AML Report 4745

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READING ABBEY: TREE-RING ANALYSIS AND DATING OF THE WATERFRONT STRUCTURES

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(November 1985)

ABSTRACT

Timber samples from waterfront structures at Reading Abbey, excavated during 1983/4, were examined at Sheffield Dendrochronology Laboratory. The ring sequences from timbers excavated in 1981 were also made available for re-analysis. The samples produced two site master curves covering the periods AD1160-1407 and AD1708-1766. The examination provided dates for over 50 per cent of the timbers, and hence probable dates of construction for many of the waterfront structures. The results were unexpected in that several of the construction phases were different in date to those originally predicted in the basis of the archaeological evidence. There were at least six phases of construction during the 13th, 14th and early 15th centuries and one during the 18th century.

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Reading Abbey: Tree-ring analysis and dating of the waterfront structures.

INTRODUCTION

The samples for this dendrochronological analysis came from oak (Quercus spp.) timbers excavated at the waterfront site of Reading Abbey. The Abbey was founded in AD1121 by Henry I, and became one of the most important and wealthiest Benedictine houses in England, receiving many grants of land and property (Fasham & Hawkes, 1984). The downfall of the Abbey occurred during the dissolution of the monasteries in the first half of the 16th century.

Reading town was strategically placed on the junction of the major east-west and north-south roads. It lies immediately west of the confluence of the River Thames and River Kennet, well above the tidal reaches of the Thames. The Abbey was built on a spur between the rivers on the eastern side of the town. The town, and especially the Abbey, was therefore very important with regard to trade and travel. Valuable and heavy cargoes would have been carried by water. Both the town and the Abbey had wharves on the Kennet, and the waterway and waterfront would have played a major role in their economies. It is, however, the Abbey and its waterfront on which the excavations were concentrated.

The site of the excavations lay on the banks of the River Kennet, near to where the Holy Brook enters the river (Figure 1). The Holy Brook, originally two channels, served as the Abbey mill stream and overflow. The first excavations, in 1981, revealed the timber remains of successive waterfronts. Although samples were taken for

dendrochronological analysis, Bridge (1983) had been unable to date them. Further excavatons during the winter of 1983/84 revealed more timber remains.

The existing model of waterfront development

As a result of the 1981 and 1983/4 excavations, P J Fasham and J W Hawkes (1984b), proposed a model for the waterfront's development (see reconstructions in Figure 2). Seven constructional phases of waterfront activity have been identified which can be dated to within the first century of the Abbey's existence, each with a life span of approximately 10 years. These structures are best interpreted as revetments as there is no evidence of active use of this area as a wharf. A partially reveted hard standing across the mouth of the Holy Brook (Figure 2a) is also thought to have been constructed in this period. No tree-ring samples were available from these structures.

During the late 13th and early 14th centuries major reorganisation of the Abbey waterfront necessitated the realignment of the River Kennet and the Holy Brook channels (Figure 2b). Initially a silt trap was constructed which was later replaced by a revetment of oak posts and planks. In the early 15th century a lock was built between the Abbey and the town wharves. This resulted in an elevation of the Abbey wharves due to the rise in water level.

After the dissolution of the Abbey the waterways declined. By late 17th century the Kennet and Holy Brook channels were badly silted up. However, after the passing of the Kennet Navigation Act in 1715, the river was embanked by a post and plank frontage and made navigable as far as Newbury. The Holy Brook channels were infilled and a new one

cut further north. Also the river frontage was moved eastwards (Figure 2c). During the last decade of the 18th century the plan to join the Kennet with the River Avon, via the Kennet and Avon canal, was carried out. The late 18th century stave built wharf was replaced by a post and plank frontage, constructed circa 1800. By the middle of the 19th century, the River Kennet and Holy Brook had attained their modern layout (Figure 1).

The Samples

Samples were examined from 49 oak timbers excavated during 1983/84. Many other timbers were found during the excavation but they were unsuitable for dating purposes. For example, most of the planks were tangentially split and had only 10-30 rings. The ring width data of the ten timbers examined by Martin Bridge (1983) from the 1981 excavations were also made available for study. The samples submitted to Sheffield were from trenches A and B, situated on either side of the 1981 excavation, trench C. Trench A lay on the banks of the medieval River Kennet. Trench B lay at the confluence of the medieval River Kennet and the Holy Brook Tail Race. Trench C lay across the mouth of the Holy Brook Overflow (Figure 3).

The samples from trenches A and B had been tentatively placed into several groups according to their approximate date (Table 1), and based on the Fasham and Hawkes model outlined above. Those from trench A came from Phase I (circa 1800) and Phase IV (late 13th and early 14th centuries). The samples from trench B were mainly from Phase IV and were further subdivided to aid dendrochronological analysis into

three broad construction phases:

i) late 13th and early 14th centuries.

ii) 14th to 16th centuries.

iii) early 16th to 18th centuries.

Trench B also provided samples from two isolated posts (273 and 274) assumed to be 17th or 18th century and a piece of driftwood (440), underlying an early landing stage, assumed to be mid 12th century.

The samples from Trench C were assumed to be late 13th and early 14th centuries as they lay on the same alignment and possibly the same structure as the Phase IV timbers from trench A (Figure 3). Sample 908 was assumed to be slightly later as it appeared to be part of a later extension to the structure. The positions of the individual timbers from each site are shown in Figures 4a-c.

The aims of this study were: firstly, to date the timbers, estimate the felling dates and thereby clarify the chronology of the waterfront's development; secondly, to produce a tree-ring chronology for the Reading area; and thirdly, to obtain any information of note about the timbers.

METHOD

The samples were deep frozen for a minimum of 48 hours to provide a firmer cross sectional surface. The cross sections were cleaned with a surform plane, whilst still frozen, to produce a surface on which each annual growth ring is clearly defined. At this stage any timbers with insufficient rings (for this study, those with less than 30) or unclear ring sequences were rejected. The wood was allowed to thaw slightly before it was measured.

The ring widths were measured on a travelling stage connected to an Apple microcomputer. The sample to be measured is observed through a low power (10x) binocular microscope. As each ring is traversed a signal is sent to the microcomputer, and the width of each ring in units of 0.02mm is automatically recorded in the microcomputer's memory and displayed on the VDU. When the ring sequence of a sample has been measured it can be printed out and also stored on a floppy disk. The sequence of ring widths of each sample is represented as graphs (width against time) on transparent semi-logarithmic paper.

The tree-ring curves were compared with each other visually by superimposing two curves, sliding one curve past the other and searching for similarities in the patterns of wide and narrow rings, which indicate that the timbers had some period of growth in common. This process, known as crossmatching, is also carried out on the Apple microcomputer. The computer program (Baillie & Pilcher, 1973) measures the amount of similarity between two ring sequences by calculating the value of Student's t for each position of overlap. Generally a t-value of 3.5 or over is significant if it is accompanied by an acceptable visual match (Baillie, 1982). Computer matching must always be checked

visually before it can be accepted, since spurious results occasionally occur.

A site master curve is produced from any matching curves by adding them together and producing an average curve. A master curve is more likely to produce a date than the ring sequence of a single sample when compared with a dated reference chronology. This is because the master curve enhances the common climatic signal but reduces the "background noise" resulting from the local growth conditions of individual trees.

The ring sequences from each group of samples (Table 1) were compared with each other for similarities and were finally tested against reference chronologies from Britain and Europe (Appendix 1).

Following the completion of crossmatching and dating, it is possible to calculate the felling dates of the timbers. Sapwood, the outer part of the oak tree, is very important in the determination of felling dates. It is easily differentiated from the heartwood, usually by its colour, but also because the large springwood vessels of the sapwood are hollow, whilst those of heartwood are filled with tyloses (Jane, 1970: 38). Sapwood, however, was often removed from the timber due to its susceptability to fungal and insect attacks.

If the sapwood on a sample is complete the exact felling year can be given. However, because the amount of sapwood in an oak tree is relatively constant, it is possible to estimate the felling year even if only a small amount of sapwood is preserved. A recent study of oak trees shows that the amount of sapwood remains constant between 10-55 rings (Hillam et al, forthcoming). If there is no sapwood present, the addition of the minimum sapwood allowance (10 rings) to the date of

the last measured heartwood ring produces a terminus post quem for felling. As the number of missing heartwood rings is unknown, the actual felling date could be much later.

Construction usually followed soon after felling since in medieval times timber was rarely seasoned unless it was to be used for panelling or furniture (see, for example, Hollstein 1980 or Rackham 1976). It would be unnecessary in any case to season timber which was intended for use in a waterfront structure. At this stage of the tree-ring analysis, however, factors such as stock-piling or timber re-use must also be considered, since they might affect the interpretation of the tree-ring dates. Thus whilst the production of dates is a completely independent process, their interpretation (i.e. calculation of felling and construction dates) can be refined by studying other archaeological evidence.

RESULTS

Of the 49 samples received from the 1983/4 excavation, only 7 were unsuitable for measurement. The annual growth rings on sample 265 were badly distorted due to the presence of knots. Three samples (230, 427 and 440) contained rings which were, in places, too close together to be distinguished reliably. Samples with less than 30 rings (143, 262 and 425) were not measured. Samples with more than 50 rings are preferred as these can be dated more readily. However, timbers with 30-50 rings can sometimes be dated but a great deal of care must be taken during crossmatching. Nine out of the ten 1981 samples, measured by Bridge (1983), were usable. Thirty three of the 59 samples from all three trenches had retained sapwood (see above). Details of orientation and number of rings of all samples from trenches A and B are given in Table 2; for trench C, see Bridge (1983). The ring width data from the 1983/4 excavation are available on request from the Sheffield Dendrochronology Laboratory.

Dating the timbers

The tree-ring sequences fell into 3 groups. The first was the group from trench A (phase I), tentatively dated to *circa* 1800. All nine of these timbers were measured, although their ring sequences were generally short. Only three of the ring sequences (39, 66 and 69) crossmatched conclusively (Figure 5). A master curve of 59 years, READING1, was constructed using the data from the three matching curves (Table 3). This master was tested against various reference chronologies, or absolutely dated ring sequences (see Appendix 1 for details). High t-values were obtained when the master covered the

period AD1708-1766 (Table 4).

The second group consisted of 17 samples from trench A (phase IV) and 5 from trench B (phase IVi) which had been tentatively dated to the late 13th and early 14th centuries. Five of the samples (143, 262, 265, 425 and 427) had proved unsuitable for measurement. The ring sequences of ten of the timbers (350, 351, 352, 353, 356, 357, 415, 416, 417 and 426), all from trench A, crossmatched each other. The level of agreement between samples 415 and 417 was very high (t=11.0) indicating that these two samples probably came from the same tree. A master curve of 187 years, READING2, was compiled from these matching curves. This was compared with various dated chronologies which gave high t-values when READING2 spanned the period AD1221-1407 (Table 5).

The third group consisted of 13 samples, all from trench B (phase IViii), which had been tentatively dated to the early 16th to 18th centuries. Only one of the samples, 230, was unmeasurable. Nine of the ring sequences (118, 123, 124, 211, 213, 215, 235, 263 and 264) crossmatched each other. The ring widths of these matching curves were averaged to produce a master curve of 163 years, READING3. This was compared with reference chronologies spanning the 16th, 17th and 18th centuries. No conclusive results were obtained within the expected period but the England and East Midlands chronologies had given t-values of 4.4 and 6.9 respectively when READING3 covered the period AD1181-1343. A comparison between READING3 and READING2 at this date produced a very good match both visually and on the computer (t=6.7). READING2 was compared with several other reference chronologies which confirmed this date (Table 5). READING2 and READING3 were combined to produce a new master, READING4, dating from AD1181-1407.

Of the five remaining samples, all from trench B, the mid 12th century sample 440 was unmeasurable. Samples 273 and 274 had been tentatively dated to the 17th or 18th centuries, whilst 212 and 454 (phase IVii) had been placed between the 14th and 16th centuries. Neither 273 and 274 or 212 and 454 crossmatched each other. The ring sequences from these four timbers, along with all unmatched samples from the second and third groups were compared with READING4 and various reference chronologies. A further four samples (127, 212, 256 and 261) from trench B were dated. These were added into READING4 resulting in a revised master, READING5, extending from AD1160-1407.

As over 50% of the measured samples from the 1983/84 excavations had been successfully dated, the ring sequences of the 1981 samples (Bridge 1983) from trench C were re-examined. Some of these were known to be on the same alignment as dated samples from trench A. The ring sequences of all of these samples, except 1134 which was not usable, were compared with each other, the master READING5 and dated reference chronologies, many of which were not available when the data were first analysed. Samples 1119 and 965 were dated and were subsequently added into READING5. This new master, known as READING, dates from AD1160-1407 (Table 5) and includes 25 samples (Figure 6). The ring width data for READING are presented in Table 6. The ring width data of masters READING2-5 are listed in Appendix 2.

The timbers

The number of rings present on the medieval samples ranged from 18-153. However, the bulk of the timbers appear to have originated from trees between approximately 50-100 years old. In general, during

the medieval period trees seem to have been felled under 100 years old, and often at about 70 years (Rackham, 1976). The dimensions of the majority of the medieval timbers found at Reading Abbey Waterfront lie between 125mm x 125mm and 175mm x 175mm. The trunks had been worked accordingly, either halved (e.g. 425), quartered (e.g. 416) or left virtually whole (e.g. 352), which could explain the presence of sapwood on so many of the samples. In some cases the whole timbers appear to have been unworked (e.g. 351). The occurence of the halved, quartered and whole timbers is approximately 1:1:1.

All of the 18th century timbers had retained sapwood and 6 out of the 9 were whole trunks. The dimensions do not vary greatly from those of the medieval timbers. However, the parent trees of all, except sample 65, appear to be under approximately 60 years old.

INTERPRETATION

Table 7 shows the felling dates, exact or estimated, of all the dated samples. Samples 39, 118, 211, 215, 350 and 416 had retained a full complement of sapwood. The bark or waney edge, indicating the last growth of the tree prior to felling, was present on all six samples, although the outer eight rings of sample 350 were not measured due to distortion. Consequently their date of felling is precise. Several other samples, 256,351 and 352 also retained a full complement of sapwood, but the edges of these samples were badly preserved. However only 3-4 rings at most could have been missed, giving felling dates of AD1407-1411 for samples 351 and 352, and AD1253-1257 for sample 256. The felling dates of the remaining dated timbers have been estimated.

Trench A

Three felling dates were identified for the phase IV timbers. The waney edge was present on sample 416 which was felled in AD1315. As only part of the earlywood is represented in the last season of growth, the tree would probably have been felled during late spring or summer. Samples 415 and 417, adjacent to 416 (Figure 4a), appear to be contemporary and are also likely to have been felled in AD1315. The bark edge is present on sample 350, and as latewood growth was present, felling probably occurred between late summer AD1395 and early spring (pre-growing season) AD1396. The last ring of sample 357, thought to be very close to the bark edge, dated to AD1388 which suggests that this sample was contemporary with 350. Approximately 12 years later timbers 351 and 352 were felled. Samples 356, 353 and 426

are probably contemporary with one or other of these two felling phases (i.e. AD1395/6 or AD1407-11) but it is not possible to determine which, even though 356 has retained some sapwood.

The felling dates for the phase I samples 39, 66 and 69 can be assessed from Figure 5. The presence of the waney edge and latewood growth indicates that felling occurred between late summer AD1766 and early spring 1767. The last ring of the sequences from samples 66 and 69 both dated to AD1765, but the waney edge did not appear to be present. The heartwood-sapwood transitions for samples 39, 66 and 69 are AD1750, 1755 and 1756. This indicates that the timbers were all probably felled at the same time.

Trench B

The samples from trench B had been sub-divided into three broad phases of construction. Samples 256 and 261 are probably contemporary which gives a felling date of AD1253-7 for the timbers from phase IVi. The only phase IVii timber to be dated is 212. This was felled after AD1276.

Three samples from phase IViii, 118, 211 and 215, all had the waney edge present and were felled in late AD1343 or early 1344 (Figure 6). Sample 213, felled between AD1341-1373, is probably contemporary with 118, 211 and 215; as is 264. Sample 123, also thought to be from phase IViii and on the same alignment as 118, 211 and 215, was felled earlier, in the period AD1283-1323. This indicates the possibility that it may be a secondary timber, perhaps re-used from phase IVii, since it may be contemporary with the phase IVii timber 212.

The felling dates of the remaining samples from phase IViii (124, 127, 235 and 263) range from after AD1257 to after AD1296. These timbers may be primary and therefore probably felled in AD1343/4, which would indicate that varying amounts of heartwood was missing. However, it is also possible that they are secondary timbers, having been robbed from phase IVii for re-use in phase IViii.

Trench C

Only two samples were dated from trench C. The final measured ring of sample 1119 was thought to mark the boundary between the heartwood-sapwood transition (Bridge 1983). This would give an estimated felling date of AD1309-1354. Sample 965 retained no sapwood so a felling date after AD1386 is assumed.

DISCUSSION

The samples from trench A appear to fall into four groups indicating that there were at least three phases of construction or repair to the waterfront structures during the 14th and early 15th centuries and one during the 18th century (Figures 5 and 6). The felling dates of the trees used to provide the timber for these phases are AD1315, 1395/6, 1407-11 and 1766/7. As wood for use on a waterfront would not need to be seasoned, it is probable that the timber was used quite shortly after it had been felled.

Samples 415-417 were used in a waterfront structure constructed AD1315 or just after, which was replaced approximately 80 years later by the structure which included samples 350 and 357, felled in AD1395/6. However, samples 351 and 352, on the same alignment and from the same structure as 350 and 357, were felled in the period AD1407-11. Stockpiling could account for trees of slightly different felling years being used in a single phase but it is doubtful that this would occur over such a long period of time. Due to the relative positions of the timbers it appears more likely that the waterfront was constructed AD1395/6 or just after and that repairs may have been necessary AD1407-11. Although samples 356, 353 and 426 are probably also contemporary with one of the two later construction phases, it is not possible to determine which one.

The felling date of sample 1119 (trench C), which is on the same alignment, and possibly the same structure as samples 415-417, indicates that it may be contemporary and thus also used in the AD1315 construction phase. Sample 965, also from trench C, is terminal to the structure which includes 350 and 351. Although felled after AD1386, it

is impossible to determine whether or not it is contemporary with either of the two later construction phases.

The three dated samples (39,66 and 69) from the 18th century structure indicate a construction phase of AD1766/7 or just after. This structure lies much further east than the medieval waterfront structures implying that the River Kennet was following a new channel. This was probably connected with the silting up of the River Kennet and Holy Brook channels following the dissolution of the Abbey.

The 13 dated samples from trench B appear to form three groups indicating three phases of construction between the mid 13th and mid 14th centuries. The felling dates of the trees used to provide the timbers for these phases are AD1253-7, 1283-1323 and 1343/4 implying that the life span of each wharf may have only been approximately 50 years. During the final construction phase, AD1343/4 or shortly afterwards, timbers appear to have been re-used from the previous phase (IVii). The dating of the phase IViii samples to the mid 14th century was unexpected and suggests that this stretch of waterfront may have been abandoned much earlier than originally anticipated.

The construction dates deduced from the tree-ring dating for the structures in trench B and trenches A and C imply that building or repair work on the banks of the Kennet and the Holy Brook Tail Race was not being carried out simultaneously.

The close correlation between many of the medieval samples implies that they grew under similar environmental conditions and probably came from the same source. It is quite probable that the Abbey owned sufficient forest to provide all of its own timber. Some samples (e.g. 262, 358 and 424), all from young trees, have much wider

average ring widths indicating that they grew under more favourable conditions, perhaps in less dense woodland or on the fringe of forests. Generally trees with very narrow rings are from woodland where competition was severe, where as trees with wide complacent rings usually originate from open contexts where little competition was experienced (Bartholin, 1978; Hillam & Morgan 1981).

The timbers used in the 18th century all tend to be from trees under approximately 60 years old. They appear to have wider average ring widths than the majority of the medieval timbers, which came from parent trees of between 50-100 years old, implying that they experienced less competition. These two points may both be related to the 17th century depletion-regeneration phase discussed in Baillie (1982). During the 17th century forests are thought to have been heavily and systematically exploited resulting in a depleted stock of oak trees of a suitable size for building. The regeneration was aided by landowners planting oaks specifically to replenish the depleted stocks (Baillie, 1982) which would have probably resulted in young oak trees of very similar ages being available for building by the middle of the 18th century.

The timbers from the medieval period span what is considered to be another depletion-regeneration phase in the 14th century (Baillie, 1982:213-215), trees having been felled throughout the 14th and early 15th centuries. If the Abbey did supply its own timber then it is quite probable that they would have avoided the depletion and subsequent regeneration.

CONCLUSIONS

The study of these samples has proved successful in that 28 of the 51 measured samples were dated and used to estimate dates for several phases of waterfront construction. The majority of the undated samples are those with short ring sequences of less than 60 years in length (Figure 7). A reference chronology covering the period AD1160-1407 was also produced for the Reading area, which may prove useful for dating other timbers, especially as it spans the 14th century for which period dated ring sequences are relatively scarce.

The tree-ring dates have resulted in the development of a new model for the Abbey's waterfronts (Figure 8). On the western bank of the River Kennet, a revetment was built in AD1315 or just after. This was replaced in AD1395/6, or just after, by a new structure which was repaired in AD1407-11. The final phase of timber building occurred in AD1766/7 or just after. Its position indicates that by this date the River Kennet was following a new channel.

The timbers from the structure at the confluence of the Holy Brook Tail Race and the River Kennet provided unexpected results in that the 3 phases of construction spanned only approximately 100 years, rather than several centuries as first thought. The timbers used in the 3 phases were felled, and probably used, in the periods AD1253-7, 1283-1323 and 1343/4. The results also suggest that the latest phase of construction made use of timbers from the previous phase. The structures on the banks of the Holy Brook therefore were not built or repaired at the same time as those along the River Kennet.

ACKNOWLEDGEMENTS

The initial work was undertaken by one of us (F P-F) for an undergraduate dissertation in the Department of Archaeology and Prehistory, Sheffield University. Work at the Sheffield Dendrochronology Laboratory is financed by the Historical Buildings and Monuments Commission for England. We would like to thank Martin Bridge, who kindly made available his 1981 data, and the Nottingham and Belfast Tree-Ring Groups for supplying data prior to publication. Finally we are grateful to Peter Fasham and John Hawkes for providing the samples and information about the site.

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LIST OF FIGURES

the number of dated and undated samples.

Figure 8: Summary of the chronological development on the Abbey Waterfront as derived from the tree-ring dates.

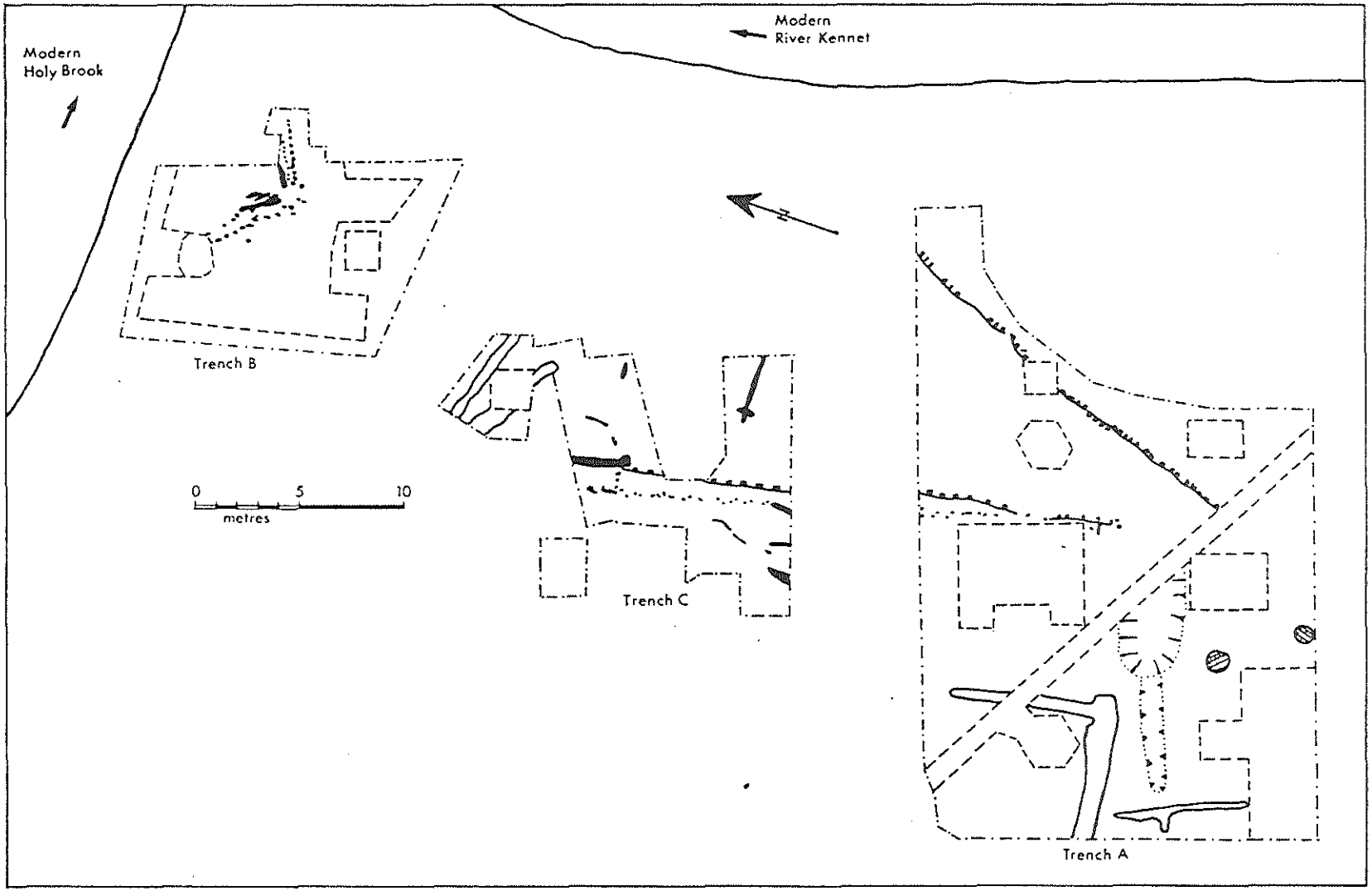
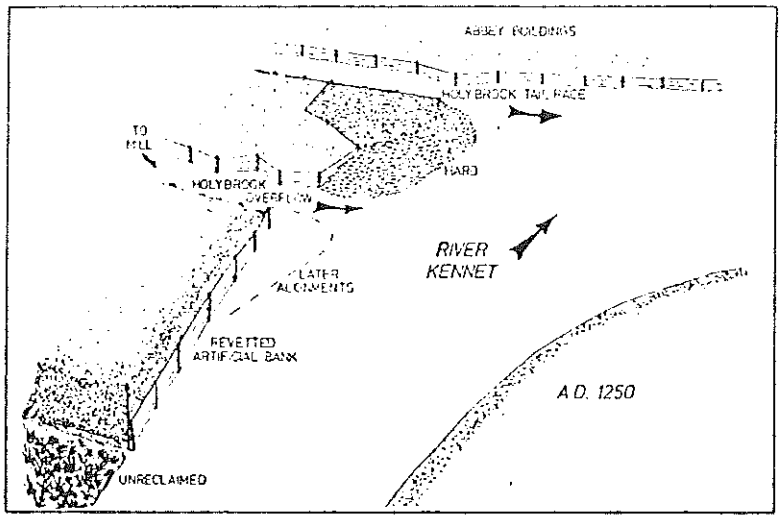
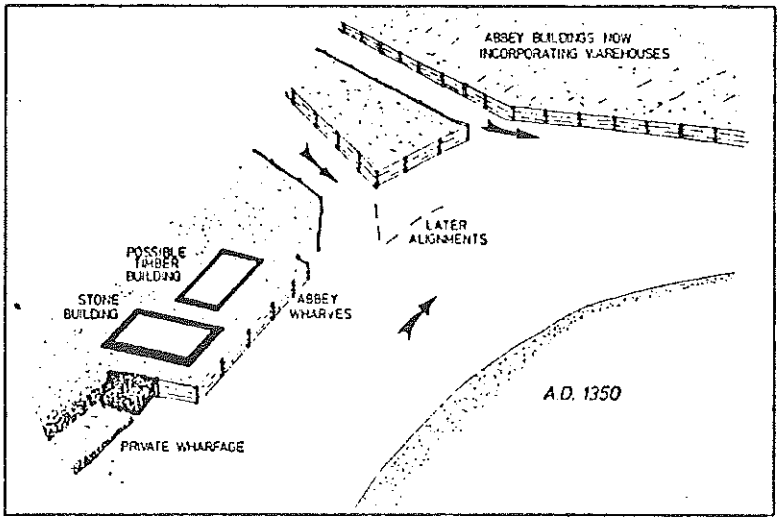

Modern
Holy Brook
Modern
River Kennet
Trench B
Trench C
Trench A
0
5
10
metres

Figure 1

a.


ABBEY BUILDINGS
HOLYBROOK TAILRACE
TO MILL
HOLYBROOK OVERFLOW
YARD
RIVER KENNET
LATER ALIGNMENTS
REVETTED ARTIFICIAL BANK
A.D. 1250
UNRECLAIMED

b.


ABBEY BUILDINGS NOW INCORPORATING WAREHOUSES
LATER ALIGNMENTS
POSSIBLE TIMBER BUILDING
STONE BUILDING
ABBEY WHARVES
A.D. 1350
PRIVATE WHARFAGE

c.

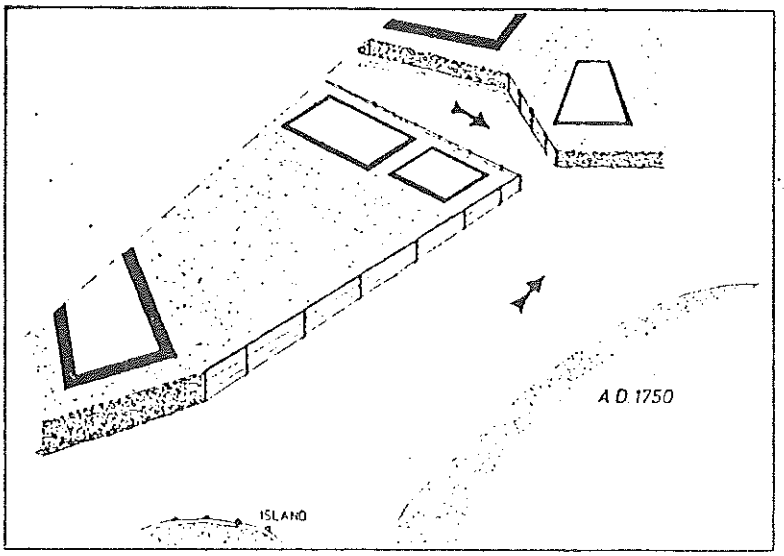

A.D. 1750
ISLAND

Figure 2

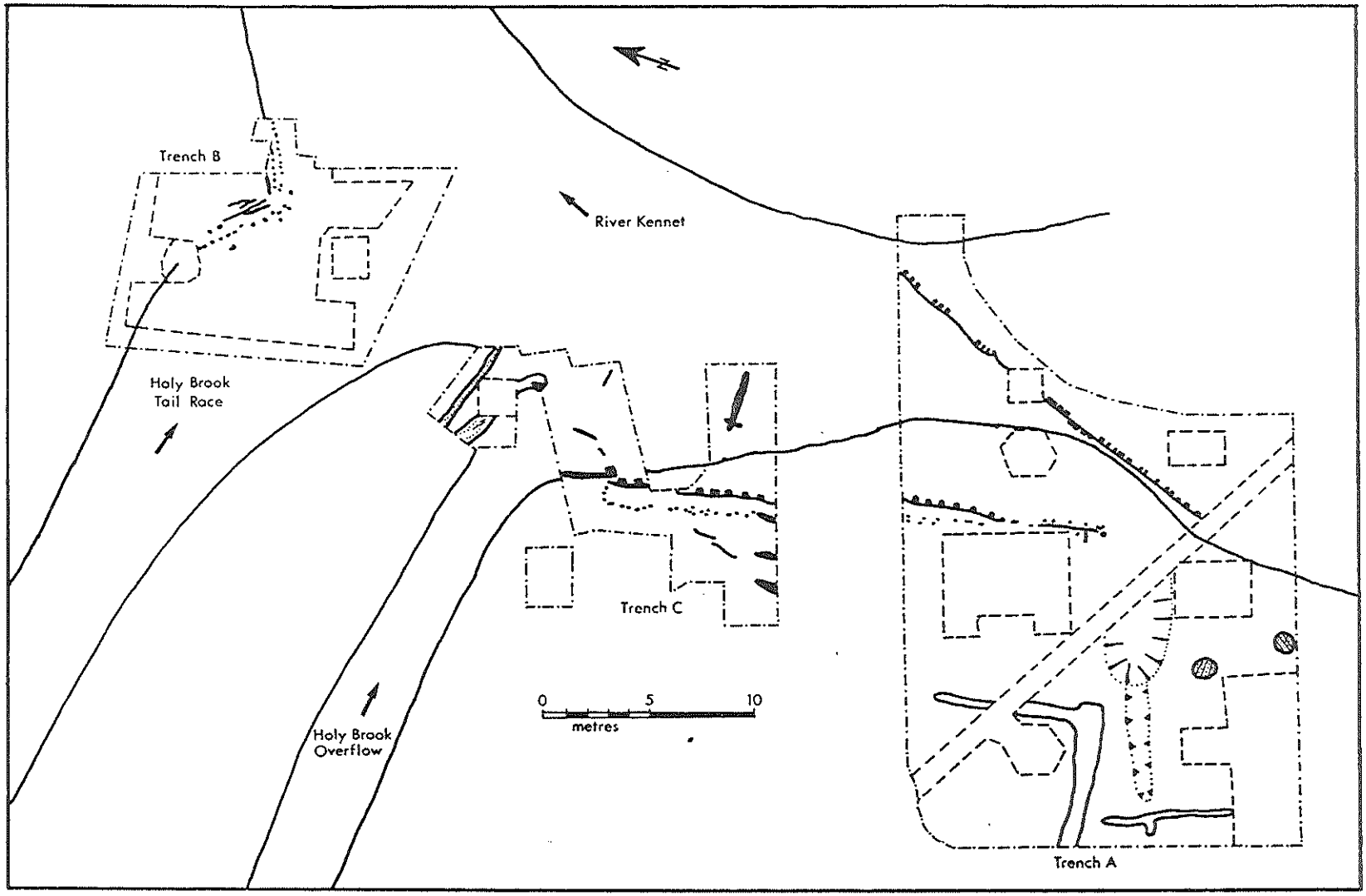

Trench B
River Kennet
Holy Brook
Tail Race
Trench C
0
5
10
metres
Holy Brook
Overflow
Trench A

Figure 3

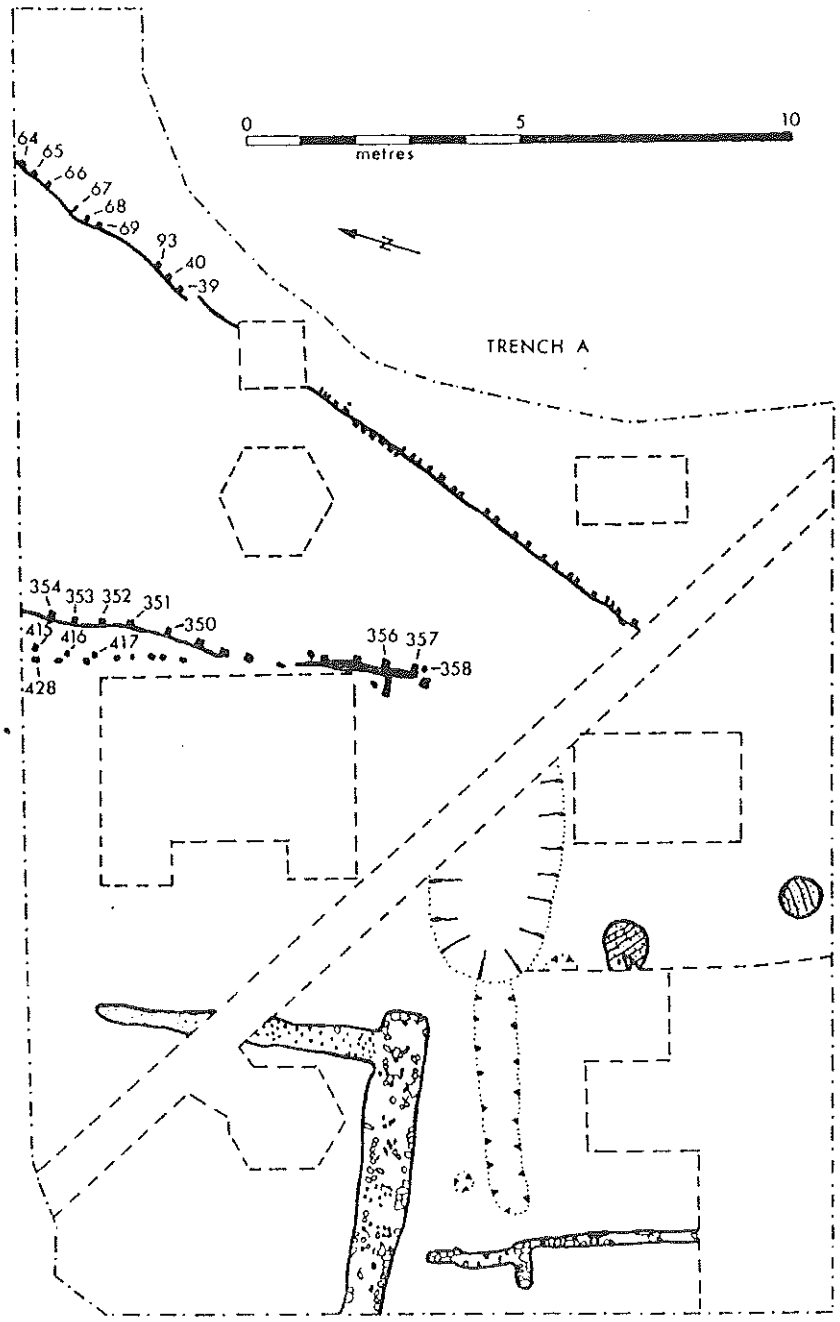

0
5
10
metres
64
65
66
67
68
69
93
40
39
TRENCH A
354
353
352
351
350
415
416
417
428
356
357
358

Figure 4a

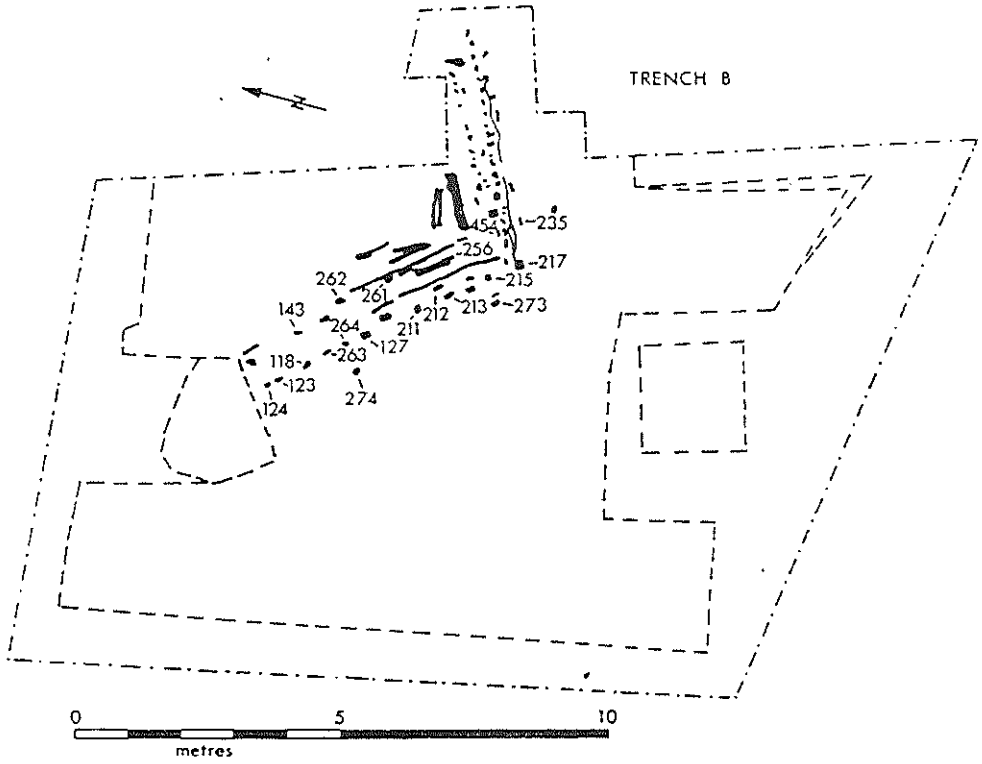

TRENCH B
235
256
217
262
261
215
143
264
211
212
213
273
118
263
127
123
274
124
0
5
10
metres

Figure 4b

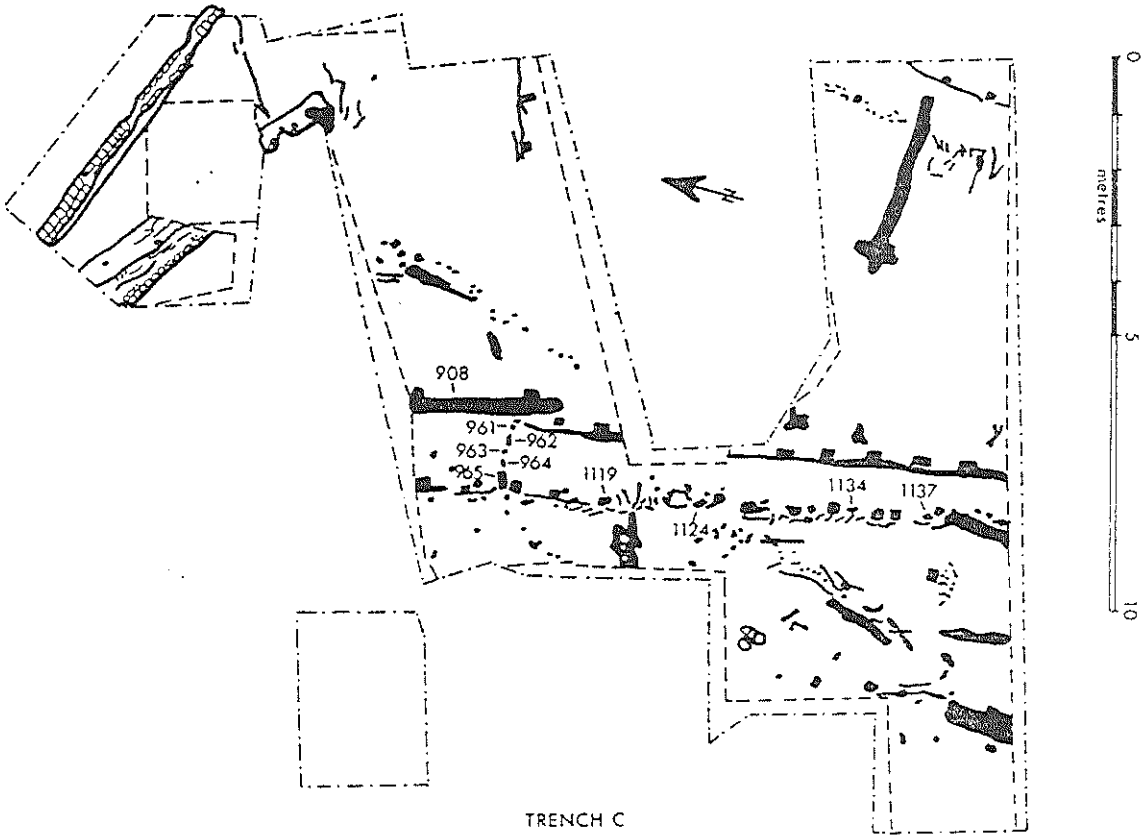

908
961
962
963
964
965
1119
1124
1134
1137
TRENCH C
0
5
10
metres

Figure 4c

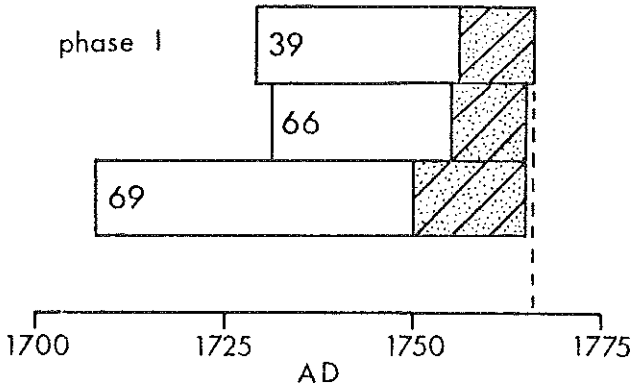
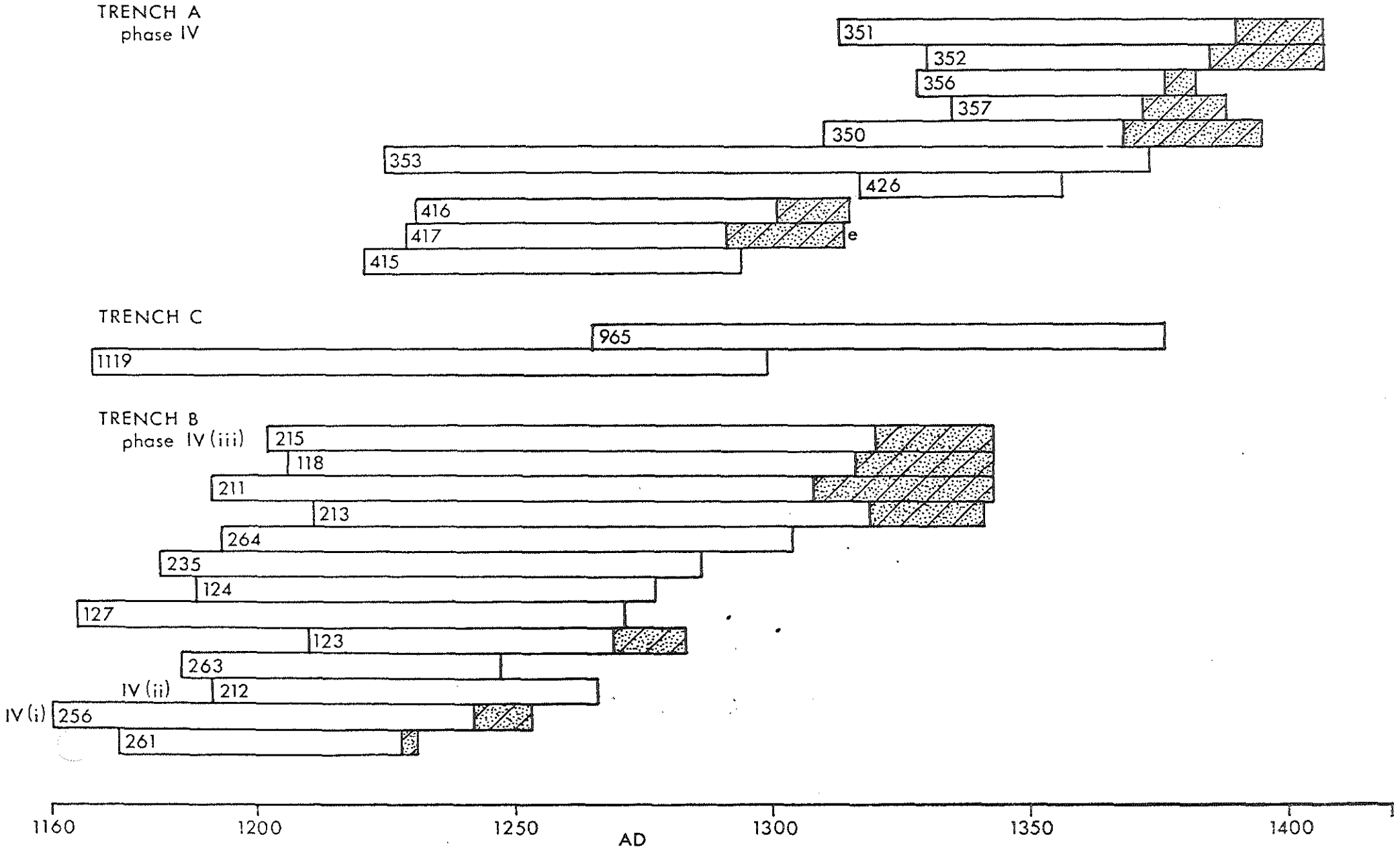


Figure 5

Figure 6


TRENCH A
phase IV
351
352
356
357
350
353
426
416
417
e
415
TRENCH C
965
1119
TRENCH B
phase IV (iii)
215
118
211
213
264
235
124
127
123
263
IV (ii)
212
IV (i)
256
261
1160
1200
1250
1300
1350
1400
AD

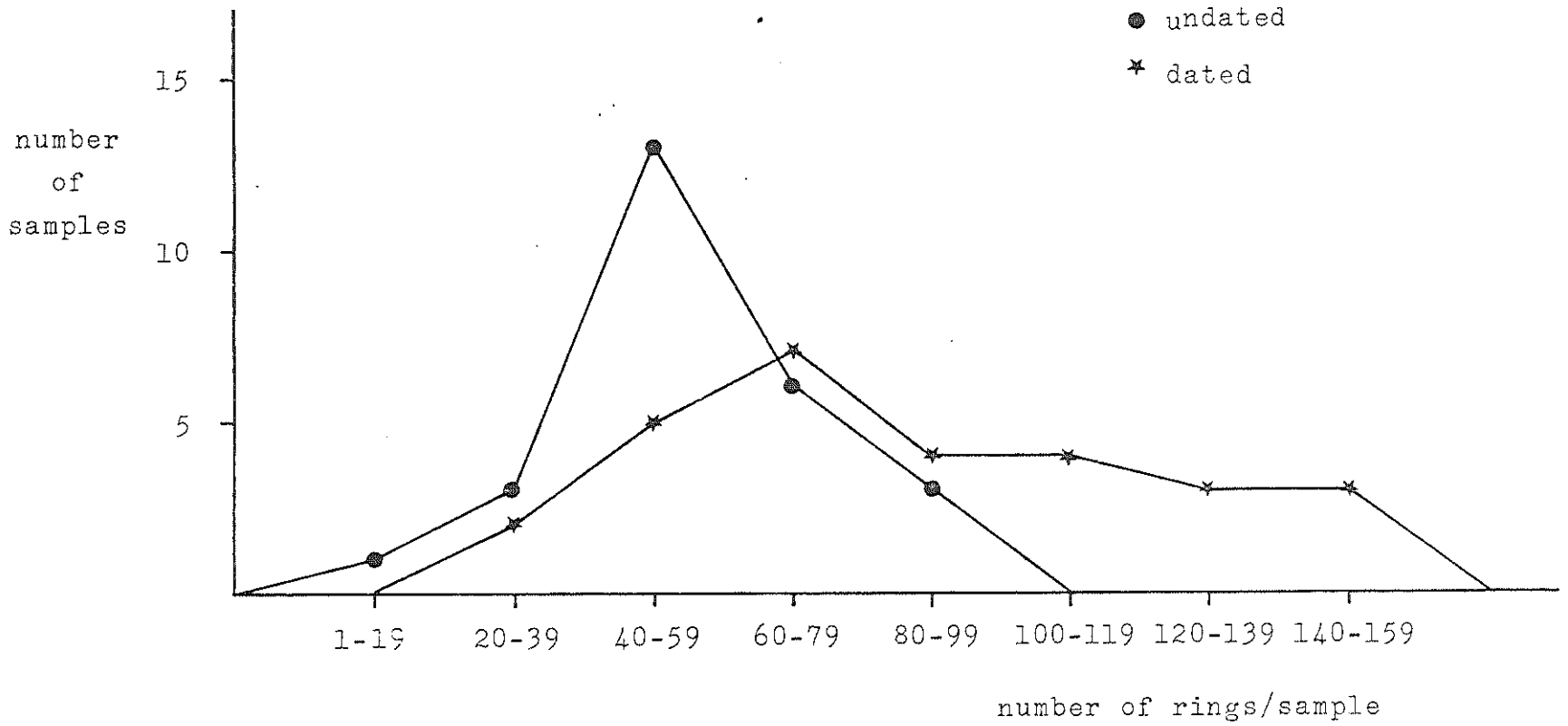

undated
dated
number of samples
15
10
5
1-19
20-39
40-59
60-79
80-99
100-119
120-139
140-159
number of rings/sample

Figure 7

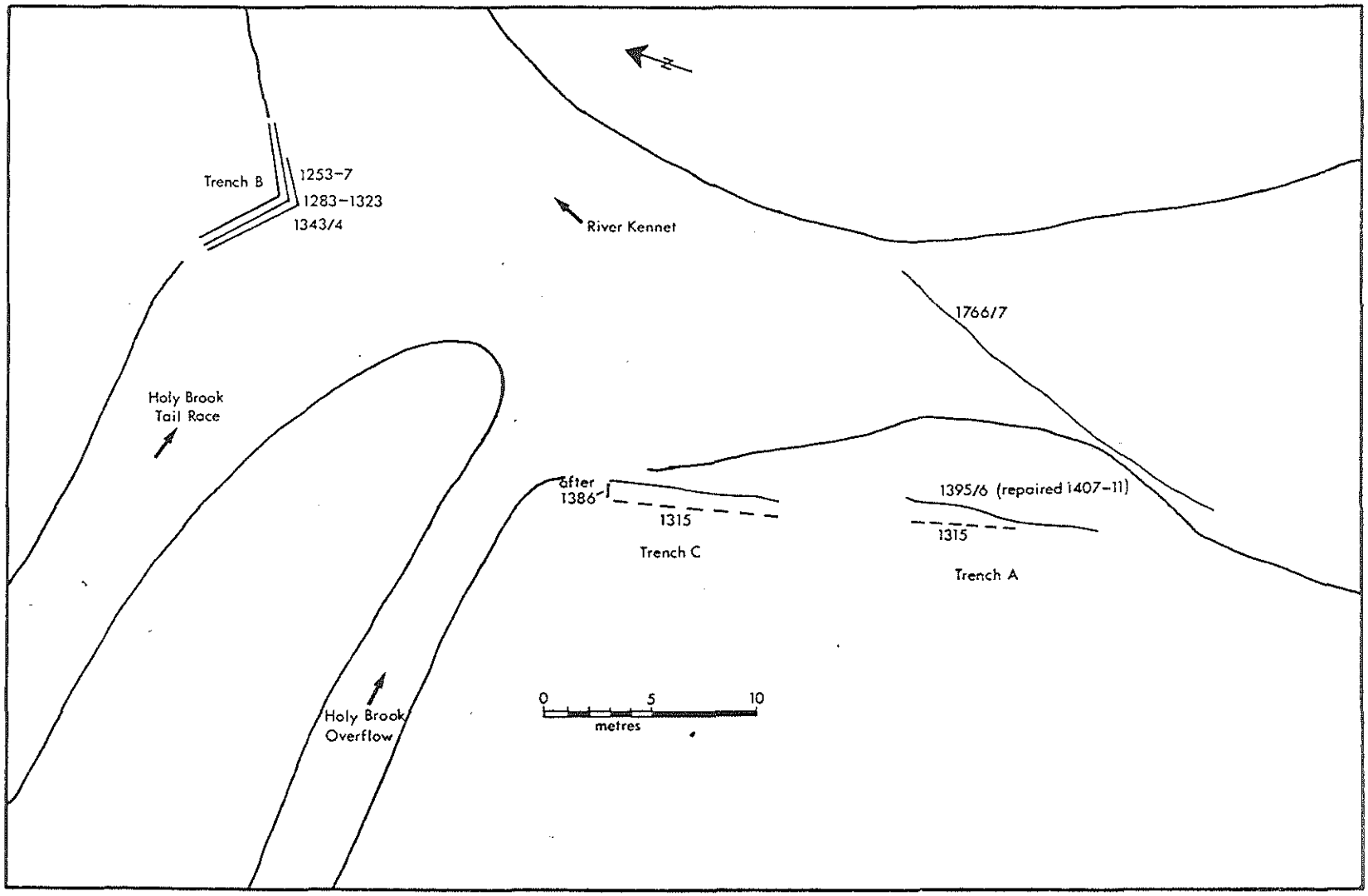
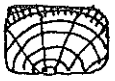
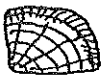

N
Trench B
1253–7
1283–1323
1343/4
River Kennet
1766/7
Holy Brook
Tail Race
after
1386
1315
Trench C
1395/6 (repaired 1407–11)
1315
Trench A
0
5
10
metres
Holy Brook
Overflow

Figure 8

Table 1: List of tree-ring samples from the 1983/84 excavation with dates suggested from the archaeological evidence.

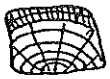
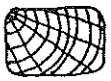
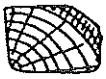
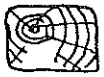
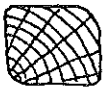
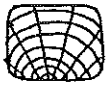
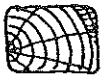
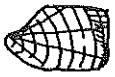
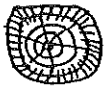
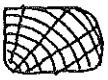
phase	date	Trench A	Trench B
-	mid 12th century	-	440
IV	late 13th-early 14th century	350 351 352 353 354 356 357 358 415 416 417 424 425 426 427 428 430	-
IVi	"	-	143 256 261 262
IVii	14th-16th century	-	212 454
IViii	early 16th-18th century	-	118 123 124 127 211 213 214 215 217 230 235 263 264
-	17th-18th century	-	273 274
I	circa 1800	39 40 64 65 66 67 68 69 93	

Table 2: Details of timbers from the 1983/84 excavation. Sketches are not to scale; cross sections are measured to the nearest 5mm; '+' indicates the presence of rings which have not been measured; sapwood is represented by shading on the sketch.

Timber no	Total no of rings	Sapwood rings	Average ring width (mm)	Dimensions (mm)	Sketch
39	38	11	3.71	150 x 125	
40	45	8	2.05	150 x 100	
64	43	16	2.31	125 x 75	
65	79	21	1.50	125 x 125	
66	35	11	3.48	175 x 175	
67	58	10	1.94	125 x 75	
68	53	21	1.94	125 x 75	
69	58	16	1.91	150 x 150	
93	55	8	2.38	175 x 175	
118	138	28	1.23	125 x 125	
123	74	14	2.34	125 x 150	
124	90	-	1.90	175 x 150	
127	107	-	1.84	175 x 175	
143	18	-	wide - up to 20mm	125 x 100	
211	153	36	1.48	175 x 150	
212	76	-	2.92	175 x 175	

cont/

Table 2/cont

21[illegible]	131	23	1.33	100 x 125	
214	69	-	3.13	175 x 100	
215	142	24	1.46	150 x 125	
217	85	-	1.70	150 x 125	
230	rings too narrow	-	-	150 x 150	
235	106	-	2.00	150 x 125	
256	94	12	3.21	180 x 100	
261	59	5	2.62	125 x 100	
262	20	8	5.22	125 x 100	
263	63	-	2.24	200 x 125	
264	112	-	1.71	100 x 100	
265	knotty	-	-	125 x 100	
273	50	-	2.58	205 x 205	
274	74	15	1.96	205 x 125	
350	78 +8	20 +8	1.32	180 x 180	
351	95	18	1.14	125 x 125	
352	78	24	1.59	150 x 180	
353	149	-	1.89	180 x 115	
354	79	22	1.43	150 x 180	

cont/

Table 2/cont

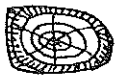
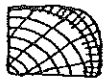
35	55	7	1.65	180 x 125	
357	54	16	1.76	180 x 180	
358	30	-	5.20	100 x 100	
415	74	-	2.03	205 x 100	
416	85	15	2.67	125 x 125	
417	79 +7	17 +7	1.83	180 x 100	
424	45	-	4.04	150 x 125	
425	-		-	205 x 100	
426	40	-	2.00	205 x 100	
427	rings too narrow	-	-	205 x 100	
428	44	-	2.37	180 x 180	
430	40	13	2.92	150 x 100	
440	rings too narrow	-	-	175 x 125	
454	74 +?11	19 +	2.06	205 x 100	

Table 3: Reading 1, AD 1708-66.

years AD	ring widths (0.02mm) 0	1	2	3	4	5	6	7	8	9	number of samples per decade
1708									89	92	1
1710	21	24	89	117	109	132	97	82	39	15	1
1720	31	56	54	50	82	69	98	124	117	132	3
1730	122	84	147	163	220	268	207	149	211	196	3
1740	119	97	92	134	115	118	261	274	211	109	3
1750	143	159	147	108	166	119	139	104	153	169	3
1760	129	196	97	155	172	135	157				3

Table 4: Dating Reading 1, AD 1708-66. (Full details of reference chronologies given in Appendix 1.)

chronology	t-value
East Midlands	5.1
England	5.2
Hampshire	5.7
Maentwrog	3.5

Table 5: Dating the medieval masters. (Details of reference chronologies given in Appendix 1.)

chronology	t-value Reading 2	Reading 3	Reading
Abbey Barn, Glastonbury	-	4.3	8.1
Bradwell Abbey, Milton Keynes	-	-	4.3
Calverley Hall, Yorkshire	-	-	2.3
Carlisle	-	3.0	2.2
Commandery, Worcester	-	-	8.1
Droitwich	6.3	4.7	7.9
Dublin	-	3.0	4.1
Dunstable	-	4.0	6.3
East Midlands	5.1	6.9	7.6
England	6.0	4.4	8.6
Germany, Munich area	-	3.7	4.5
Germany, Trier area	-	4.8	4.4
Nantwich, Cheshire	-	-	3.5
Trig Lane, London	-	4.2	6.9
Wick, St Cuthberts	5.5	-	6.6
Reading 2	-	6.7	-

Table 6: Reading master chronology, AD 1160-1407

years AD	ring widths (0.02mm) 0	1	2	3	4	5	6	7	8	9	number of samples per decade
1160	211	314	320	299	403	316	255	238	315	306	2
1170	297	288	246	214	200	186	199	127	156	200	4
1180	151	181	181	174	142	165	165	185	135	123	6
1190	174	167	136	152	119	112	134	115	89	105	10
1200	136	157	132	126	95	110	109	98	122	119	11
1210	124	120	113	99	108	129	150	121	107	117	14
1220	123	118	110	101	83	107	153	112	114	127	16
1230	96	76	72	75	103	116	81	131	109	117	17
1240	111	87	77	96	85	89	92	105	64	86	17
1250	96	103	90	98	97	118	84	103	84	98	15
1260	105	109	117	78	76	87	87	72	76	87	15
1270	96	117	85	98	89	73	65	91	72	72	14
1280	96	98	96	94	99	107	108	64	60	88	12
1290	104	114	124	127	116	91	96	96	72	71	11
1300	74	77	73	57	49	56	68	63	83	71	8
1310	63	55	64	59	72	81	85	95	69	98	9
1320	79	103	103	97	84	67	53	79	113	133	9
1330	109	57	65	63	86	120	101	72	71	91	12
1340	87	82	71	89	77	75	106	93	86	76	8
1350	63	78	71	75	58	50	57	84	54	60	8
1360	52	40	45	71	67	47	56	72	75	89	7
1370	81	66	66	55	56	65	62	39	48	38	6
1380	40	40	52	54	52	74	85	72	80	80	4
1390	76	46	51	92	61	79	60	53	67	60	2
1400	77	68	59	69	50	43	55	59			2

Table 7: Summary of tree-ring dates. Dates of heartwood-sapwood transitions, if present, are given in brackets; * - bark edge.

Trench/phase	sample	date span (AD)	felling dat.
A IV	350	1310-1387(1368)	1395/96*
	351	1313-1407(1390)	1407-11*
	352	1330-1407(1385)	1407-11*
	353	1225-1373	after 1383
	356	1328-1382(1376)	1386-1430
	357	1335-1388(1372)	1388-1426
	415	1221-1294	after 1304
	416	1231-1315(1301)	1315
	417	1229-1307(1291)	1314*
	426	1317-1356	after 1366
A I	39	1729-1766(1756)	1766/67*
	66	1731-1765(1755)	1765-1809
	69	1708-1765(1750)	1765-1804
B IVi	256	1160-1253(1242)	1253-1257*
	261	1173-1231(1228)	1238-1282
B IVii	212	1191-1266	after 1276
B IViii	118	1206-1343(1316)	1343/44*
	123	1210-1283(1269)	1283-1323
	124	1188-1277	after 1287
	127	1165-1271	after 1281
	211	1191-1343(1308)	1343/44*
	213	1211-1341(1319)	1341-1373
	215	1202-1343(1320)	1343/44*
	235	1181-1286	after 1296
	263	1185-1247	after 1257
	264	1193-1304	after 1314
C	965	1265-1376	after 1386
	1119	1168-1299	after 1309

Appendix 1

Details of reference chronologies used in the dating of the Reading tree-ring sequences.

chronology	date span
Abbey Barn, Glastonbury (Bridge 1983)	1095-1334
Bradwell Abbey, Milton Keynes (Bridge 1983)	1083-1279
Calverley Hall, West Yorkshire (Hillam 1981)	1261-1480
Carlisle (Baillie & Pilcher pers comm)	893-1600
Commandery, Worcester (Pilcher pers comm)	1273-1465
Droitwich (Hillam 1985)	1178-1415
Dublin (Baillie 1977)	855-1306
Dunstable, Bedfordshire (Bridge 1983)	1172-1302
East Midlands (Laxton et al unpubl)	882-1976
England - includes various regional chronologies (Baillie & Pilcher pers comm)	404-1981
Germany, Munich area (Becker 1981)	370BC-AD1969
Germany, Trier area (Hollstein 1980)	400BC-AD1965
Hampshire (Barefoot 1975)	1635-1972
Maentwrog, Wales (Leggett et al	1710-1974
Nantwich, Cheshire (Leggett 1980)	930-1330
Trig Lane, London (Tyers pers comm)	1207-1382
Wick, St Cuthberts (Bridge 1983)	1255-1496

Appendix 2 Details of master chronologies Reading 2-5, including ring widths in units of 0.02mm

MASTER CHRONOLOGY

READING
READING2

TREE W61A 415 STARTS AT YEAR 1 ENDS AT YEAR 74 N= 74

TREE W61A 353 STARTS AT YEAR 5 ENDS AT YEAR 153 N= 149

TREE W61A 417 STARTS AT YEAR 9 ENDS AT YEAR 87 N= 79

TREE W61A 416 STARTS AT YEAR 11 ENDS AT YEAR 95 N= 85

TREE W61A 350 STARTS AT YEAR 90 ENDS AT YEAR 167 N= 78

TREE W61A 351 STARTS AT YEAR 93 ENDS AT YEAR 187 N= 95

TREE W61A 426 STARTS AT YEAR 97 ENDS AT YEAR 136 N= 40

TREE W61A 356 STARTS AT YEAR 108 ENDS AT YEAR 162 N= 55

TREE W61A 352 STARTS AT YEAR 110 ENDS AT YEAR 187 N= 78

TREE W61A 357 STARTS AT YEAR 115 ENDS AT YEAR 168 N= 54

MASTER STORED IN FILE CALLED READING2
****

READING
READING2
187

58	51	57	48	87	172	97	102	109	71	1	1	1	1	2	2	2	2	3	3
98	82	111	146	145	83	181	125	149	154	4	4	4	4	4	4	4	4	4	4
97	108	155	110	103	119	128	83	98	102	4	4	4	4	4	4	4	4	4	4
115	96	92	95	137	106	176	137	150	144	4	4	4	4	4	4	4	4	4	4
132	183	78	80	106	119	72	71	118	166	4	4	4	4	4	4	4	4	4	4
180	93	119	115	92	69	116	65	79	108	4	4	4	4	4	4	4	4	4	4
111	103	121	135	140	120	59	64	97	117	4	4	4	4	4	4	4	4	4	4
118	129	116	127	78	98	102	67	72	89	4	4	4	4	3	3	3	3	3	3
82	86	58	56	62	75	73	128	96	85	3	3	3	3	3	3	3	2	2	3
62	83	67	92	102	99	115	79	126	102	3	3	4	4	4	3	4	4	4	4
123	141	140	114	83	56	102	158	172	141	4	4	4	4	4	4	4	5	5	6
61	71	64	105	151	121	74	76	107	99	6	6	6	6	7	7	7	7	7	7
93	78	92	69	65	100	86	75	67	59	7	7	7	7	7	7	7	7	7	7
66	59	67	52	46	57	77	47	55	48	7	7	7	7	7	7	6	6	6	6
35	42	70	68	42	52	65	72	85	78	6	6	6	6	6	6	6	6	6	6
59	56	49	48	60	56	39	48	38	40	6	6	6	5	5	5	5	5	5	5
40	52	54	52	74	85	72	80	80	76	5	5	4	4	4	4	4	3	2	2
46	51	92	61	79	60	53	67	60	77	2	2	2	2	2	2	2	2	2	2
68	59	69	50	43	55	59	2	2	2	2	2	2	2						

TREES INCLUDED ARE - W61A 415 W61A 353 W61A 417 W61A 416 W61A 350 W61A 351 426 W61A 356 W61A 352 W61A 357

MASTER CHRONOLOGY

READING
READING3

TREE W61B 235 STARTS AT YEAR 1 ENDS AT YEAR 106 N= 106

TREE W61B 263 STARTS AT YEAR 5 ENDS AT YEAR 67 N= 63

TREE W61B 124 STARTS AT YEAR 8 ENDS AT YEAR 97 N= 90

TREE W61B 211 STARTS AT YEAR 11 ENDS AT YEAR 163 N= 153

TREE W61B 264 STARTS AT YEAR 13 ENDS AT YEAR 124 N= 112

TREE W61B 215 STARTS AT YEAR 22 ENDS AT YEAR 163 N= 142

TREE W61B 118 STARTS AT YEAR 26 ENDS AT YEAR 163 N= 138

TREE W61B 123 STARTS AT YEAR 30 ENDS AT YEAR 103 N= 74

TREE W61B 213 STARTS AT YEAR 31 ENDS AT YEAR 161 N= 131

MASTER STORED IN FILE CALLED READING3
****

READING
READING3
163

268	251	228	223	156	169	192	184	173	240		1	1	1	1	2	2	2	3	3	3
193	168	167	127	121	151	132	91	115	122		4	4	5	5	5	5	5	5	5	5
136	113	112	82	104	115	104	121	129	125		5	6	6	6	6	7	7	7	7	8
130	124	100	109	133	161	127	101	114	118		9	9	9	9	9	9	9	9	9	9
118	111	98	67	91	117	99	96	114	91		9	9	9	9	9	9	9	9	9	9
64	65	59	86	103	77	113	100	96	94		9	9	9	9	9	9	9	9	9	9
80	60	73	78	77	80	94	50	62	80		9	9	9	9	9	9	9	8	8	8
90	84	88	93	108	75	72	60	69	83		8	8	8	8	8	8	8	8	8	8
91	87	65	66	59	55	45	56	55	59		8	8	8	8	8	8	8	8	8	8
74	67	70	58	52	55	60	58	52	62		8	8	8	8	8	8	8	7	7	7
61	68	59	52	58	61	39	38	54	58		7	7	7	6	6	6	5	5	5	5
67	63	64	59	61	66	53	49	51	56		5	5	5	5	5	5	5	5	5	5
64	59	45	41	47	59	55	58	55	48		5	5	5	5	4	4	4	4	4	4
47	50	40	42	52	60	54	46	57	41		4	4	4	4	4	4	4	4	4	4
55	51	43	44	39	40	44	50	64	52		4	4	4	4	4	4	4	4	4	4
45	44	50	52	53	62	61	60	56	58		4	4	4	4	4	4	4	4	4	4
38	40	57		4	3	3														

TREES INCLUDED ARE - W61B 235 W61B 263 W61B 124 W61B 211 W61B 264 W61B 215 W61B 118 W61B 123 W61B 213

MASTER CHRONOLOGY

READING4
READING4

MASTER STORED IN FILE CALLED READING4
****

READING4
READING4
227

268	251	228	223	156	169	192	184	173	240	1	1	1	1	2	2	2	3	3	3
193	168	167	127	121	151	132	91	115	122	4	4	5	5	5	5	5	5	5	5
136	113	112	82	104	115	104	121	129	125	5	6	6	6	6	7	7	7	7	8
130	124	100	109	133	161	127	101	114	118	9	9	9	9	9	9	9	9	9	9
112	105	93	65	90	127	98	97	112	86	10	10	10	10	11	11	11	11	12	12
74	70	75	104	115	78	133	107	112	112	13	13	13	13	13	13	13	13	13	13
85	74	98	87	85	92	104	61	74	87	13	13	13	13	13	13	13	12	12	12
98	88	89	93	117	85	106	85	96	103	12	12	12	12	12	12	12	12	12	12
104	119	69	70	74	76	54	61	76	94	12	12	12	12	12	12	12	12	12	12
109	75	86	77	65	59	78	60	61	78	12	12	12	12	12	12	12	11	11	11
79	80	81	85	90	84	47	49	73	84	11	11	11	10	10	10	9	9	9	9
89	92	87	89	67	78	71	55	58	68	9	9	9	9	8	8	8	8	8	8
70	69	49	46	53	65	62	81	68	63	8	8	8	8	7	7	7	6	6	7
53	64	53	67	77	76	84	62	91	71	7	7	8	8	8	7	8	8	8	8
89	96	91	79	61	48	73	110	124	105	8	8	8	8	8	8	8	9	9	10
54	60	58	83	115	99	69	70	88	84	10	10	10	10	11	11	11	11	11	11
76	66	81	69	65	100	86	75	67	59	11	10	10	7	7	7	7	7	7	7
66	59	67	52	46	57	77	47	55	48	7	7	7	7	7	7	6	6	6	6
35	42	70	68	42	52	65	72	85	78	6	6	6	6	6	6	6	6	6	6
59	56	49	48	60	56	39	48	38	40	6	6	6	5	5	5	5	5	5	5
40	52	54	52	74	85	72	80	80	76	5	5	4	4	4	4	4	3	2	2
46	51	92	61	79	60	53	67	60	77	2	2	2	2	2	2	2	2	2	2
68	59	69	50	43	55	59				2	2	2	2	2	2	2			

TREES INCLUDED ARE - READING2 READING3

MASTER CHRONOLOGY

READING
READING5

TREE W61B 256 STARTS AT YEAR 1 ENDS AT YEAR 94 N= 94

TREE W61B 127 STARTS AT YEAR 6 ENDS AT YEAR 112 N= 107

TREE W61B 261 STARTS AT YEAR 14 ENDS AT YEAR 72 N= 59

TREE W61B 212 STARTS AT YEAR 32 ENDS AT YEAR 107 N= 76

MASTER STORED IN FILE CALLED READING5
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READING
READING5
248

211	314	320	299	403	316	255	238	259	233	1 1 1 1 1 2 2 2 2 2
232	306	248	217	206	201	195	120	157	183	2 2 2 3 3 3 3 3 3 3
149	197	191	180	144	147	142	160	130	125	3 4 4 4 4 5 5 5 6 6
182	171	138	150	119	114	140	119	92	107	6 8 8 9 9 9 9 9 9 9
139	158	132	128	95	112	114	102	126	125	9 9 10 10 10 10 11 11 11 11
128	122	117	101	110	134	157	123	105	115	12 13 13 13 13 13 13 13 13 13
121	117	106	98	80	98	136	104	108	121	13 14 14 14 14 15 15 15 15 16
92	74	70	73	99	113	78	129	106	114	16 17 16 16 16 16 16 16 16 16
108	84	72	94	82	85	88	103	61	79	16 16 16 16 16 16 16 16 15 15
87	98	89	99	97	116	82	101	84	99	15 15 15 15 14 14 14 14 14 14
100	105	117	71	70	79	75	59	69	79	14 14 14 14 14 14 14 13 13 13
91	105	75	86	77	65	59	78	60	61	13 13 12 12 12 12 12 12 11 11
78	79	80	81	85	90	84	47	49	73	11 11 11 11 10 10 10 9 9 9
84	89	92	87	89	67	78	71	55	58	9 9 9 9 9 8 8 8 8 8
68	70	69	49	46	53	65	62	81	68	8 8 8 8 8 7 7 7 6 6
63	53	64	53	67	77	76	84	62	91	7 7 7 8 8 8 7 8 8 8
71	89	96	91	79	61	48	73	110	124	8 8 8 8 8 8 8 8 9 9
105	54	60	58	83	115	99	69	70	88	10 10 10 10 10 11 11 11 11 11
84	76	66	81	69	65	100	86	75	67	11 11 10 10 7 7 7 7 7 7
59	66	59	67	52	46	57	77	47	55	7 7 7 7 7 7 7 6 6 6
48	35	42	70	68	42	52	65	72	85	6 6 6 6 6 6 6 6 6 6
78	59	56	49	48	60	56	39	48	38	6 6 6 6 5 5 5 5 5 5
40	40	52	54	52	74	85	72	80	80	5 5 5 4 4 4 4 4 3 2
76	46	51	92	61	79	60	53	67	60	2 2 2 2 2 2 2 2 2 2
77	68	59	69	50	43	55	59			2 2 2 2 2 2 2 2

TREES INCLUDED ARE - READING4 W61B 256 W61B 127 W61B 261 W61B 212