 30 rings recorded by the authors (Haddon-Reece et al 1989,1990) than with overall "national" figures of 10 to 55 quoted by other researchers (eg Hillam et al 1987). In fact, there is a significant difference both in variance and mean, but the numbers are clearly too few for extended statistical analysis. A lower sapwood estimate for the South of England has been reported by other workers also (eg J M Fletcher, 15 to 35 rings; and A C Barefoot, 13 to 33 rings, both pers comm). In practice, research to estimate sapwood from observations of a large number of samples (eg Hughes et al 1981) usually indicates that the distribution of sapwood numbers is skewed, with a long "tail" towards the higher numbers of sapwood rings, and that the process of logarithmic transformation to remove skewness has the effect of raising both the lower and the upper 95% points, more so for the upper one. It therefore seems safest to apply a 95% confidence range of H/S+10 to H/S+55 to the North range timbers.

8a. East range

For the two timbers with bark edges the felling dates are:

a05: AD1535, spring felling
a07: AD1535, spring felling

Also, some timbers here have no bark edge but have H/S boundary dates consistent with a05 and a07. Using the confidence range indicated by the other East range timbers and including that sapwood which does exist, felling date ranges may be quoted (for completeness) as:

a04: AD1530 - 1540 (95% confidence)
a06: AD1528 - 1539 (95% confidence)
a12: AD1511 - 1540 (95% confidence).

8b. North range (sixteenth century elements)

Only felling date ranges can be quoted (with 95% confidence), and then combined using the method used by the Nottingham University group (see footnote to Howard et al 1990) by taking the average of the H/S boundaries and adding to it the confidence limits. The combined value can be further refined by including the known information from the sapwood from a31 and a33, although it must be noted that both sapwood pieces had a bark edge, which implies felling certainly after 1531 (purlin a33) and about 1536 (lintel a31) but probably before 1545. (No numerical probability can be applied to this narrowed range):

a27: AD1520 - 1565 (95% confidence)
a31: AD1516 - 1561 (95% confidence)
a33: AD1520 - 1565 (95% confidence)
AD1531 - 1564 (combined)
a31,33 AD1531 - 1545 (including sapwood information)

8c. Stairs

Of the five samples, four had sapwood and three had bark edges. Felling dates are:

a23: **AD1576, spring felling**
a24: **AD1575/6, winter felling**
a25: **AD1576, spring felling**
a22: AD1554 - 1580 (95% confidence).

8d. North range (fifteenth century roof)

In the North range roof, only sample a44 had (incomplete) sapwood, and then only 3 rings. There is therefore no real evidence on which to choose a sapwood estimate for the arch-braced roof. As it would be improper to apply the sapwood figures from the East range, a felling date range for the arch-braced roof may be estimated from sample a44 using the 10 to 55 figure of Hillam et al:

a44: AD1486 - 1531 (95% confidence).

Although crumbly sapwood was present on many of the timbers but could not be sampled, it is quite reasonable to expect that the outer ring of each core would lie at, or very close to, the H/S boundary. Making that assumption and applying the 10 to 55 sapwood ring estimate to the mean of the outer measured rings produces a range identical with that of a44 alone.

9. Summary of results and conclusion

As will be seen from Table 1 and Figure 6, it has been possible to date with confidence 24 of the 40 timbers sampled for tree-ring dating at Acton Court. From the tree-ring record, building activity at Acton Court in the sixteenth century is circumscribed by the felling of the East range timbers in **spring AD1535** and the felling of the timber for the turret stair treads in **winter AD1575/spring 1576.**

No exact felling date could be found for any timber in the sixteenth century North range work. The estimated felling date for a ground floor lintel is **about AD1536,** and the lintel connecting the arch-braced roof to the East range was felled **soon after AD1531.** The felling date range for the re-used arch-braced roof on the North range is (with 95% confidence) **AD1486 to 1531.**

10. Acknowledgements

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YORKSHIRE 2:
1192-1663
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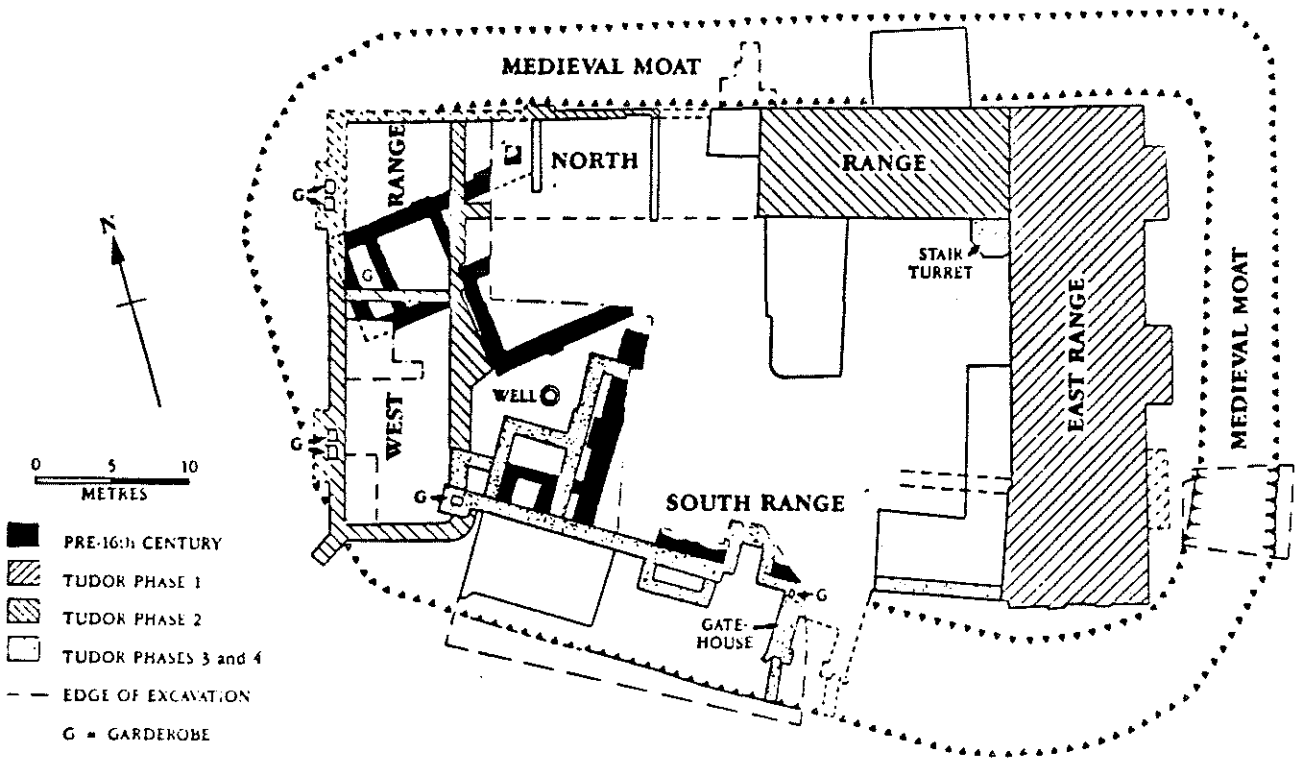


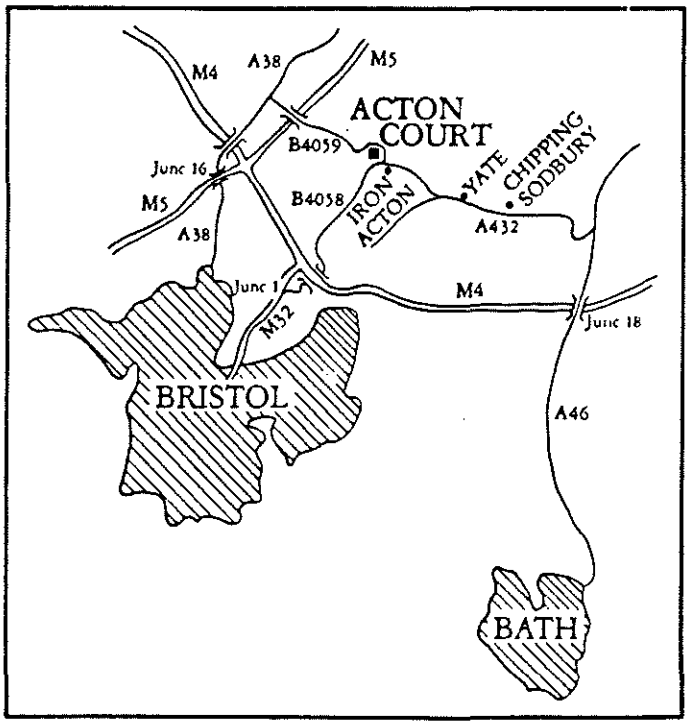


Figure 1 Site location and layout

(Bath Archaeological Trust)

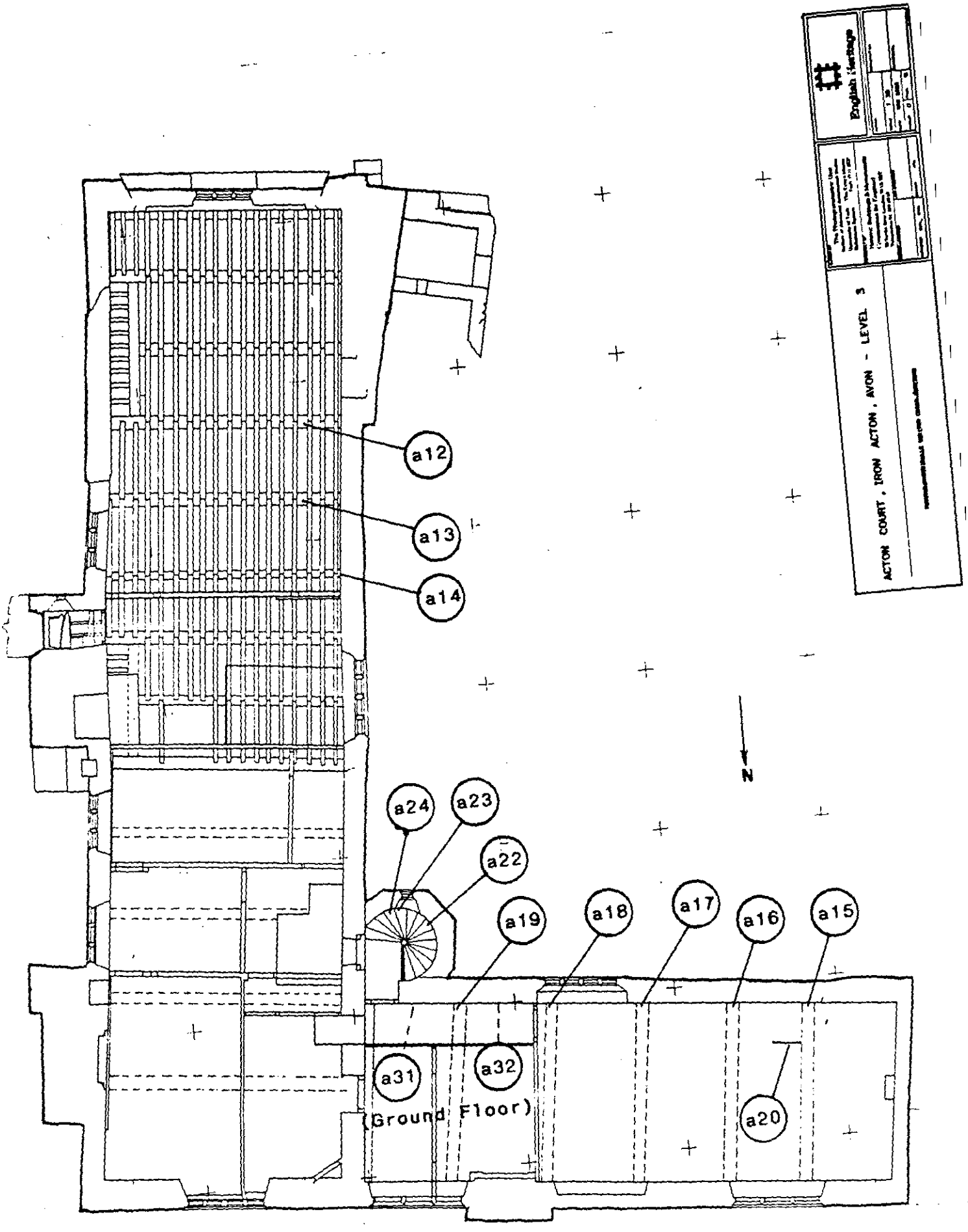


Figure 2 1st floor building plan with sample locations

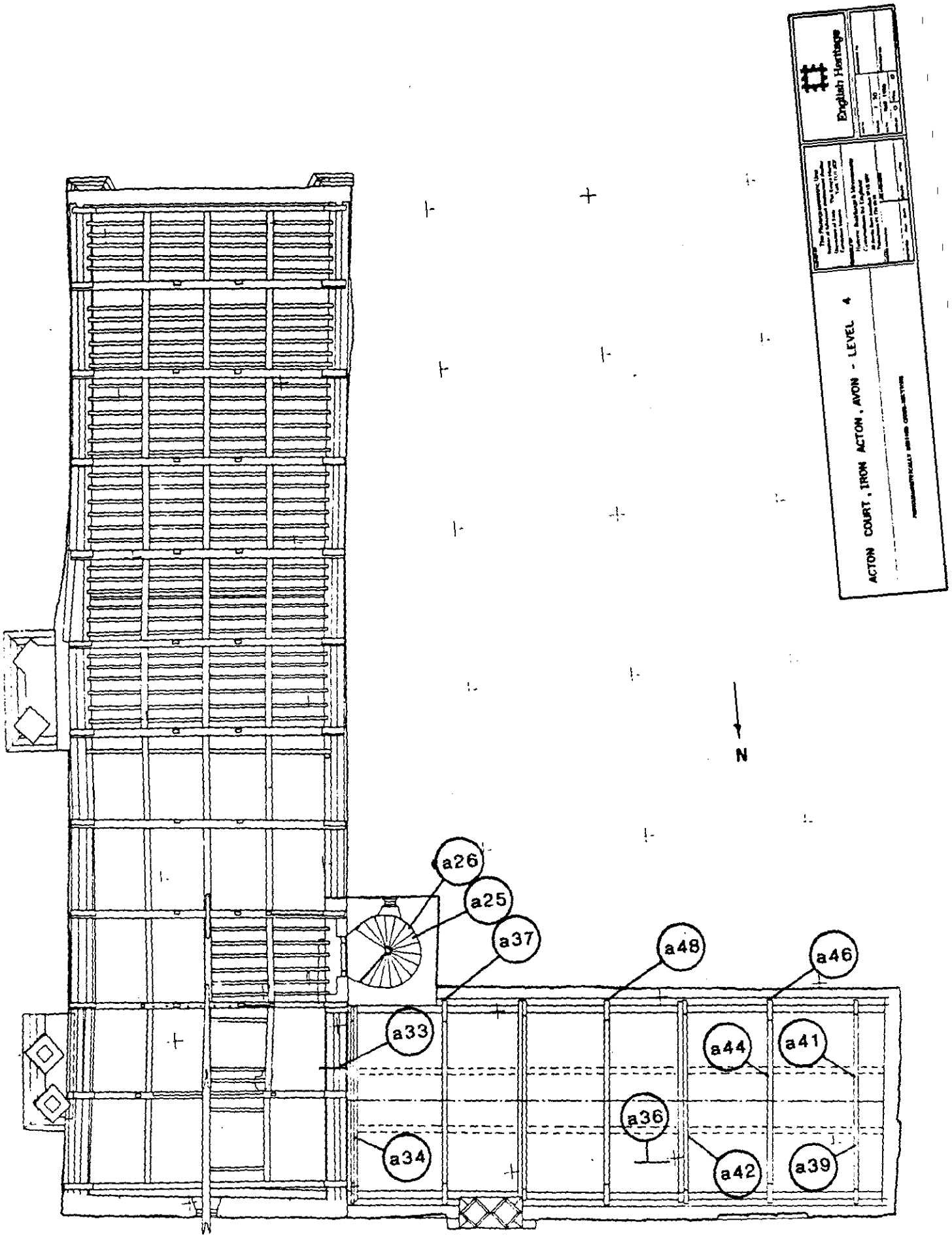


Figure 3 Roof plan showing sample locations

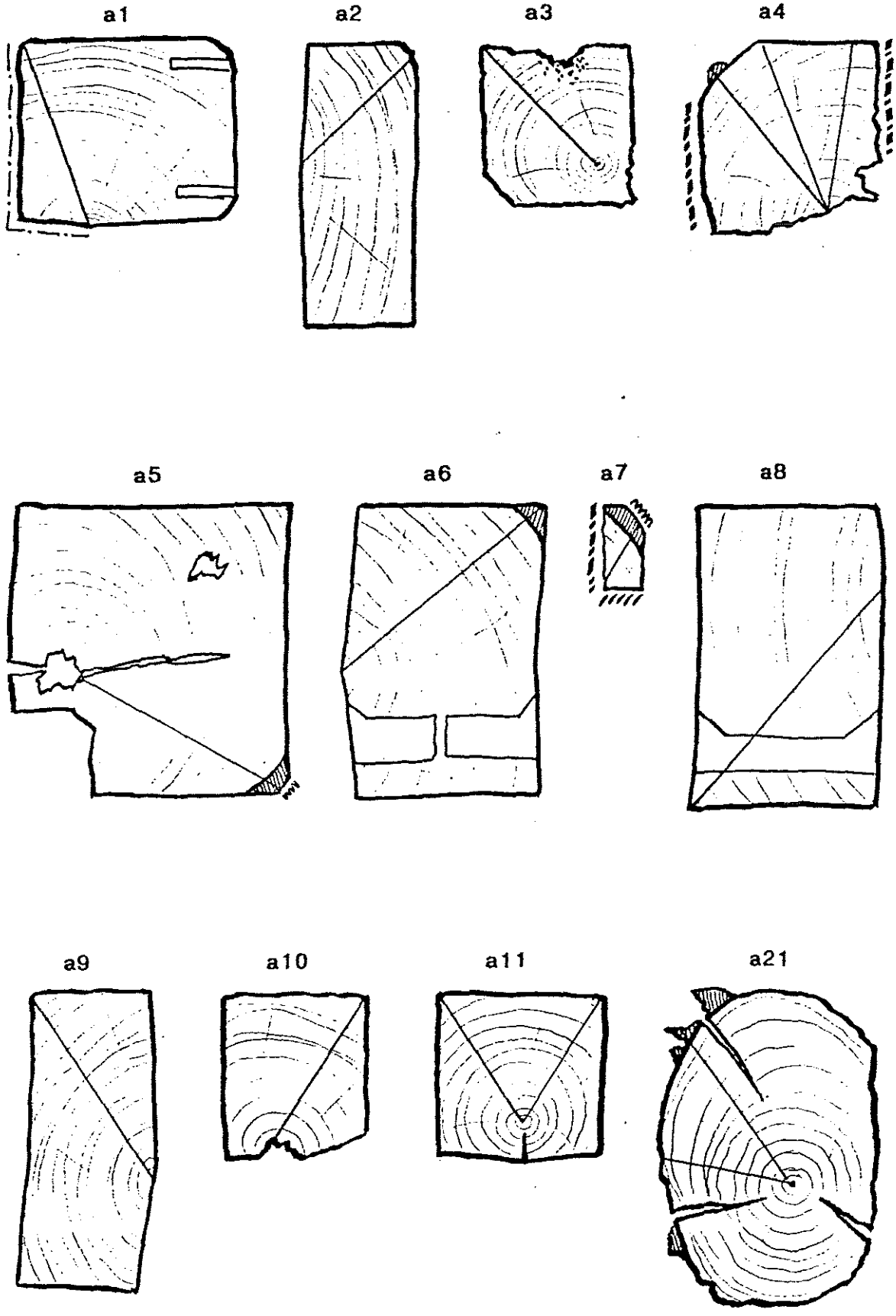


Figure 4 Cross-section of slices cut

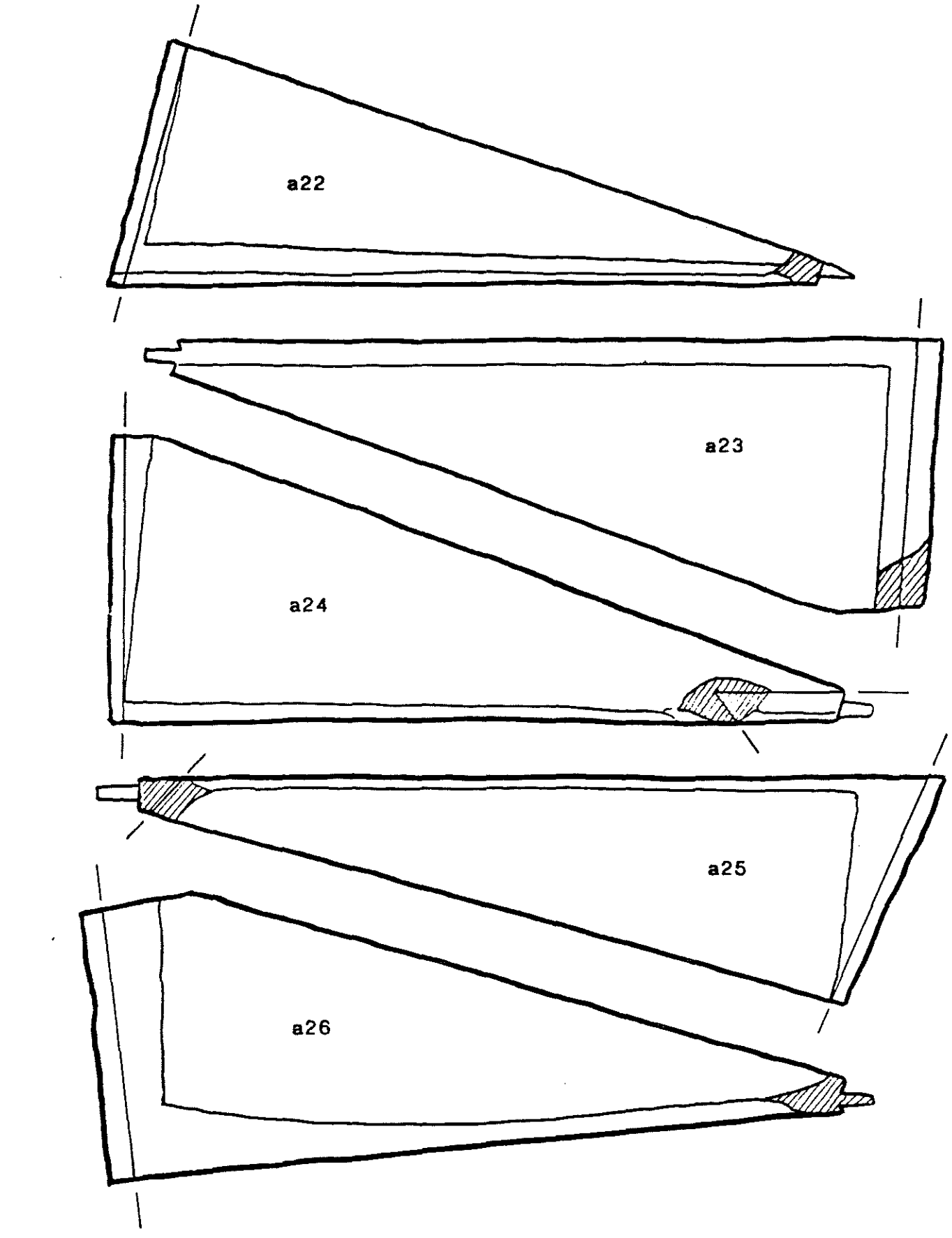
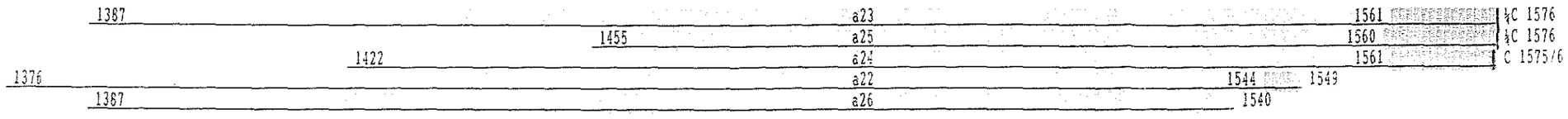


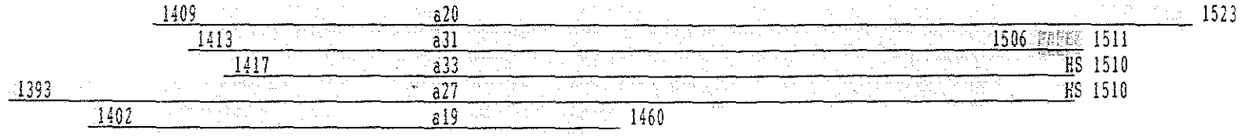
Figure 5 Stair treads sampled

Acton Court

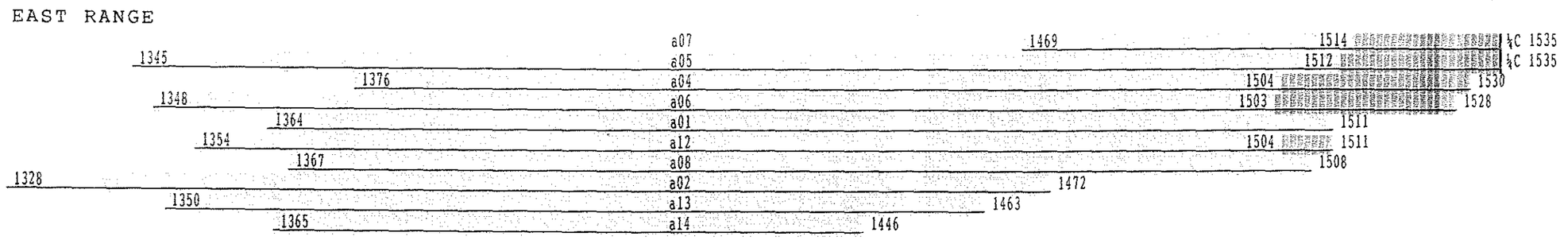
STAIR TURRET



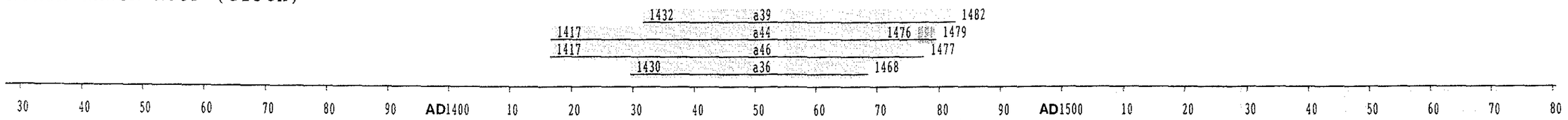
NORTH RANGE (C16th)



EAST RANGE



NORTH RANGE ROOF (C15th)



KEY: = HEARTWOOD
= SAPWOOD (INCOMPLETE)
= VISUALLY MATCHED SAPWOOD
½C = COMPLETE SAPWOOD - SPRING FELLED
½C = COMPLETE SAPWOOD - SUMMER FELLED
C = COMPLETE SAPWOOD - WINTER FELLED
HS = HEARTWOOD/SAPWOOD TRANSITION

Figure 6. Samples in chronological position

APPENDIX A

Principles of Dendrochronology

The remarks that follow apply particularly to broad-leaved oak (Quercus robur, Q. petraea and their hybrids) as found in historic buildings. Its behaviour is broadly similar to that of other temperate deciduous trees, and it can sometimes be matched to elm or beech, for instance. For the dendrochronologist of historic buildings it is particularly valuable for its prevalent use as well as for its specific virtues of clear ring boundaries, easily spotted "false rings", ease of measurement (usually), well-defined sapwood and good cross-matchability.

Each year, the tree adds one tree ring, or increment of growth, just under the bark. In spring it make large vessels for the conduction of sap: these are seen as a line of "pores" on a cross-section. In the summer it adds mainly fibrous material for support, with a few smaller vessels interspersed. In the autumn, growth stops until the next spring. A ring under magnification therefore looks like a band of macaroni (spring wood) followed by a zone of spaghetti (summer wood). (This vivid simile was suggested by Dr. D.G.Wilson F.L.S.)

Dendrochronology relies on the similarity in response of trees to their growing conditions. In general, trees of the same species growing under similar conditions will add relatively wide rings in good years and relatively narrow rings in poor years. A series of successive tree-ring widths therefore presents a year by year record of the weather. A reference chronology (or "master curve") can be constructed backwards in time from the present year by overlapping and amalgamating successively older timbers. Given such a master chronology, it should therefore be possible to "cross-match" a sample against it by a sliding comparison until an exact calendrical date is found for the growth rings.

It generally happens that individual samples from a building match better between themselves than with master curves since their growth patterns incorporate so much of their local micro-climate. In addition, each will possess its own idiosyncrasies, often random rather than systematic. By placing the samples alongside each other in correct chronological position and then averaging them into a local site chronology, much of the random "noise" is removed, including the small but inevitable measurement error. This averaging technique improves the "signal/noise" ratio, and thus helps to clarify that climatic signal present in the samples which can be cross-matched against the climatic pattern over a much wider region. It is believed that a common climatic signal extends, albeit weakly, over the whole of the British Isles and north-western Europe.

The site master curve is matched against regional and national master curves using a statistical cross-matching procedure. The most widely used procedure (the CROS program: Baillie and Pilcher, 1973) is to advance a sample curve along a master curve in yearly steps, calculating the product-moment correlation coefficient at every position of overlap, and then to test the strength of the match using Student's "t" test. ('Student' was the pen-name of W S Gosset, the statistician who devised the test in 1908.) A t-value greater than t=3.5 is held to indicate that so strong a match could only have occurred by chance alone on that combination of data less than 1 in 1000 times, although this threshold is varied according to the stage in the process. At the initial stage of matching samples against each other, a

lower t-value may be accepted as an indicator provided it is endorsed by an acceptable visual match. A safer level of t=4.0 or over is generally preferred for the final cross-matching of a site master against reference curves.

Most dendrochronologists place great reliance on visual matching as an adjunct to statistical procedures (the authors of this report among them). The reason is that the CROS program filters out all but "high frequency" information on the basis of a five-year moving average. This rejects the low frequency (longer term) trends which can be very valuable in comparing timbers from a local source where a peculiar local weather pattern partially masks the effects of regional weather patterns.

It is usually found that the successive addition of more samples to a site master or sub-master improves the match with master curves, although a point is sometimes reached where further additions start to reduce t-values, sometimes quite drastically. This appears to be due to the gradual reinforcement of a particularly local signal, caused, say, by microclimate, woodland management or peculiar growing conditions.

For the exact estimation of a felling date of a timber, the presence of complete sapwood is vital. Sapwood is the outermost band of rings (typically 20-30) used for conduction. At a rate of about one ring per year, the older, innermost, sapwood ring is turned into heartwood: its vessels are stopped up with balloon-like tyloses, various chemicals such as tannins are deposited in its elements, and it thereafter plays no further part in the living processes of the tree. Sapwood is usually recognisable, therefore, by the absence of tyloses, and often by a paler colour to the wood.

When a bark edge is also present, an exact felling date is possible, but unfortunately, since sapwood is especially prone to insect attack, it is often trimmed off by carpenters. When the bark edge is missing, and the sapwood is clearly incomplete, one must rely on a statistical estimate of sapwood rings based on the examination of a large number of trees of all ages with complete sapwood. Values vary according to geographical conditions and locality, as well as to the tree's habitat (see, eg, Desch 1981), being typically lower in the South of England than in the North. For example, in the Oxfordshire region, one can expect with 95% confidence that there will be between 10 and 30 rings of sapwood complete to the bark edge (Haddon-Reece, Miles and Munby, 1990), and these figures have also been reported by other workers on southern English timbers. A commonly used "national" estimate is 10 to 55 rings (eg, Hillam, Morgan and Tyers, 1987). The best estimate for any particular building is to be derived from the timbers of the building itself, provided sufficient have bark edges and one can be reasonably sure of a common timber source. With the heartwood/sapwood boundary discernible, these lower and upper bounds added to the outermost heartwood ring date give a statistical felling date range.

If an acceptable cross-match is found, the usual practice is to quote the date of the outermost ring of the timber, or the range spanned from earliest to latest ring. The allowance for missing sapwood is then added if appropriate.

APPENDIX B Tree-ring data

All measurements are x 0.01mm.

East <1328-1534> a01+a02+a04-a08+a12+a13
207,1328
405 369 275 269 293 251 187 488 365 437
219 275 161 202 218 129 88 331 331 235
407 415 430 540 387 476 423 342 378 289
246 239 248 274 278 304 341 248 305 268
263 294 256 187 215 258 328 294 278 252
248 252 230 264 278 220 183 249 246 231
215 207 177 178 166 186 158 186 284 191
177 194 238 201 180 216 212 204 253 202
202 243 207 175 158 123 135 161 141 136
151 121 152 162 165 198 170 137 144 151
175 164 121 120 141 122 97 108 134 145
147 118 127 123 120 105 85 110 99 121
117 126 117 144 120 111 120 118 146 120
122 113 138 129 121 146 95 120 125 98
99 112 154 142 126 142 108 137 137 94
117 136 142 167 159 148 145 102 130 139
123 123 139 120 105 126 116 130 160 167
118 131 126 109 103 137 158 158 164 210
170 179 158 170 162 133 126 142 144 138
132 118 111 107 111 104 95 94 114 115
112 93 78 131 111 109 122

N15th <1417-1482> a36+a39+a44+a46
66, 1417
292 364 295 420 361 232 347 369 340 304
278 307 260 247 343 326 265 257 309 307
221 216 231 261 260 213 231 252 319 326
284 231 267 223 255 240 204 210 188 203
209 189 146 164 184 205 245 169 180 217
231 201 194 223 223 217 248 173 263 174
106 80 86 118 159 206

N16th <1393-1523> a27+a31+a20+a33
131,1393
251 150 151 231 131 150 188 176 180 140
179 194 136 262 186 238 212 205 171 135
117 129 129 119 169 195 126 190 155 187
237 189 187 144 137 169 170 147 200 189
151 182 166 198 172 143 131 170 183 140
110 121 118 136 111 118 139 156 162 108
97 94 89 86 90 97 85 114 93 99
130 103 134 122 111 93 109 131 151 127
141 116 143 119 90 88 106 104 149 136
117 123 91 118 145 122 133 152 121 99
105 90 99 174 123 118 147 116 89 111
107 128 128 120 109 108 118 114 93 137
108 90 101 127 106 96 97 77 76 100
70

North <1393-1523>
a27+a20+a31+a33+a36+a39+a44+a46
131,1393
251 150 151 231 131 150 188 176 180 140
179 194 136 262 186 238 212 205 171 135
117 129 129 119 210 251 183 266 224 202
274 249 238 197 184 215 200 190 261 257
208 220 237 252 196 179 181 215 221 176
170 186 218 231 197 175 203 189 209 174
150 152 138 144 149 143 116 139 139 152
187 136 157 169 171 147 146 170 182 166
187 140 194 142 97 85 99 107 151 150
117 123 91 118 145 122 133 152 121 99
105 90 99 174 123 118 147 116 89 111
107 128 128 120 109 108 118 114 93 137
108 90 101 127 106 96 97 77 76 100
70

Treads <1376-1575> a22-a26
200,1376
321 224 116 164 159 144 271 223 148 156
150 198 160 127 146 120 125 095 127 107
143 139 106 113 205 212 112 122 188 255
348 245 213 237 175 135 114 064 126 153
139 142 127 101 161 181 194 205 190 129
130 128 159 169 140 182 186 135 110 128
160 177 136 128 152 131 163 131 125 148
174 291 166 176 108 121 141 203 211 210
219 227 245 250 288 290 230 328 240 236
276 161 153 157 217 222 174 235 165 241
153 050 047 072 107 111 073 085 114 109
137 124 114 106 122 103 110 093 096 110
134 143 103 109 113 081 084 128 139 227
153 117 125 155 125 146 182 172 145 147
136 128 203 175 161 082 078 081 066 069
080 085 092 100 087 101 092 094 115 123
138 133 113 114 145 130 096 117 103 129
085 078 071 107 098 119 144 190 151 165
162 098 104 194 145 189 184 176 234 177
101 179 281 221 200 223 146 186 181 163

ACTON <1328-1575> East+N15th+N16th+Treads
248,1328
405 369 275 269 293 251 187 488 365 437
219 275 161 202 218 129 88 331 331 235
407 415 430 540 387 476 423 342 378 289
246 239 248 274 278 304 341 248 305 268
263 294 256 187 215 258 328 294 283 249
234 242 222 250 277 220 179 239 235 222
200 185 169 162 155 169 150 163 244 173
157 173 225 202 159 189 204 211 277 211
208 237 200 165 144 109 132 152 136 163
182 139 194 187 183 225 201 169 159 157
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158 145 167 164 151 136 134 161 167 186
150 167 144 165 146 145 151 147 163 156
159 147 174 171 159 205 148 164 180 143
132 135 176 176 152 183 135 185 143 83
87 106 121 146 131 121 130 101 129 136
120 120 137 115 105 111 103 116 155 148
113 128 119 95 99 127 145 172 149 156
141 155 135 149 169 150 132 140 138 130
164 144 132 91 94 89 79 80 95 98
101 97 84 110 98 98 117 123 138 133
113 114 145 130 96 117 103 129 85 78
72 107 98 119 144 190 151 165 162 98
104 194 145 189 184 176 234 177 101 179
281 221 200 223 146 186 181 163