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Summary

A massive restoration project during 1986-7 on the medieval Zacharias's Building, Cornmarket, Oxford, (SP 5128 0634) produced twenty-five timber off-cuts for dendrochronological analysis. Initial analysis undertaken in 1987 tentatively dated eighteen of the samples, three producing felling dates from the winter of AD 1381/2 and another to the winter of AD 1386/7. These were summarised in Haddon-Reece et al 1988 and in Munby et al 1992. Further analysis in 1996 confirmed ten of these dates which included two felling dates from the winter of AD 1381/2, a third from the winter of AD 1382/3, but did not confirm acceptably the AD 1386/7 felling date previously reported. Six samples were combined to form a new master chronology ZACHS96 spanning the years AD 1164-1381, with slightly higher t-values.

Authors' addresses :-

Mr D W H Miles
Mill Farm
Mapledurham
Oxon
RG4 7TX

Mr D Haddon-Reece
Thorgill House
Thorgill Rosedale
Pickering
N.Yorks
YO18 8SG

**THE TREE-RING DATING OF
THE NEW INN
26-28 CORNMARKET, OXFORD**

1. Introduction and objectives

The site was assembled by John Gibbes, a prominent Oxford vintner, at an unknown date, but vacant land on which part of the inn was built was leased from the adjacent church of St Michael at the Northgate in March 1386 for one hundred years, with permission to build new houses on it. Gibbes died in AD 1386 or 1387, and in 1396 his son granted the 'New Inn and five shops' to feoffees. The inn was of courtyard-type, of stone and timber-framing, with traceried windows and both crown-post and clasped-purlin roofs. Certain features are comparable with contemporary work at New College and are fully described in Munby *et al* 1992.

The site under investigation comprised two buildings: that at 26 and 27 Cornmarket and the rear wing at 26 Ship Street. Both were occupied for almost a century by Zacharias and Co (Zachs for Macks), well known waterproof clothing suppliers, who ceased trading in 1981. In 1983 the premises were inspected by Julian Munby and David Sturdy who produced an architectural *Zacharias Report* on the Cornmarket range, highlighting the importance of the building. Immediately afterwards the lease was surrendered to Jesus College and the premises were repossessed. In 1984 planning and listed building consent applications were submitted with proposals by the Architects Design Partnership. Concern was expressed of the impact on the historic fabric of the original structures, and Freddie and Mary Charles were appointed consultant architects later in the year. By the middle of 1985 a programme of restoration and repair was approved, and an eighteen-month programme of work commenced in November of that year.

The work was carried out Alfred Groves and Sons, contractors, and this involved the almost complete dismantling of 26 and 27 Cornmarket and removal to their yard at Milton under Wychwood. A detailed account of the repair process can be seen in Charles (1988). At the end of May 1987 the building was fully repaired and was shortly afterwards tenanted by Laura Ashley on the ground and first floors, and with accommodation for Jesus College on the top floor.

The primary objective for dating the building was to ascertain whether the two ranges were coeval, and how the dates related to the documentary references. For this reason particular importance was laid on obtaining *precise* felling dates. Thus the dating was requested by the Inspector of Historic Buildings, Paul Drury, and was carried out in the Ancient Monuments Laboratory of English Heritage.

2. Methods

All samples were of oak from what appeared to be primary first-use timbers. All offcuts resulting from the repair process were assessed and only those with complete sapwood or with reasonably long ring sequences were considered. The dry samples were sanded without pre-treatment 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 was plotted as a graph of width against year on log-linear graph paper. The graphs of each of the samples in the phase under study are then compared visually and, if found satisfactory and consistent, are averaged to form a mean curve for the site or phase. This mean curve and any unmatched individual sequences are compared against dated reference chronologies to obtain an absolute calendar date for each sequence.

Once the samples were matched visually, they were then independently matched by computer. During the original analysis in 1987, the ring-width series were compared on the main frame laboratory computer with a variant of the Belfast CROS program (Baillie and Pilcher 1973) adapted by D Haddon-Reece. During the 1996 reassessment by D Miles, the computer work was carried out on an IBM compatible 486SX computer for statistical cross-matching using . A version of the programs in use in the Ancient Monuments Laboratory were written in BASIC by D Haddon-Reece, late of the Ancient Monuments Laboratory and latterly re-written in Microsoft Visual Basic by M R Allwright and P A Parker. The bar diagram graphics software was written by M R Coome.

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 early wood 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 national sapwood estimate for British oaks is given as between 10 and 55 rings with a 95% confidence range (Hillam *et al* 1987). Sometimes a regional sapwood estimate may be used, for instance a 95% confidence range of 10-30 has been found to be more appropriate for Oxfordshire (Haddon-Reece and Miles forthcoming) If no sapwood or heartwood/sapwood boundary survives, then the minimum number of sapwood rings is added to the last-measured ring to give a *terminus post quem*.

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 a year or two 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 is common practice to build timber-framed structures with green or unseasoned timber (Charles 1984).

3. Results

1987 analysis

Groves's workshop was visited in 1986 by D Haddon-Reece during the repair of the timber-frames, and the offcuts were examined with building historian Julian Munby to ascertain provenance. From these 25 offcuts were selected and removed to the Ancient Monuments Laboratory for analysis. Except in a few instances it was not possible to identify positively which *particular timber* the offcut was from, but the contemporaneity of the samples was confirmed by the building historian and all samples were then labelled in Roman numerals from I to XXV. For the 1996 re-analysis, and for this report, these were renumbered in arabic *zck1-25*.

Since the samples were sections removed from timbers in the course of repairs, some did not retain their full section. However, most timbers appeared to be heart-sawn, although a few joists were boxed heart. Six of the samples retained complete sapwood, five with both the spring vessels as well as the summer growth complete, indicating felling in the winter, and one sample had the spring vessels formed indicating felling between March and May. With only two exceptions, all timbers examined were from trees less than 80-100 years old when felled. Sample *zck19* had less than 25 rings and was not processed.

Sample *zck17* was significantly different in nature to the other samples from the site. This was a section of a jetty bracket, without any sapwood, heartwood/sapwood boundary, or anywhere near the centre of the tree. Despite this it had over 185 rings, and would have originated from a slow-growing tree at least 300-400 years old. This was the first sample to be processed, and it dated immediately to span the years AD 1164-1348.

The other samples were processed, but none matched conclusively sample *zck17* with the exception of a short overlap match with *zck7*. Therefore, the other samples were matched with each other within four separate groups: front-range joists, front-range post, front-range rafters, and rear-range jetty joists and bracket. Altogether eighteen samples were matched together into these four groups, mainly through visual cross-matching with statistical computer confirmation.

The groups were then matched together and ***ZACHS***, a mean of 223 rings, was constructed. This had already been dated through *zck17*, and this was again compared against the reference chronologies and dated, spanning the years AD 1164-1386. Full details of the timbers sampled and the dates obtained in the initial analysis can be seen in Table 1.

1996 Re-analysis

Since the late 1980's, the stringency with which practitioners have viewed the acceptability of t = 3.5 has risen. It has been observed, time after time, that batches of sample cross-matchings in which the frequency of matches at t = 3.5 have been far greater than the chance workings can possibly allow given that there can be no more than one real cross-date between any pair of samples. To confirm visual matches, t-values of at least 4.5 and preferably over 5.0 are now required. However, the CROS dating routine is not entirely appropriate for sequences under 70 rings in length, and lower t-values may be expected for shorter ring-width comparisons. It was decided therefore to review the 1987 analysis, with the benefit of vastly improved multiple crossmatching and sorting routines. The archive was therefore multiplied by 100 to remove the decimal point and new arabic sample numbers ascribed.

Leaving sample ***zck17*** aside, four samples (***zck1***, ***zck2***, ***zck4***, and ***zck7***) were found to match each other with suitable visual and statistical correlations. These were combined to form an intermediate site mean ***zzsq1*** of 74 rings. This was compared against the dated reference chronologies and was dated to span the years AD 1308-1381.

The intermediate mean ***zzsq1*** was then compared with the other individual samples, and sample ***zck11*** was found to match at AD 1374 with a t = 4.87. A new intermediate mean ***zzsq2*** was made and this was again compared with the reference chronologies, with improved results.

Sample ***zck17*** was again dated individually and the date span of AD 1164-1348 was confirmed. As this was found to match the second intermediate mean ***zzsq2*** at t = 5.13, it was combined with the other five to form a third intermediate mean ***ZACHS96***. This was again compared with the reference chronologies and the results were again substantially stronger.

The other individual samples were then compared with ***ZACHS96*** and sample ***zck8*** was found to match with t=6.11 at AD 1380. Similarly, sample ***zck18*** was found to match with t=4.99 at AD 1382. Although this is a short ring sequence, the visual matches were acceptable, and the sample important as it gave a felling date for the rear range. Sample ***zck23*** was found to match with a t=4.82 at AD 1381, although the sample has several bands of narrow rings. These three samples were then combined with the components of ***ZACHS96*** to form a second, enlarged, site master. However, subsequent comparisons against the reference chronologies dropped, so it was decided to abandon this second site master, and ***ZACHS96*** became the site master of 218 rings spanning the years AD 1164-1381. Table 2 shows the cross-matching matrix of the dated samples from the site, six of which were combined to form the site master.

Sample ***zck5*** was compared against the site master but as it matched with only a t = 4.02 at AD 1335, it was decided not to include it with the site master. However, this date was confirmed when compared with the reference chronologies (Table 3).

None of the other samples were found to date conclusively when compared against either the site masters or the reference chronologies, and although dates had been ascribed to some them previously during the initial analysis, these matches were not strong enough to be confirmed. Some of the samples showed signs of severe variability, sample ***zck6*** for instance is so extreme that it is unlikely to ever match.

Details of the samples taken, including date span, sapwood, mean ring width, and confirmed felling dates/date ranges are included in Table 4. The t-value matches for the intermediate and site masters against the reference chronologies are shown in Table 5. Figure 4 is a bar diagram showing the dated samples in chronological position.

4. Conclusion

Of the twenty-five samples taken from off-cuts at Zacharias in Oxford, eighteen samples had provisionally dated in 1987. Recent analysis with more stringent levels of acceptability confirmed ten dates, including two felling dates of winter AD 1381/2, and a third from the winter of AD 1382/3.

The recent analysis however did not confirm acceptably the AD 1386/7 felling date previously reported for sample ***zck12***. The dating would now suggest a much tighter range for felling dates, strongly implying construction before the AD 1386 documentation. Quite how this is reconciled is not forthcoming. However, the dating did conclude that the front range along Cornmarket Street was coeval with the rear wing along Ship Street.

Six of the dated samples were combined to form a new master chronology ***ZACHS96*** spanning the years AD 1164-1381, with slightly higher *t*-values.

5. Acknowledgements

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Table 1: Provisional summary of 1987 results *(from Munby et al 1992)*

TABLE VII.1: CROSS-MATCHING AND T-VALUES

	Cornmarket samples		
	joists	rafters	post V
Ship Street jetties	5.97	1.33	3.72
Cornmarket joists	–	4.76	4.99
Cornmarket rafters	–	–	1.74

TABLE VII.2: MEASURED SAMPLES FROM ZACHARIAS

Timber	*No.*	*A.M. Lab no.*	*Location*	*Date range*
THE CORNMARKET SHOPS				
Post	V	871399	1F main post	AD1250–1341
Joists	I	871396	1F principal	AD1308–1381*
	II	871379	1F joist	AD1318–1359
	III	871382	1F joist	AD1335–1373
	IV	871401	?F joist	AD1311–1364
	VII	871395	?F joist	AD1320–1365
	VIII	871394	1F joist	AD1337–1379
	IX	871391	?F joist	AD1346–1378
	X	871387	?F joist	AD1321–1366
			Mean for joists:	AD1308–1381
Rafters	XI	871400	rafter	AD1321–1374
	XII	871384	rafter	AD1316–1386*
	XIII	871404	rafter	AD1297–1380
	XV	871403	rafter	AD1305–1381*
			Mean for rafters:	AD1297–1386
Undated	VI	871386	2F principal joist	(78 rings)
	XIV	871381	purlin	(38 rings)
	XVI	871385	wall-plate	(75 rings)
THE SHIP STREET NORTH RANGE				
Jetty	XVII	871390	jetty bracket	AD1164–1348
	XVIII	871388	jetty joist	AD1343–1381*
	XX	871402	jetty joist	AD1324–1370
	XXII	871392	jetty joist	AD1338–1379
	XXIII	871397	jetty joist	AD1288–1381
			Mean for jetties:	AD1164–1381
Undated	XIX	871398	jetty joist	(<30 rings)
	XXI	871393	jetty joist	(39 rings)
	XXIV	871389	jetty joist	(28 rings)
THE GALLERY				
Undated	XXV	871383	'vestibule'	(39 rings)

Initial site sample numbers are given as well as the final Laboratory ones; IF = first floor; * = complete sapwood (bark edge present) – uncertain for sample XXIII.

Table 2: matrix of *t*-values and overlaps for dated samples

	zck2	*zck4*	*zck5*	*zck7*	*zck8*	*zck11*	*zck17*	*zck18*	*zck23*
	1359	1364	1335	1365	1380	1374	1348	1382	1381
zck1	5.49	3.05	3.59	3.96	2.47	3.74	2.78	3.82	4.29
	42	54	28	46	43	54	41	38	74
zck2		1.37	2.51	3.65	0.32	2.61	3.89	-	1.36
		42	18	40	22	39	31	-	42
zck4			2.85	6.08	1.27	3.27	3.45	1.81	2.86
			25	45	27	44	38	21	54
zck5				2.46	-	1.10	3.90	-	1.28
				16	-	15	86	-	33
zck7					1.53	3.20	5.20	1.15	3.36
					28	45	29	22	46
zck8						8.01	0.61	3.93	2.79
						37	11	37	43
zck11							2.57	4.29	4.21
							28	31	54
zck17								-	3.05
								-	46
zck18									3.11
									38

Table 3: Dating of ***zck5*** (AD 1250-1335) against reference chronologies at AD 1335

Reference chronology	**Spanning**	**Overlap**	**t-value**
QUEEN *(Haddon-Reece et al 1989)*	1203-1341	86	5.08
HARMOT3 *(Tyers pers comm)*	1262-1420	74	5.44
LEWKNOR *(Haddon-Reece et al 1990)*	1188-1350	86	5.66
MONKS *(Miles and Haddon-Reece forthcoming)*	1166-1300	51	5.79
TLT19 *(Tyers pers comm)*	1130-1407	96	6.53

Table 4: 26 and 27 CORNMARKET and 26 SHIP STREET, OXFORD - SUMMARY OF TREE-RING DATING

Sample number	Timber and position	Dates AD spanning	H/S bdry	Sap-wood	No of rings	Mean width mm	Std devn mm	Mean sens mm	Felling seasons and dates/date ranges
Front Range - 26 Cornmarket									
* *zck1*	1st floor principal beam	1308-1381	1364	17C	74	2.46	1.32	0.206	winter 1381/2
* *zck2*	1st floor joist	1318-1359	1359	H/S	42	2.74	1.17	0.347	1369-1389
zck3	1st floor joist/beam	-		6	38	3.03	0.92	0.228	
* *zck4*	Joist	1311-1364	1364	H/S	54	2.24	1.21	0.255	1374-1394
zck5	Principal post	1250-1335			86	2.69	1.10	0.281	after 1345
zck6	2nd floor princ beam, S end	-			78	2.26	1.15	0.407	
* *zck7*	Joist?	1320-1365	1365?	H/S?	46	2.44	0.72	0.242	1375-1395
zck8	1st floor joist	1338-1380	1362	18	43	1.98	0.86	0.320	1381-1392
zck9	Joist	-		8	33	3.47	1.05	0.195	
zck10	Joist	-			46	2.17	0.97	0.319	
* *zck11*	Rafter	1321-1374	1364	10	54	1.81	0.92	0.337	1375-1394
zck12	Rafter	-		13C	71	1.10	0.72	0.384	
zck13	Rafter	-		15C	84	0.73	0.36	0.244	
zck14	Purlin	-		15	38	2.92	0.88	0.253	
zck15	Rafter	-		13	77	1.15	0.78	0.250	
zck16	Wall plate	-		14¼C	75	2.71	1.53	0.232	
Rear Range - Ship Street									
* *zck17*	Jetty bracket	1164-1348			185	1.43	0.86	0.276	after 1358
zck18	Jetty joist	1344-1382	1367	15C	39	1.89	0.59	0.228	winter 1382/3
zck20	Jetty joist	-		3	47	1.98	0.64	0.232	
zck21	Jetty joist	-		1	39	2.56	1.28	0.216	
zck22	Jetty joist	-		H/S	42	2.37	1.42	0.249	
zck23	Jetty joist	1303-1381	1365	16C?	79	1.94	0.93	0.301	?winter 1381/2
zck24	Jetty joist	-		H/S	28	3.74	1.26	0.188	
zck25	Vestibule post or joist	-		H/S	39	2.58	1.28	0.212	
zzsq1	Mean zck1+2+4+7	1308-1381			74	2.37	0.95	0.194	
zzsq2	Mean zck1+2+4+7+11	1308-1381			74	2.31	0.92	0.208	
= *ZACHS96*	**Site Master**	**1164-1381**			**218**	**1.72**	**0.89**	**0.262**	

Key: * = sample included in site-master; ¼C,C = bark edge present, partial or complete ring: ¼C = spring, or C = winter felling;
H/S bdry = heartwood/sapwood boundary - last heartwood ring date; **std devn** = standard deviation; **mean sens** = mean sensitivity

Table 5: Dating of intermediate site means *zzsq1*, *zzsq2*, *zck17*, and site master *ZACHS96* against reference chronologies

Reference chronology	**Spanning**		**t-values overlaps**			
		Vs:	***zzsq1***	***zzsq2***	***zck17***	***ZACKS96***
		at:	**1381**	**1381**	**1348**	**1381**
MANORFM	1296-1401		5.17	5.51	3.28	4.58
(Miles and Haddon-Reece 1993)			74	74	53	86
KENT88	1158-1540		4.66	5.78	4.18	5.57
(Laxton and Litton 1989)			74	74	185	218
HARMOT3	1262-1420		5.93	5.77	4.68	5.79
(Tyers pers comm)			74	74	87	120
TLT19	1130-1407		7.09	7.63	5.16	6.61
(Tyers pers comm)			74	74	98	131
SHERFLD	1251-1390		5.13	4.99	5.24	6.63
(Miles and Haddon-Reece 1993)			74	74	185	218
EASTMID	882-1981		3.57	3.70	8.20	8.28
(Laxton and Litton 1988)			74	74	185	218
MONKS	1166-1300		-	-	8.80	8.80
(Miles and Haddon-Reece forthcoming)			-	-	135	135
SOUTH	406-1594		5.30	4.98	9.60	9.30
(Hillam and Groves 1994)			74	74	185	218
OLDCHRCH	1177-1365		4.35	4.33	8.56	9.42
(Miles and Haddon-Reece forthcoming)			58	58	172	189
READING	1160-1407		5.66	5.30	10.21	10.14
(Groves et al 1985)			74	74	185	218

Table 6: Ring-width data of the site master chronology ***ZACHS96*** at AD 1381

ZACHS96 (1164-1381) zck1+zck2+zck4+zck7+zck11+zck17

ring widths (0.01mm)	**number of trees per year**
317 498 444 294 293 319 318 317 134 124	1 1 1 1 1 1 1 1 1 1
208 342 269 263 350 418 296 353 415 242	1 1 1 1 1 1 1 1 1 1
131 271 268 361 169 182 260 229 174 343	1 1 1 1 1 1 1 1 1 1
177 176 210 228 150 134 230 234 161 250	1 1 1 1 1 1 1 1 1 1
220 196 150 156 234 132 298 274 192 267	1 1 1 1 1 1 1 1 1 1
173 194 183 174 115 153 106 105 058 089	1 1 1 1 1 1 1 1 1 1
087 067 139 062 101 141 123 117 134 054	1 1 1 1 1 1 1 1 1 1
096 096 057 113 071 161 127 104 053 053	1 1 1 1 1 1 1 1 1 1
058 045 080 103 057 078 071 061 057 043	1 1 1 1 1 1 1 1 1 1
056 085 079 134 102 091 091 086 117 083	1 1 1 1 1 1 1 1 1 1
072 087 095 078 086 090 151 146 082 110	1 1 1 1 1 1 1 1 1 1
099 083 098 120 069 055 113 098 093 097	1 1 1 1 1 1 1 1 1 1
096 136 169 090 087 120 143 100 136 194	1 1 1 1 1 1 1 1 1 1
136 104 143 093 075 087 091 075 106 061	1 1 1 1 1 1 1 1 1 1
066 071 144 105 375 301 294 262 284 235	1 1 1 1 2 2 2 3 3 3
253 262 253 219 193 222 212 229 202 219	3 3 3 3 4 4 5 6 6 6
211 151 088 194 265 261 227 156 168 196	6 6 6 6 6 6 6 6 6 6
289 295 257 185 232 299 236 210 161 144	6 6 6 6 6 6 6 6 6 6
217 252 245 267 274 243 272 346 319 322	6 6 6 6 6 5 5 5 5 5
230 199 178 138 090 143 128 169 157 244	5 5 5 5 5 5 4 4 4 4
285 165 085 102 146 233 218 176 190 155	4 3 2 2 2 2 2 2 2 2
097 125 128 118 139 165 111 110	2 1 1 1 1 1 1 1

Figure 1: Site location plan (*from Munby et al 1992*)

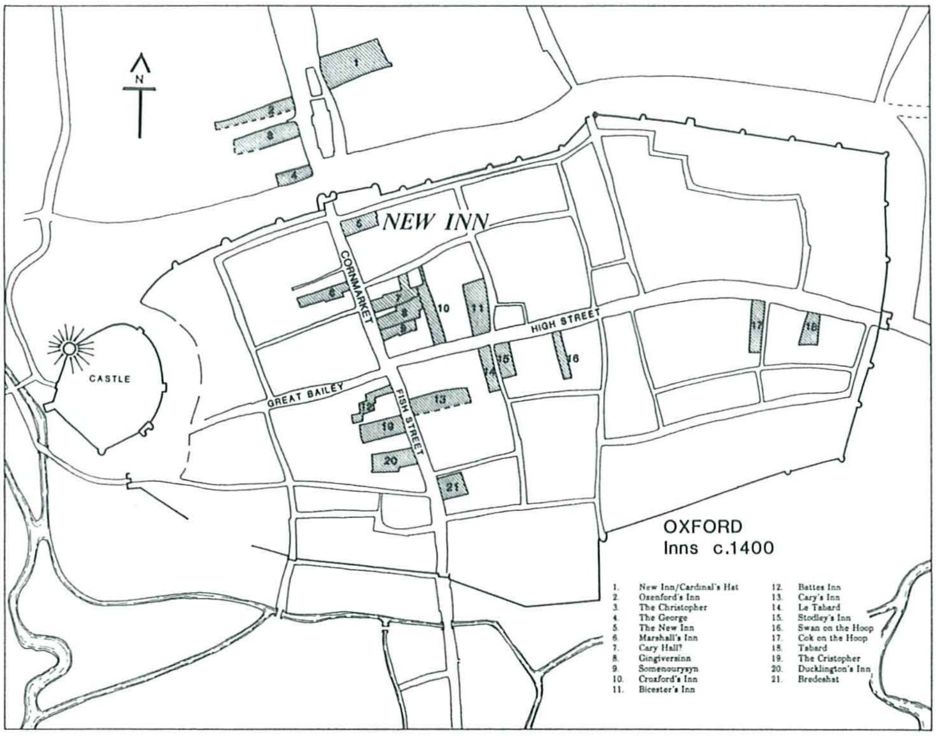


Fig. 1. Location of Zacharias's (The New Inn) and other Oxford Inns in *c.* 1400.

Figure 2: Reconstruction view of buildings (*from Munby et al 1992*)

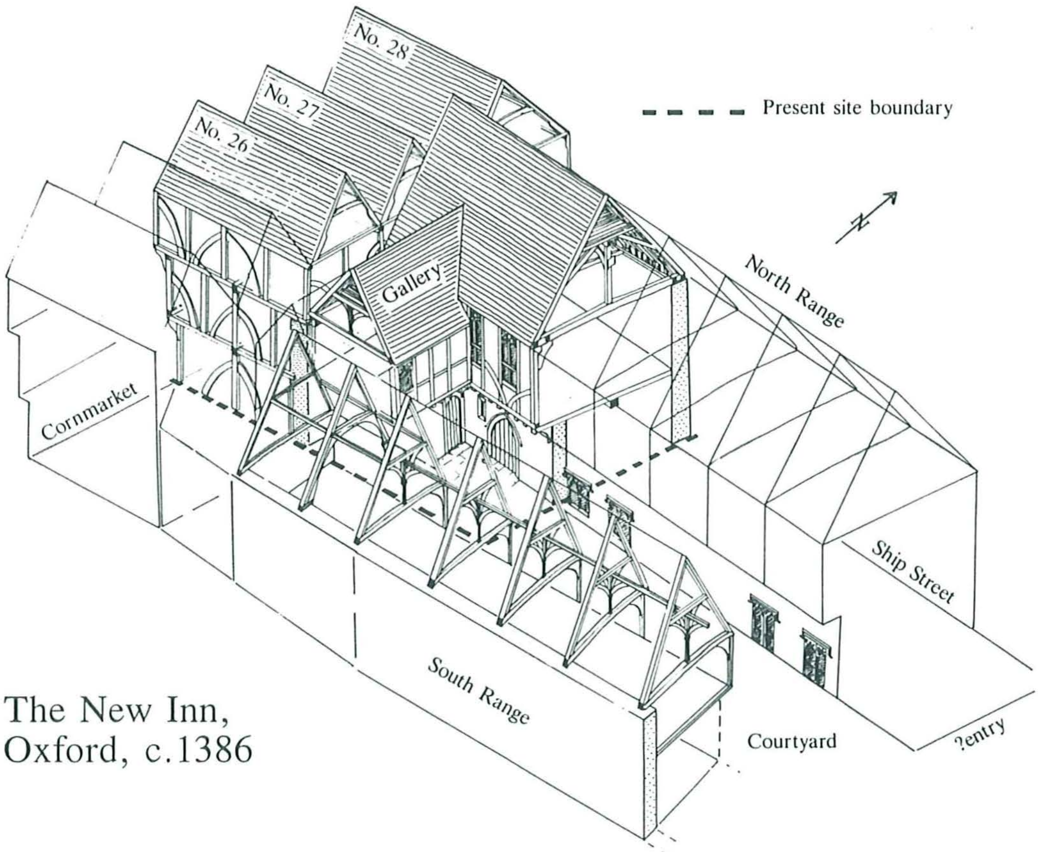
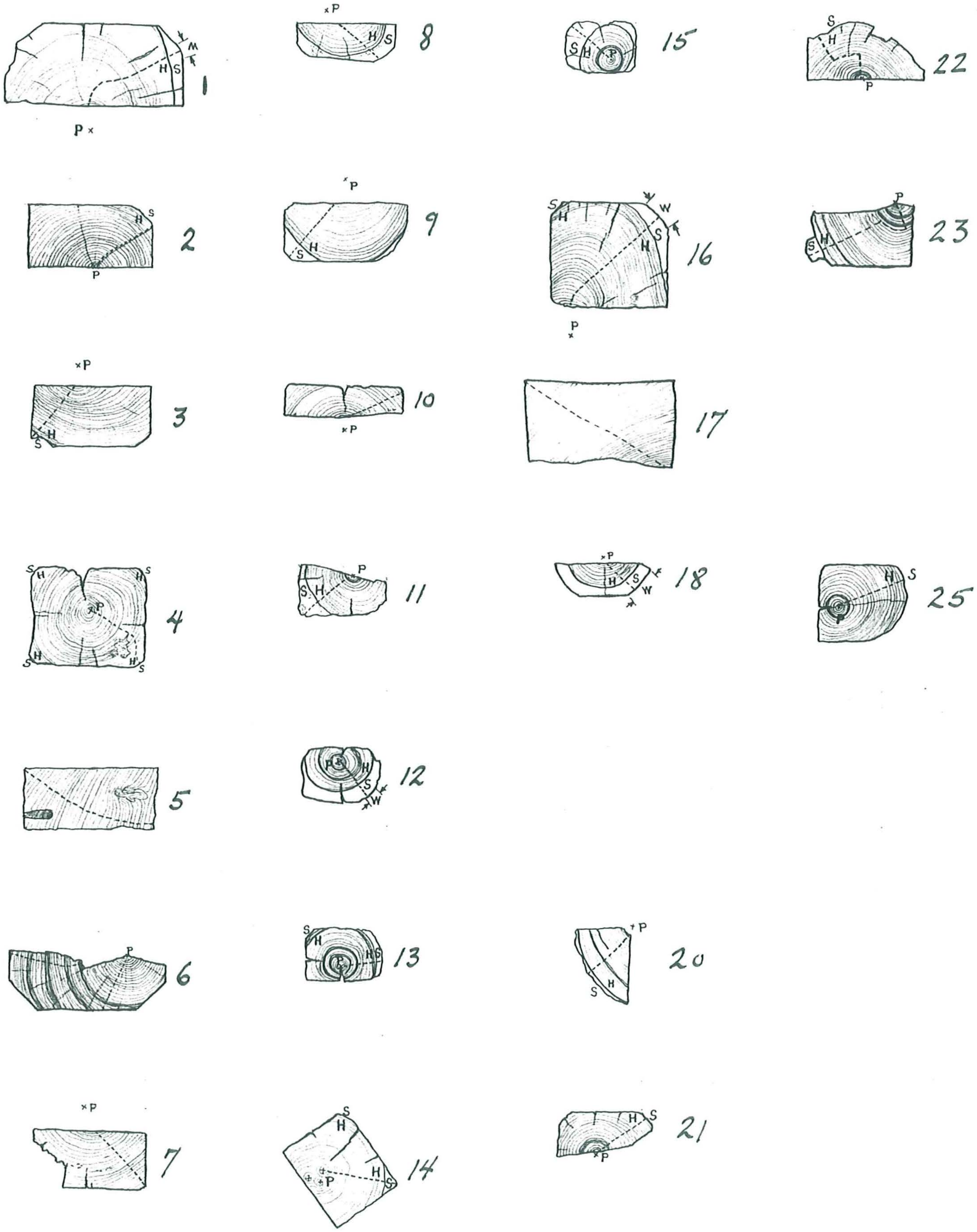


Fig. 10. The New Inn: reconstruction view of buildings.

Figure 3: Sections of timber offcuts sampled



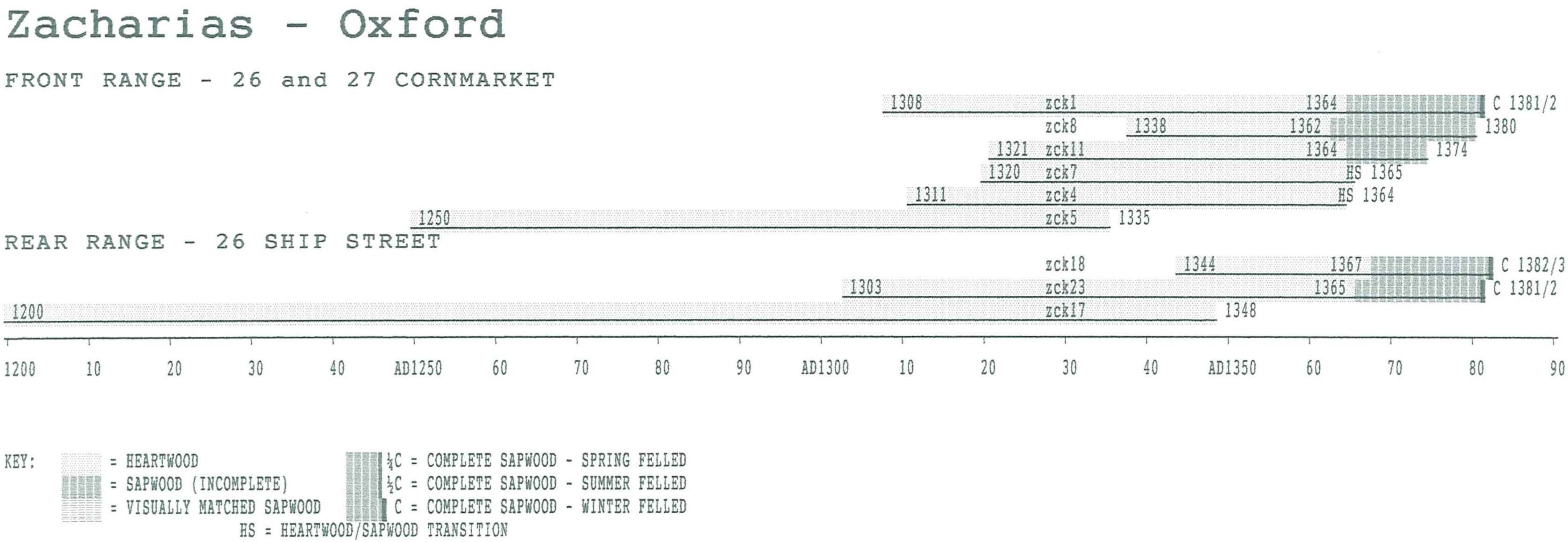


Figure 4: Bar diagram of dated samples in chronological position