Ancient Monuments Laboratory
Report 7/2000

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Summary

Twelve tree-ring samples were taken from eleven waterlogged bridge timbers excavated from the Convent Ditch in Abingdon Vineyard excavation site, Abingdon, Oxfordshire (SU 499 972). Eight of the timbers dated, six being combined to form a 114-year chronology spanning the years AD 1394-1507 and producing a precise felling date of spring AD 1508. The dating has also shown that associated elements including planking and stakes are from the same period of construction.

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1. INTRODUCTION AND OBJECTIVES

Remains of a late medieval timber bridge were found at Abingdon, Oxfordshire, during excavations by the Oxford Archaeological Unit in advance of the construction of new offices for the Vale of White Horse District Council in 1990 (Fig 1). The bridge lay within a late medieval moat known as the Convent, or Great Ditch, which lay on the west side of the abbey precinct and was fed by a channel of the River Stert (Figs 2 and 3). The moat was 12 m wide with steep sides and a flat base, and was probably dug in the fourteenth century after the Great Riot of AD 1327, during which the abbey was sacked (Fig 4).

In the bottom of the moat two trestles of the timber bridge were found *in situ* (Figs 5 and 6). Each trestle consisted of a long horizontal sill-beam into which were tenoned uprights and angled bracing timbers, each sill-beam resting upon three roughly-squared lengths of elm tree trunk. One trestle lay in the middle of the moat, and originally had three uprights, of which only two survived. Along one side of this trestle a plank stood on edge, resting in a groove cut into the elm tree trunks and held in place by three large wooden pegs or stakes (Fig 7). The other trestle, which lay close to the west side of the moat, had two uprights, of which only one remained. Approximately 1 m of the uprights survived, preserved beneath the level of permanent waterlogging.

Three timbers were initially submitted to the Ancient Monuments Laboratory in 1989 as part of a laboratory research project to construct a tree-ring chronology for Oxfordshire (Haddon-Reece *et al* 1993). However, as the results were not conclusive, additional samples were awaited. As the post-excavation work was due to be completed and written up during 1997, additional samples were obtained from eight of the conserved timbers in the Oxfordshire County Museum store at Standlake.

2. METHODOLOGY

All samples were of oak (*Quercus* spp.) taken from what appeared to be primary first-use timbers. The first three samples were sections cut from the east trestle by Tim Allen of the Oxford Archaeological Unit in 1989: ***abv3942*** from the base plate, ***abv3943*** from the south brace, and ***abv3944*** from the south post. All were waterlogged and at least two slices appeared to have virtually complete sapwood surviving. The three samples were frozen with liquid nitrogen and surfaced with a Surform rasp/plane to prepare the surface for measuring.

The remaining samples were obtained in 1996 after the timbers had been conserved with PEG. The wax impregnation was found to hinder the coring process somewhat, but it was discovered that by drilling more slowly, better results were achieved. It was found that as the timber was reasonably sound when excavated, the centre of the timbers were not impregnated with PEG, making the process of sampling easier once the outer 25mm was passed. Cores were generally taken rather than slices, for as there remained a possibility of the timbers eventually being put on display, it was desirable to sample non-destructively. This was achieved by using a 16mm hollow auger powered by an electric drill. It was necessary to resort to a limited number of small V-section slices. The three stakes still retained virtually complete sapwood and were too small to be successfully cored, so an 8mm V-section was removed from the side of each (Fig 7). Also, the west baseplate retained complete sapwood, but this became detached at the heartwood/sapwood transition during coring. A 12mm V-

cut was made at the bottom of the baseplate in a non-visible location adjacent to the core hole. This encompassed an area of complete sapwood which extended into the heartwood, thus allowing the two core fragments to be joined together with certainty. Some difficulty was found in mounting the cut sections since the PEG tended to repel PVA glue.

The dry samples were sanded on a linisher using 60 to 1200 grit abrasive paper, and were cleaned with compressed air, to allow the ring boundaries to be clearly distinguished. They were then measured under a x10/x30 microscope using a travelling stage electronically displaying displacement to a precision of 0.001mm, rounded to the nearest 0.01mm. After measurement, the ring-width series for each sample were plotted as a graph of width against year. The graphs of each of the samples in the phase under study were then compared visually at the positions indicated by the computer matching and, when found satisfactory and consistent, were averaged to form a mean curve for the site or phase. This mean curve and any unmatched individual sequences were then compared against dated reference chronologies to obtain an absolute calendar date for each sequence.

Here this was accomplished by using a combination of both visual matching and a process of qualified statistical comparison by computer. The samples were first matched by computer, and then independently visually checked with graphs. When an undated sample or site sequence is compared against a dated sequence, known as a reference chronology, an indication of how good the match is must be determined. Although it is almost impossible to define a visual match, computer comparisons can be accurately quantified. Whilst it may not be the best statistical indicator, Student's t-value has been widely used amongst British dendro-chronologists. The cross-correlation algorithms most commonly used are derived from Baillie and Pilcher's Belfast CROS programme (Baillie and Pilcher 1973), compared on an IBM compatible PC. A version of this and other programmes were written in BASIC by D Haddon-Reece, and latterly re-written in Microsoft Visual Basic by M R Allwright and P A Parker.

In comparing one sample or site master against other samples or chronologies, t-values over 3.5 are considered significant, although in reality it is common to find demonstrably spurious t-values of 4 and 5 because more than one matching position is indicated. For this reason, dendrochronologists prefer to see some t-value ranges of 5, 6, and higher, and for these to be well replicated from different, independent chronologies with local and regional chronologies well represented. Where two individual samples match together with a t-value of 10 or above, this may suggest they originated from the same tree.

Once a tree-ring sequence has been firmly dated in time, a felling date, or date range, is ascribed where possible. With samples which have sapwood complete to the underside of, or including bark, this process is relatively straight forward. Depending on the completeness of the final ring, ie if it has only the spring vessels or earlywood formed, or the latewood or summer growth, a *precise felling date and season* can be given. If the sapwood is partially missing, or if only a heartwood/sapwood transition boundary survives, then an *estimated felling date range* can be given for each sample. The number of sapwood rings can be estimated by using a statistically derived sapwood estimate with a given confidence limit. An accepted sapwood estimate for British and Irish oaks is given as between 10 and 55 rings with a 95% confidence range (Hillam *et al* 1987). A recent review of the geographical distribution of dated sapwood data from historic building timbers has shown that a 95% range of 9-41 rings is more appropriate for southern counties (Miles 1997a), which will be used throughout this report. If no sapwood or heartwood/sapwood boundary survives, then the minimum number of sapwood rings from the appropriate sapwood estimate is added to the last measured ring to give a *terminus post quem* or *felled after* date.

Some caution must be used in interpreting solitary precise felling dates. Many instances have been noted where timbers used in the same structural phase have been felled one, two, or more years apart.

Where ever possible, a *group* of precise felling dates should be used as a more reliable indication of the *construction period.* It must be emphasised that dendrochronology can only date when a tree has been felled, not when the timber was used to construct the structure under study. However, it was common practice to build timber-framed structures with green or unseasoned timber and that construction usually took place within twelve months of felling (Miles 1997a).

3. RESULTS

Initially, only three samples were submitted by the OAU: ***abv3942***, ***abv3943***, and ***abv3944***. These three samples failed to match each other conclusively, and only one sample, ***abv3942***, appeared to date against the reference chronologies. This had 80 rings and seemed to span the years AD 1428-1507. As it appeared to have virtually complete sapwood, with only a ring or two missing, a felling date range of AD 1507-1511 was offered. However, the *t*-value matches were low, and although the result was communicated verbally, the results were never confirmed, pending the analysis of further samples not yet submitted. Despite the tentative nature of the results, the date managed to find itself in print, first in Watson (1989) as 1510 AD, and again in Allen (1990) where it was presented as *c*1510 AD.

In anticipation of writing up the post-excavation work on the site during 1997, interest again developed in the bridge timbers and consideration was given to writing up the dendrochronology on the bridge timbers. Over seven years had elapsed since the initial analysis had been done in 1989, and it was hoped that, with the tenfold increase in local and national reference chronologies, a set of stronger matches would be found which would confirm the provisional results. However, in running the data against the new chronologies only resulted in obtaining several equally strong 'new' dates, both pre-dating and post-dating the AD 1507 date (Fig 8a). Clearly more samples were required or the samples would have to be considered undated. Consequently, on the 10th of December 1996 the bridge timbers were unearthed in the Oxfordshire County Museum Service's store at Standlake and eight additional timbers were sampled. Details of each sample, including date, number of rings, sapwood complement, location, and other characteristics are summarised in Table 1, and scale section drawings of each timber is shown in Figure 9.

Initially six samples were found to match together: ***abv3939***, ***abv3922***, ***abv3923***, ***abv8013***, ***abv3942***, and ***abv3920*** (Table 2). These were combined to form the site master ***ABINGDON*** of 114 rings which was compared with the reference chronologies and found to date, spanning the years AD 1394-1507 (Tables 3 and 4). This confirmed the previously provisional date of AD 1507 for sample ***abv3942***, and the increased matches with the reference chronologies were singularly stronger (Fig 8b).

Two samples were taken from the west trestle baseplate ***abv3939***: ***a*** was a core which had broken at the heartwood/sapwood boundary, and ***b*** was a V-section cut on the bottom of the timber to bridge the broken segments of core ***a***. In comparing the two, it was found that the core had not lost any rings, and both were combined together to form the mean ***abv3939*** with a *t*-value of 6.51. As this was one of the timbers included in the site master, and as it had complete sapwood, a precise felling date of spring AD 1508 could be given. During examination of the timbers, it appeared from the orientation of the saw marks and knots that this timber had come from the same tree as the east trestle baseplate, ***abv3942***. Whilst the *t*-value match of 8.32 between the two timbers would support the theory, they were not sufficiently high enough to warrant combining into a single mean of the two. Generally a threshold *t*-value of 10 is passed before combining individual samples thought to be from the same parent tree.

Sample ***abv3922*** had what appeared to be complete sapwood, but the area of the V-section was slightly abraded at the outside edge, therefore the last ring was not measured, but a felling date of *c* AD 1507 was given. Finally, sample ***abv3942*** had what appeared to be complete sapwood, but again as the surface was damaged, a felling date range of AD 1507-11 was given. The other three dated samples, ***abv3920***, ***abv3923***, and ***abv8013*** had incomplete sapwood, thereby giving respective felling date ranges of AD 1480-1512, 1501-1526, and 1495-1527. These are all entirely consistent with the felling date of AD 1508 from sample ***abv3939***.

Two additional samples were found to match the individual samples as shown in Table 2. Sample ***abv3925*** dated against the site master with a *t*-value of 6.83, with a last measured ring of AD 1485. As this sample had seven rings of sapwood, an estimated felling date range of AD 1487-1519 was given. Sample ***abv8035*** dated against the site master with a *t*-value of 5.24, with a last measured ring date of AD 1481. As this sample had the heartwood/sapwood transition, an estimated felling date range of AD 1490-1522 was given. Despite the acceptable matches between the other samples and the site master, it was found that by including these in an all encompassing site master actually *decreased* the matches with the reference chronologies, so they were left out.

Three samples remained undated. Sample ***abv3927*** of 47 rings matched sample ***abv3943*** of 76 rings with a $t = 6.98$. However, neither the individual samples nor the resulting mean matched at any date conclusively. Sample ***abv3944*** with 88 rings also failed to date. All of these illustrated particularly wild, distorted growth patterns which have been noted to some extent in most of the samples analysed (Fig 10).

4. CONCLUSIONS

Of the eleven timbers sampled from the remains of the waterlogged bridge excavated from the Convent Ditch, eight dated, six being combined to form a 114-year chronology spanning the years AD 1394-1507 and producing a precise felling date of spring AD 1508. The dating has also shown that associated elements including planking and stakes are from the same period of construction (Fig 11).

Preliminary analysis in 1989 of three samples produced inconclusive results for one of the samples. By including an additional eight samples taken in 1996, it was possible to confirm the provisional date (Fig 8b). With the additional precise felling dates or significantly narrowed felling date ranges produced, one is now able to more accurately assess the dating of the structure as a whole, and to suggest a construction date during or shortly after AD 1508.

5. ACKNOWLEDGEMENTS

The author is grateful for the assistance of Mr Tim Allen of the Oxford Archaeological Unit both for providing the 1989 samples and for background information and much of the text in the introduction. Assistance was given by Jonathan Wallis and Christine Edbury at the Oxfordshire County Museums Store, where a workshop was provided. David Haddon-Reece agreed to include the site as part of the Oxfordshire Mean Curve research. Jennifer Hillam and Cathy Groves of the English Heritage funded Sheffield University Dendrochronology Laboratory kindly reviewed the difficult material and confirmed the results. Acknowledgements are also given to the Ancient Monuments Laboratory of English Heritage, Ian Tyers, and to Sheffield Dendrochronology Laboratory, for both published and unpublished data.

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Table 1: Summary of tree-ring dating

Sample number		Timber and position	Dates AD spanning	H/S bdry	Sapwood	No of rings	Mean width mm	Std devn mm	Mean sens mm	Felling seasons and dates/date ranges
BRIDGE, CONVENT DITCH, ABINGDON VINEYARD										
* ***abv3920***	c	Centre strut, east trestle	1394-1473	1471	2	80	1.56	0.92	0.174	1480-1512
* ***abv3922***	s	Stake, east trestle	1439-1506	1473	33	68	0.89	0.31	0.163	*c.* 1507
* ***abv3923***	s	Stake, east trestle	1413-1500	1485	15	88	0.74	0.22	0.200	1501-1526
abv3925	c	S centre post, west trestle	1388-1485	1478	7	98	0.99	0.45	0.234	1487-1519
abv3927	c	N brace, west trestle	-		h/s	47	2.17	1.01	0.210	
abv3939a	c	Base plate, west trestle	1395-1507	1481	26¼C	113	1.40	0.59	0.221	
abv3939b	s	ditto	1454-1507	1484	23¼C	54	1.12	0.33	0.180	
* ***abv3939***		Mean of ***abv3939a*** + ***abv3939b***	*1395-1507*	*1483*	*24¼C*	*113*	*1.38*	*0.58*	*0.210*	*spring 1508*
* ***abv3942***	s	Base plate, east trestle	1428-1507	1481	26	80	2.07	0.81	0.253	1507-1511
abv3943	s	S brace, east trestle	-		26	76	1.53	1.00	0.223	
abv3944	s	S post, east trestle	-		h/s	88	2.30	0.85	0.267	
* ***abv8013***	s	Stake, east trestle	1436-1486	1486	h/s	51	1.24	0.30	0.153	1495-1527
abv8035	c	Plank, east trestle	1422-1481	1481	h/s	60	0.97	0.53	0.288	1490-1522
* = ***ABINGDON*** **Site master**			**1394-1507**			**114**	**1.45**	**0.65**	**0.175**	

Key: * = sample included in site-master; c,s = core, slice; = pith included in sample; = within 5 rings of centre; ¼C,½C,C = bark edge present, partial or complete ring: ¼C = spring (ring not measured), ½C = summer/autumn, or C = winter felling (ring measured);
H/S bdry = heartwood/sapwood boundary - last heartwood ring date; std devn = standard deviation; mean sens = mean sensitivity

Table 2: *t*-values and overlaps for components of ***ABINGDON*** with ***abv3925*** and ***abv8035***

Sample:	***abv3922***	***abv3923***	***abv8013***	***abv3942***	***abv3920***	***abv3925***	***abv8035***
dated at:	1506	1500	1486	1507	1473	1485	1481
abv3939	6.53	5.52	6.19	8.32	5.13	6.09	5.88
	68	88	51	80	79	91	60
	abv3922	2.94	5.74	4.31	2.77	3.56	4.61
		62	48	68	35	47	43
		abv3923	3.12	3.28	4.56	5.89	2.69
			51	73	61	73	60
			abv8013	5.13	1.74	4.98	3.34
				51	38	50	46
				abv3942	2.63	5.09	3.47
					46	58	54
					abv3920	3.34	2.82
						80	52
						abv3925	2.06
							60

Table 3: Dating of ***ABINGDON*** against reference chronologies at AD 1507

Reference chronology	**Spanning**	**Overlap**	**t-value**
* EASTMID *(Laxton and Litton 1988)*	882-1981	114	4.33
WHTOWER3 *(Miles and Worthington 1997)*	1301-1489	96	4.51
*‡ HIGH *(Fletcher unpubl)*	1367-1477	84	4.55
HANTS97 *(Miles 1997b)*	1041-1972	114	4.62
OXPRISON *(Miles and Haddon-Reece 1995)*	1411-1551	97	4.66
*‡ KITCHEN *(Fletcher unpubl)*	1394-1507	91	4.80
WC KITCH *(Hillam unpubl)*	1331-1573	114	4.84
*‡ NUFF *(Haddon-Reece et al 1989)*	1404-1627	114	4.88
*‡ MDM11 *(Miles and Haddon-Reece 1993)*	1355-1471	78	4.90
* OXON93 *(Haddon-Reece et al 1993)*	632-1987	114	5.13
MASTERAL *(Haddon-Reece and Miles 1993)*	404-1987	114	5.29
THAXTED2 *(Tyers 1990)*	1345-1526	114	6.36

* Component of MASTERAL

‡ Component of OXON93

Table 4: Ring-width data for site master curve

ABINGDON AD 1394-1507 Convent Ditch Bridge, Abingdon - mean of samples
abv3939+3922+3923+8013+3942+3920
114 rings, starting date AD 1394

ring widths (0.01mm)										number of samples in master									
286	310	297	266	265	255	285	328	219	335	1	2	2	2	2	2	2	2	2	2
283	213	296	297	261	309	193	181	147	131	2	2	2	2	2	2	2	2	2	3
113	96	109	167	97	75	85	84	75	88	3	3	3	3	3	3	3	3	3	3
125	83	74	111	169	176	180	219	174	168	3	3	3	3	4	4	4	4	4	4
145	184	144	176	147	120	91	116	143	115	4	4	5	5	5	6	6	6	6	6
101	83	132	142	128	97	84	120	120	127	6	6	6	6	6	6	6	6	6	6
141	132	136	122	128	137	186	160	144	157	6	6	6	6	6	6	6	6	6	6
112	128	128	123	124	156	144	108	104	101	6	6	6	6	6	6	6	6	6	6
77	112	126	106	108	148	120	148	97	88	5	5	5	5	5	5	5	5	5	5
95	101	117	159	128	98	101	60	58	60	5	5	5	4	4	4	4	4	4	4
58	69	68	96	89	98	121	150	117	120	4	4	4	4	4	4	4	3	3	3
116	112	143	228							3	3	3	2						

Figure 1: Site location plan *(after Allen 1990)*

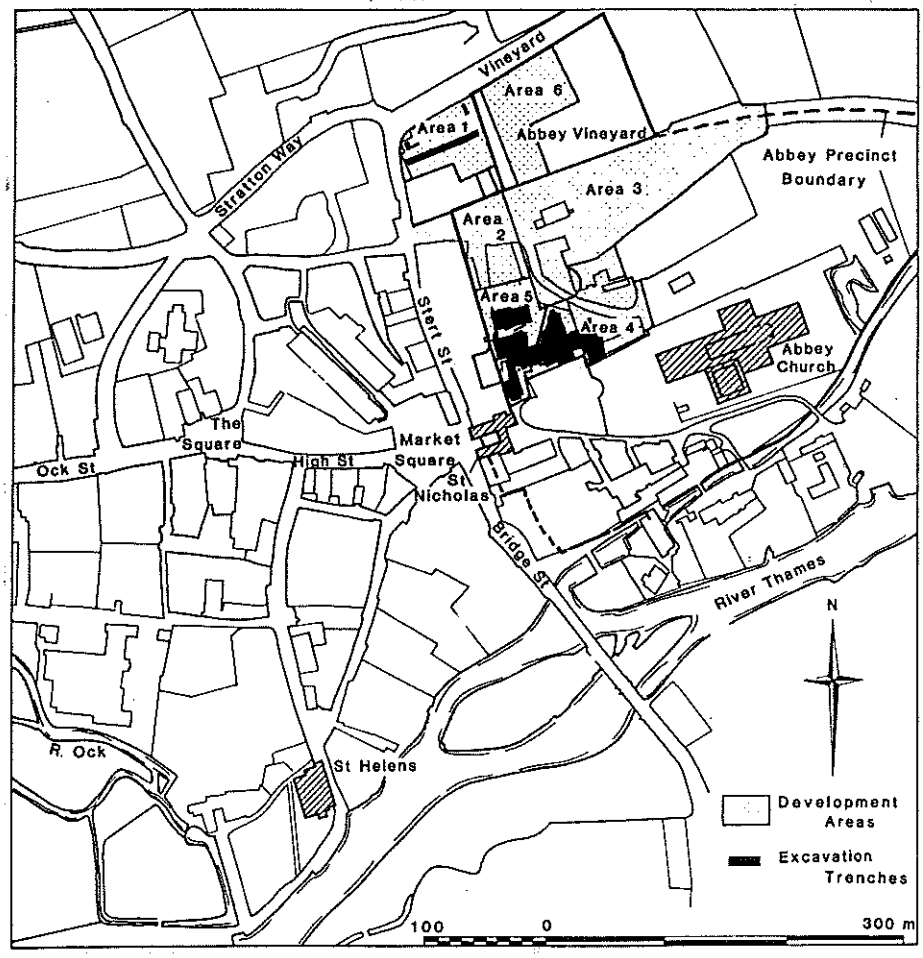


Figure 2: Plan of Abbey precinct *Allen 1990*

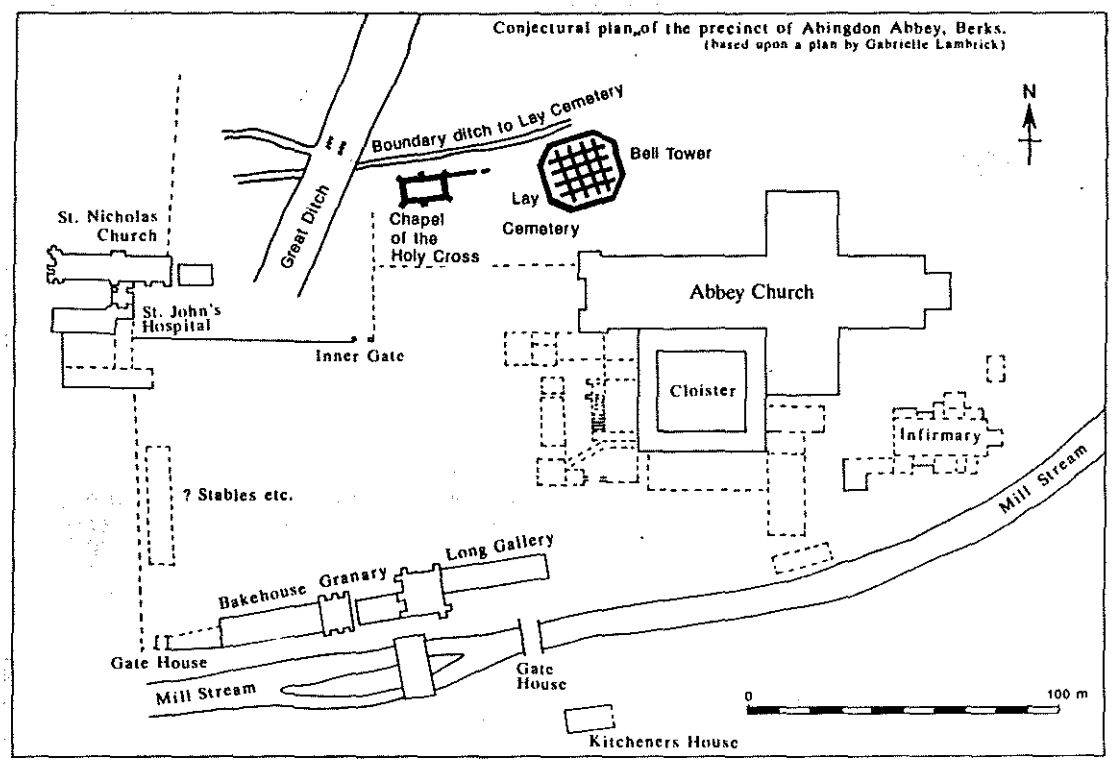


Figure 3: Plan of excavation *Allen 1990*

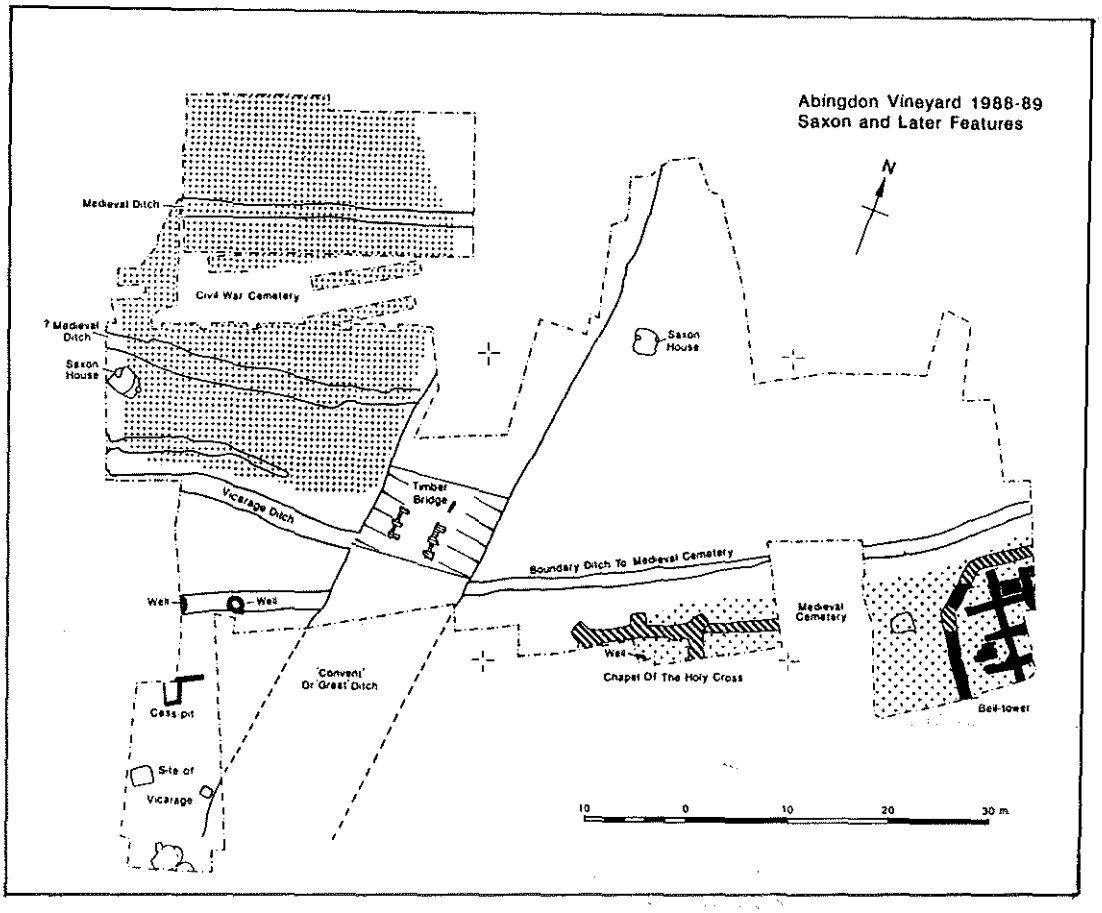
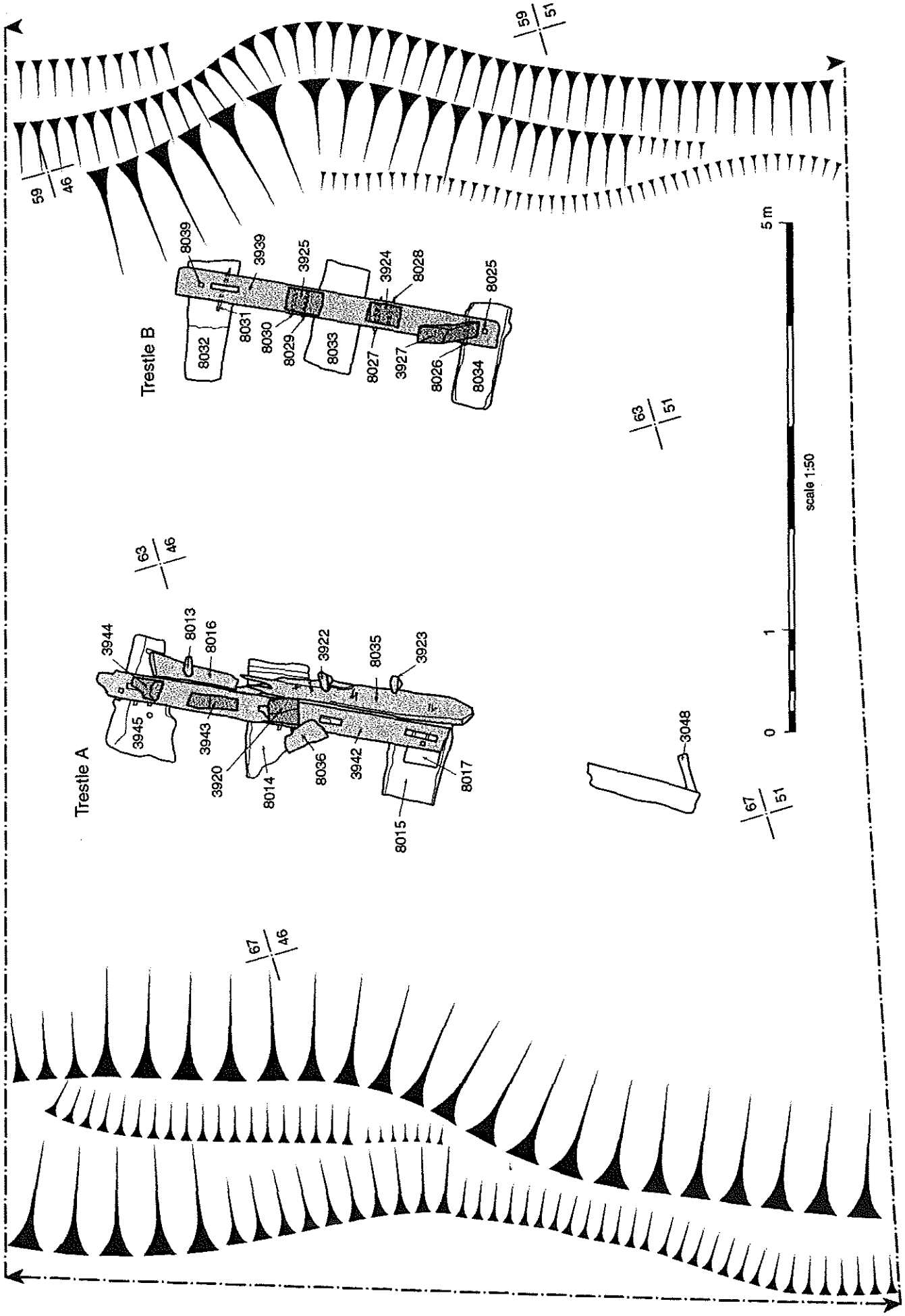


Figure 4: Plan of excavation *(Oxford Archaeological Unit)*



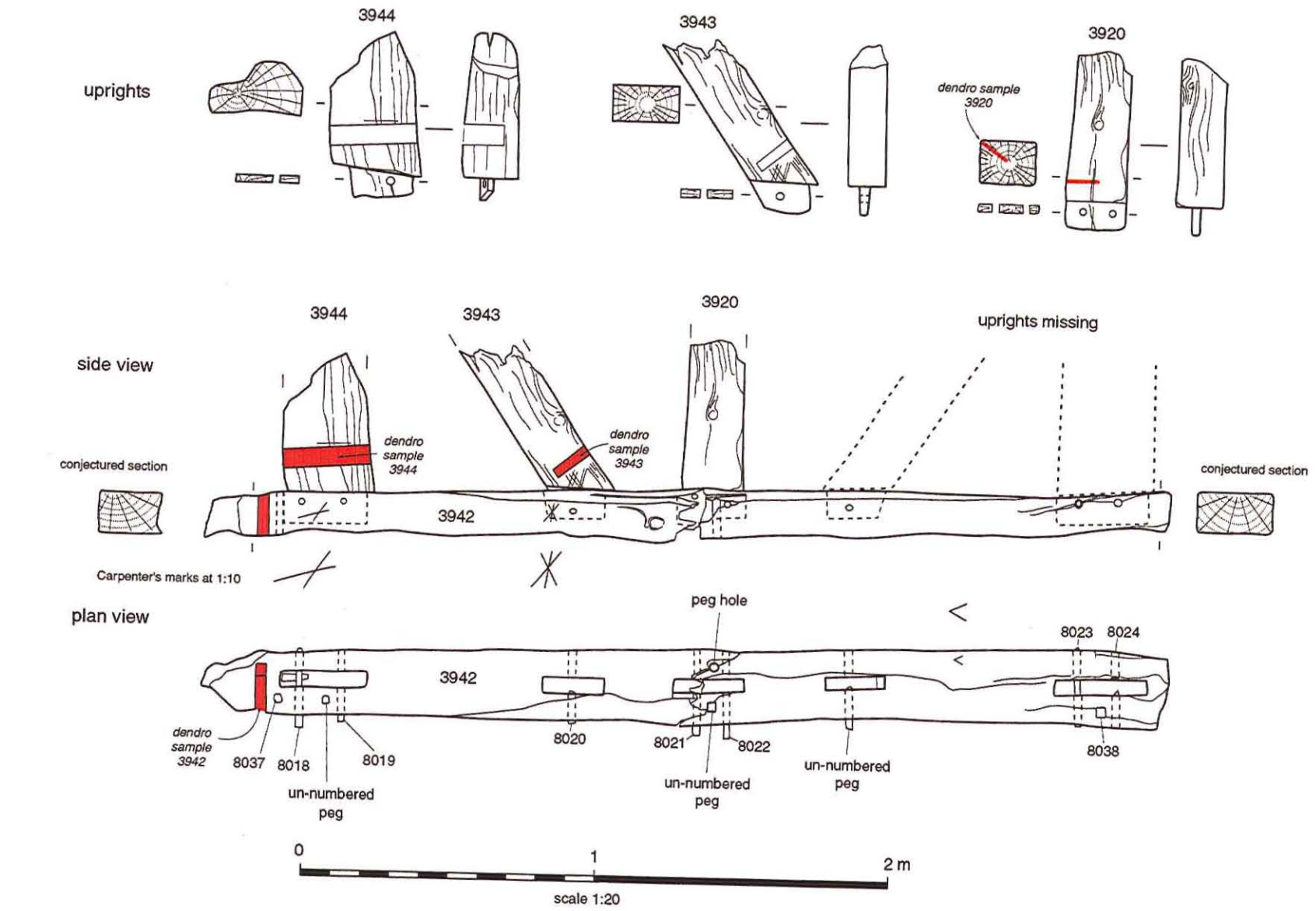


Figure 5: Plan and elevation of east trestle showing sample locations (*Oxford Archaeological Unit*)

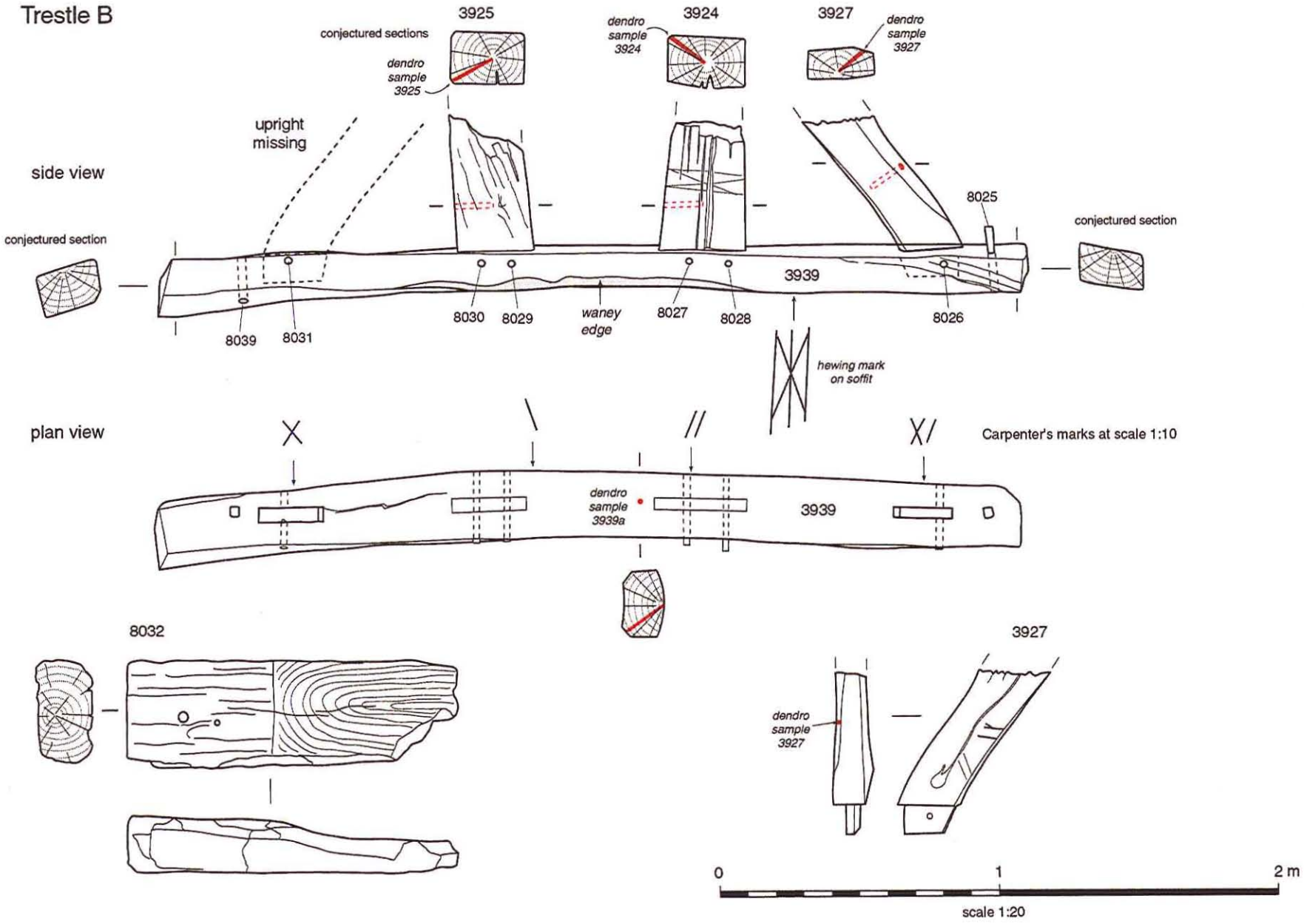


Figure 6: Plan and elevation of west trestle showing sample locations (*Oxford Archaeological Unit*)

Figure 7: Details of plank and stakes (*Oxford Archaeological Unit*)

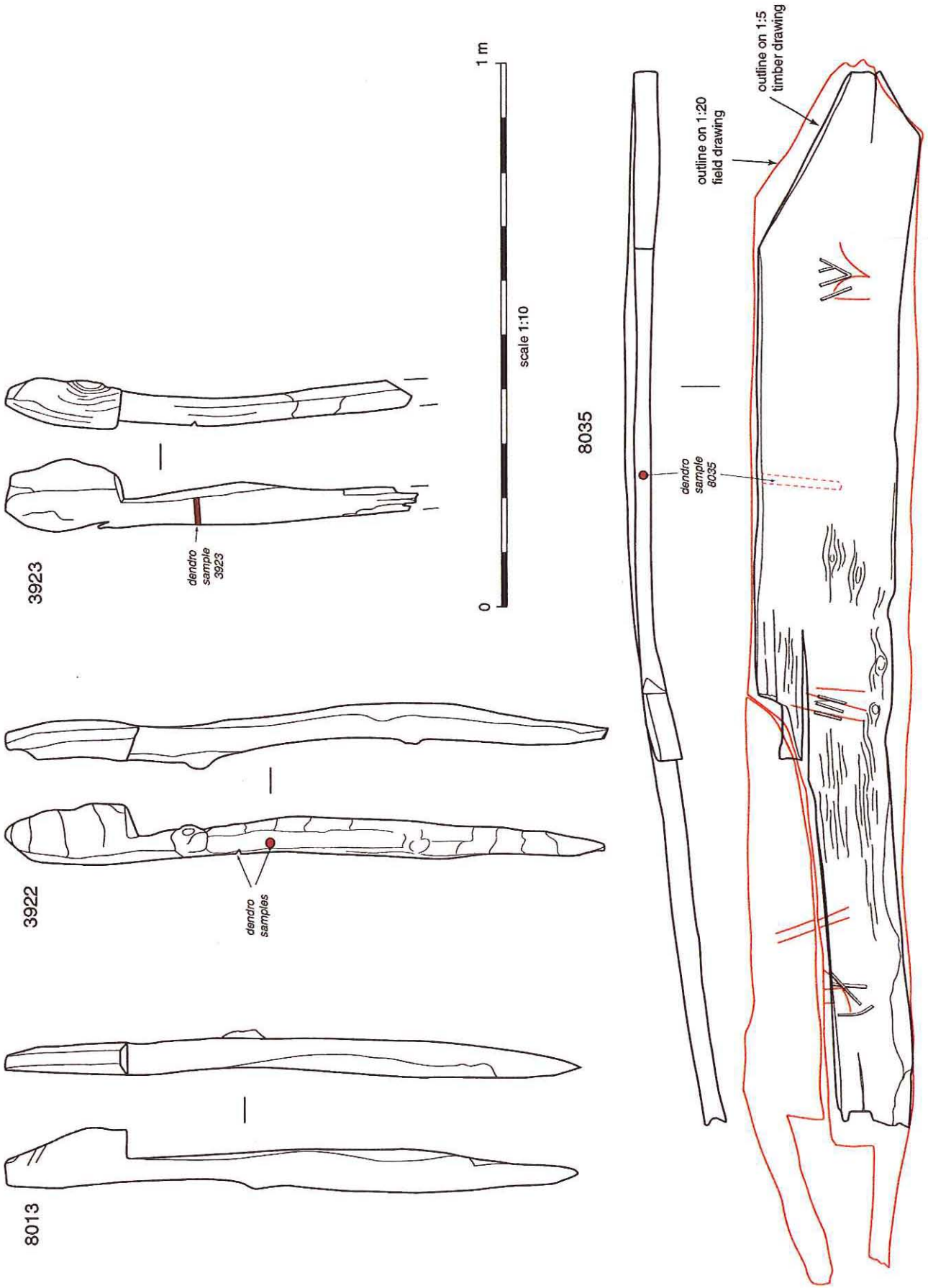


Figure 8a: Millennium histogram of matches of ***abv3942*** against 479 reference chronologies

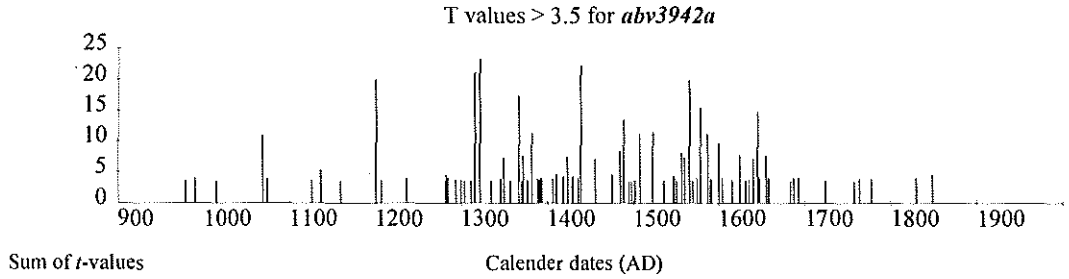


Figure 8b: Millennium histogram of matches of ***ABINGDON*** against 479 reference chronologies

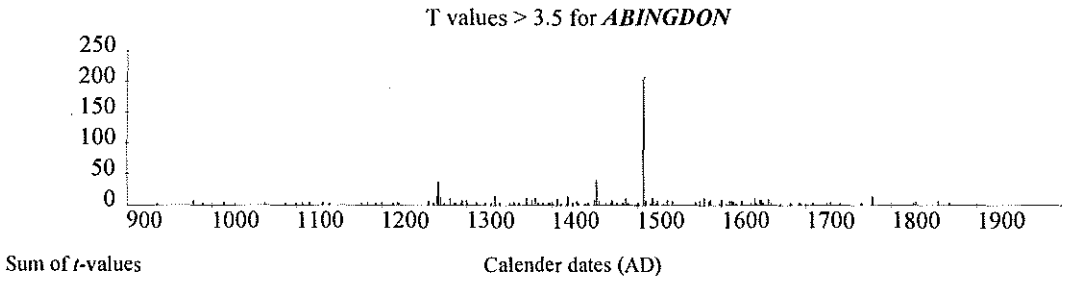


Figure 9: Sections of timbers sampled

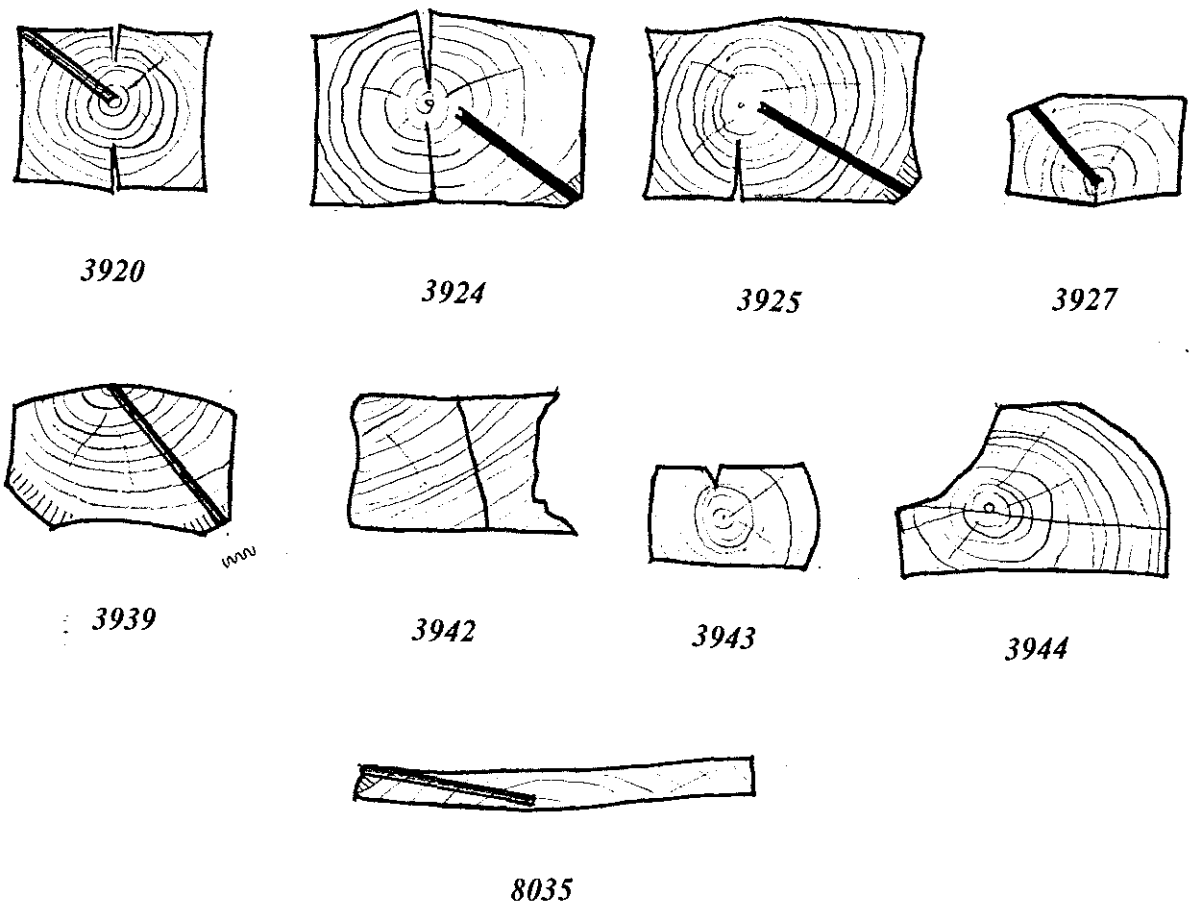


Figure 10: Scale representations of individual ring sequences

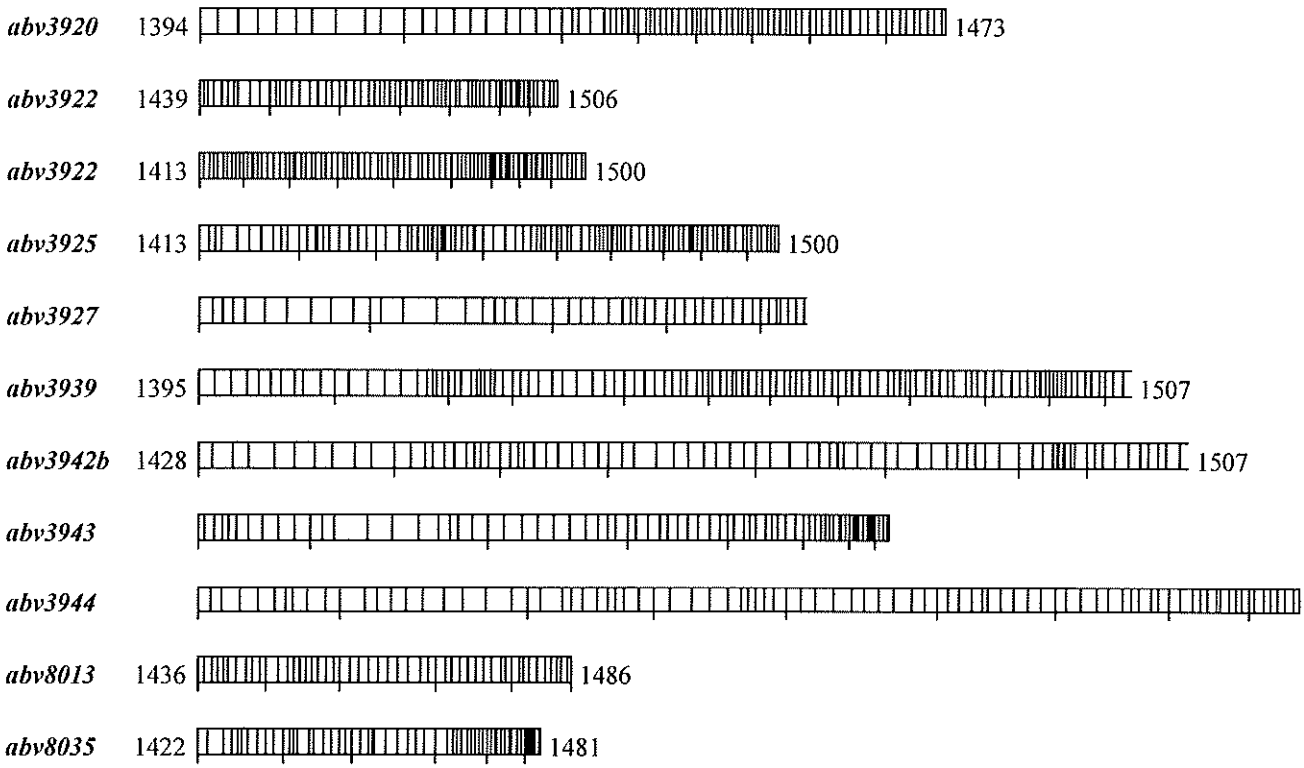


Figure 11: Bar diagramme showing relative positions of samples and felling dates/ranges