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Tree-Ring Dating of the Medieval waterfronts at the Seal House site.

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A brief interim report on the dendrochronological dating of the Roman and medieval waterfronts examined along the north bank of the Thames at the Seal House and New Fresh Wharf sites has already been published (Morgan, 1977; Schofield, 1975; Morgan & Schofield, 1978). Since then, the examination of further timbers from the medieval Seal House waterfronts by Jennifer Hillam at Sheffield, and the further comparison of original tree-ring curves with new data, has allowed the results to be modified. Further timbers have been accurately dated and the tentative matches have been withdrawn, so that all the details of the timbers and the dating given here arein their final form, unless hitherto undated timbers are matched in the future. The writer is grateful to Jennifer Hillam for her collaboration with later results and contribution to this report, as well as to the Ancient Monuments Laboratory of the Department of the Environment for financing the work, and to the staff of the Department of Urban Archaeology of the Museum of London.

In total, 43 oak timbers from the three successive waterfronts (I, II and III) and associated structures were examined. Thin sections were sawn from integral members of the waterfronts- posts, braces and planks - in the hope of giving exact calendar dates to their construction and associated deposits, and also from associated features such as drains, and from stray timbers. The suitability of the wood for absolute dating was first confirmed by Fletcher in 1975, when he examined two timbers (441 and 478) from a drain (context 471) associated with Waterfront III, and was able to date the ring-width curve of 441 easily to between 1021 and 1179 by comparison with a reference curve for Germany west of the Rhine (Hollstein, 1965). Most of the remaining

sections, still waterlogged, were then transported to Sheffield and examined in 1975-6, financed by the DoE; a few more sections and duplicates were then examined by Jennifer Hillam in Sheffield in mid-1977.

This report includes full details of all the timbers - their ages and the way in which they were cut from the tree, the raw ring-width values for each timber, and the dating of the curves with implications for the dating of the waterfronts themselves.

The technique of tree-ring analysis.

The sawn sections of wood were kept moist in polythene bags, mainly to protect the outer sapwood where present, as it deteriorates quickly on drying and is crucial to the establishment of an accurate felling date. The inner heartwood was generally very black and hard. In this condition the samples were deep-frozen and then could be surfaced with a surform plane and sharp knife to expose the growth rings with maximum clarity.

The original measurements were taken with a x10 lens containing a scale graduated in .1mm; many were subsequently remeasured using new equipment at Sheffield - a binocular microscope with long travelling stage, linked via a linear transducer to a digital voltmeter giving readout of the ring-widths traversed by the microscope (a system devised and in part constructed at the Ancient Monuments Laboratory). The ring-width values were plotted on semilogarithmic recorder paper for comparison both visually, and using a computer program written in Belfast (Baillie & Pilcher, 1973) which compares pairs of curves and assigns a Student's *t* value to each point of overlap. A *t* value in excess of 3.5 suggests a good match between the two curves at that point, which must then be checked visually, but reasonable visual matches need not necessarily be accompanied by a high *t* value. Some examples can be found in Table 2.

used for the same purpose (e.g. boards 387 C, D, E and F) or when cut from the same tree (e.g. boards 387 D and E). All the posts are complete or halved trunks hewn to a square cross-section, and the braces are usually quartered with the sapwood removed. A certain amount of variation in the cut of the braces may be suggestive of re-use, e.g. timbers 479 and 480 (see also below). Sapwood is preserved only rarely on the important timbers from known contexts within the waterfronts, i.e. where it would be an aid to dating, but is commonly found on the young wide-ringed posts which are of no value for dating.

It is difficult to assess the general age ranges of trees being exploited for use in the waterfronts and thus gain some insight into woodland management practices in the south-east in the twelfth and thirteenth centuries. This is mainly due to the comparatively small numbers of samples in each function group from each waterfront, and to the immense variation in age, ring-width and possibly source. Definite information would require total sampling from 100m or more of excavated waterfront.

The average ring-widths in the timbers vary from extremely fast growth to almost no growth at all, and suggest that the waterfronts do not consist of planned structures for which the carpenter selected suitable trees for the purpose from a local woodland, as was probably the case in the Roman waterfront examined at Seal House and New Fresh Wharf (Morgan, 1977; Schofield & Miller, 1976) or in the prehistoric trackways of the Somerset Levels (Morgan, 1976). Whereas in the latter, the timber forms a homogeneous group originating in the same trees or same woodland, for the waterfronts of medieval date the requisite timber was perhaps collected from a stockpile or during demolition, and thus probably varies in date and in source. Such a situation

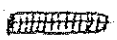
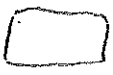
might be expected in the more complex and organised economy of urban life.

Archaeological evidence suggested a certain amount of re-use of ancillary timbers, such as the braces of Waterfront III shown in Fig. 2. The nearer brace, 480, is particularly interesting; not only does it show superfluous constructional features, but its cross-section has also distorted from rectangular to rhomboid, which is typical of quartered green oak which has been allowed to dry naturally (Hollstein, 1965). It is not likely or necessary that timber for a waterfront would be seasoned. Brace 480 thus appears to represent definite evidence in at least one case for re-use; unfortunately proof could not be found in tree-ring dating, since only 28 growth rings were present. In fact there is no evidence for re-use in the dating except possibly timber 637 in Waterfront I which is thought to be a secondary insertion; it would probably not be apparent in any case on such a scale of a few years unless all the sapwood remained on the timbers.

Dating of the tree-ring curves.

Because of the great variations in sensitivity and average ring-width, the curves were initially difficult to match and thus date. 32 out of the 43 timbers had sufficient numbers of rings for measurement and comparison; the basis for dating proved to be Hollstein's reference curve for Germany west of the Rhine (1965) which extends from the present day back to before 700 B.C. By means of this, timber 441 had initially been dated to 1021-1179 with a high t value of 6.9. Subsequently timber 478 was dated to 1019-1193 and timber 497D to 1001-1137 without difficulty. All three curves were of similar type to each other and to the reference curve - of 1-2mm average ring-width and

Table 1

Sample no. *dated	Context	No.of rings	No.of sapwood rings	Dimensions cm	Cut	Average ring-width mm
Fourteenth-sixteenth century						
50		c.45	-	25 x 21		wide
854		78	12	27 x 21 radius 25		3-5
871		30	-	28 x 24 radius 21		wide
875		59	9	33 x 32 radius 15		1-4
878		73	-	~~XXXXXXX~~ 38 x 5		2-5
Waterfront III						
379	Upright post	36	12	21 x 18 radius 15		3-6
381	Upright post	37	7	21 x 18 radius 17		3-7
383	Upright post	27	5	17 x 16 radius 13		5-7
384	Upright post	47	-	18 x 17 radius 15		2-5
387 C*	Horizontal plank	(242) 154	-	41 x 3		1-3
387 D*	Horizontal plank	99	-	25 x 5		1-3
387 E*	Horizontal plank	106	-	40 x 5		1-3
387 F*	Horizontal plank	100	-	13 x 2		1-2
433*	Stray	170	30	17 x 8		.5-2
441*	Drain plank	159	-	24 x 2		1-2
455*	Drain plank	(191) 168	-	10 x 2		~~1-2~~ .5-1.5
478*	Drain post	175	-	25 x 12		.5-1.5

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waterfronts, no matter how well dated archaeologically, cannot give such accurate construction dates as the timbers themselves.

The results also contribute further to the evidence accumulated by Fletcher (1977) for corresponding growth patterns in southern England and southern Germany over this period, and enable German reference curves to be used for dating English material of periods for which we have no reference material.

Timber 582 suggests a felling date of c.1140, as does timber 686 - in view of its increased age and narrow rings, probably 30-40 years can be allowed for sapwood. Timber 637, a young tree, may have only about 20 sapwood rings, or it may be slightly later than the other timbers; the archaeological evidence suggests that it was secondary. Timbers 596 and 640 may be earlier in date, or their later rings may have been lost by trimming.

Waterfront I was thus probably constructed about 1140, with timber 637 possibly being added a few years later.

Finally a stray timber, 629, provided a sensitive curve dated to between 914 and 1054; it has no sapwood and must have been cut after about 1080.

Conclusions.

The examination of a range of varied material from the Seal House waterfronts has given some indication of the variability which might be expected even in apparently homogeneous groups of timbers. This variability was evident not only in the average growth rates and patterns, but also in the levels of cross-dating both between timbers and with reference curves from England and Germany. By this period, and in an urban context, it is no longer possible to assume that most or all timbers from a structure will have come from the same source and span the same period of time. Interpretation of the dating here is made much more difficult by the absence of sapwood.

The construction dates indicated by the dendrochronological analysis are consistently about 50 years earlier than those suggested by the pottery, and it is thought unlikely that such a time difference could be accounted for by seasoning or stockpiling without resulting in serious deterioration of the wood. Material associated with the

the presence of sapwood, and is well illustrated by timber 433 which retained all its sapwood to the bark edge. The outermost ring is only partially formed, indicating that the tree was cut in late spring/summer, and dating of the curve showed the year to be 1203. As is unfortunately so often the case, this timber was a stray piece of unknown association to the waterfront, so the accurate date is not of any value in dating the structure.

The tree-ring dates therefore suggest that Waterfront III was constructed in the first half of the thirteenth century.

(Timbers 558 and 568, which were tentatively added to the initial block diagram (Morgan, 1977), cannot be definitely dated by further comparisons; they both have very sensitive growth patterns with fluctuations suggestive of a late twelfth century date, corrsponding particularly in the 1180's and 1190's. The early part of the curves cannot however be matched and the date confirmed. This is unfortunate as both have sapwood and were involved in the waterfront's construction, but their suspected positions fully confirm the dating.)

Waterfront II

Only three timbers out of 8 examined from this waterfront were dated with certainty. Timber 469 has sapwood remaining, giving a felling date of c.1170; timber 469 B must have been cut after about 1165, and timber 497 D after about 1160. The construction date for Waterfront II, based on this limited evidence, is probably about 1170.

Waterfront I

The accuracy of the dating of this waterfront has been greatly increased by the examination of further samples by Jennifer Hillam. A total of 7 timbers were dated, two of which had sapwood.

been felled after a certain date, including allowance for the missing sapwood. It is impossible to ascertain how much heartwood may also be missing.

If the date of felling can be determined quite accurately, the date of construction may still be uncertain to some extent, in view of possibilities such as re-use and seasoning, but the gap is unlikely to exceed a few years.

A later limit may also be imposed by the life span of the oak which rarely exceeds 250-300 years; thus only few rings are likely to be missing from timbers such as 478.

Interpretation of the dating is based on an examination of the block diagram (Fig. 4):

Waterfront III

Five timbers integral to the waterfront's construction could be dated - 387 C, D, E and F were horizontal planks pegged to the verticals, and 479 was a diagonal brace (Fig. 2). None showed any trace of sapwood. Their final growth rings lie between 1160 and 1183, and with an allowance for sapwood it might be supposed that felling took place after about 1210 - it is impossible to say how soon after.

Three further dated timbers - 455, 478 and 441 - were used in a drain running out from the top of the waterfront. Their final rings date to between 1179 and 1193, and indicate a felling date after about 1220. It is impossible to prove from the tree-ring dates whether the drain and waterfront are constructed of wood felled the same time; the suggestion is that the drain is slightly later, but 10 or 20 years are easily accounted for in the trimming of a timber, particularly boards. Such fine dating is possible only in

or matched with each other.
of rings but could not be dated. Of the later timbers, 854, 875 and 878 are rather young for dating when the context is vague; 854 and 878 do however come from the same tree. The curves for timbers 497 C, 528 and 626 are quite complacent and poor in quality, and may never be absolutely dated. The growth rings of 555, 558, 568, 503, 609 and 615 are however sensitive and very suitable for matching; they could probably be dated if similarities of the growth pattern could be recognised over longer periods of time. The raw data for all these curves is given in the appendix.

Interpretation of the dating.

Consideration must now be given to the likely construction dates for the waterfronts suggested by the tree-ring dates. Examination of associated pottery indicated provisional dates of c. 1200 for Waterfront I, 1225 for Waterfront II and 1250-75 for Waterfront III, and it was of interest to see how these dates fitted with the dendrochronological results.

Several points must be emphasised here. Firstly all the 20 dated curves shown in Fig. 4 are absolutely dated in calendar years - there is no question of their dates being tentative, or of the German reference curve by which they were dated being provisional in any way. So every growth ring of the 20 timbers was formed in a known year.

Secondly the felling date of a tree can only be determined accurately, to within about ± 5 years, if some sapwood is preserved on the timber; the average number of 20-30 rings in a mature oak allows a close estimate of the position of the bark edge and thus the year of felling, even if only one sapwood ring remains. Only four of the dated timbers have some sapwood (433, 469, 582 and 686). In its absence, we can only examine the date of the final growth ring of all the dated timbers in each waterfront, and conclude that the trees must have

Twelve of the timbers shown in the block diagram (Fig. 4) have been used to create a mean curve extending from A.D. 861 to 1193; their selection was based on quality of cross-matching [illegible], and the curve was calculated by simple averaging. The timbers involved are 433, 455, 441, 478, 387 D, E and F, 497 D, 611, 637, 686 and 629. The values for this curve are given in Table 3 from 950 to 1193; the first 90 years are not included since they are based on narrow rings of timber 611 and a few rings of 629, which can be found in the appendix if required.

The mean curve differs little from a previous one (Morgan, 1977) based on 8 timbers, and the addition of further material would probably not affect the degree of year-to-year variation to any extent. The 8 timber curve gave t values of 5.9 with the German curve (Hollstein, 1965), 7.76 with the south German curve (Huber & Giertz-Siebenlist, 1969), and 8.5 with the London area curve (now REF 6 in Fletcher, 1977 - REF 6 now includes a number of the Seal House curves, and so differs little from the mean curve given here).

The proportion of undated curves is of equal interest. The reasons are various - they may have less than 50 rings, they may not be contemporary or they may have a ring-width pattern which is not suitable for cross-dating (this could include complacency or distortion). Eleven of the Seal House timbers were too young for dating, with less than 50 rings (750, 871, 379, 381, 383, 384, 480, 533, 515, 527 and 605); these are mainly posts or braces consisting of the complete trunk (see Table 1). Measurement of the ring-widths even of such young timbers can sometimes indicate at least that they are contemporary with each other, as might be expected in this case from the row of posts (379, 381, 383 and 384), but no evidence at all for such contemporaneity could be found.

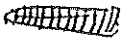
The remaining 12 timbers provided sufficiently long series

moderate year-to-year variation.

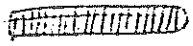
The remaining curves required repeated re-examination before their synchronisation could be achieved, due to the difficulties of attempting to match such varied material. Even so, 12 of the curves could not be dated with certainty, although the positions of several are strongly suspected and most no doubt lie within the time range under consideration. Four were initially given tentative positions (cf. Fig. 4 in Morgan, 1977), but were withdrawn after further thorough comparisons, since tentative dates are felt to be misleading to the archaeologist, who may not appreciate the uncertainties involved.

Details of the 20 dated curves are given in Table 2, which includes the years spanned by the rings of each timber and the $\underline{t}$ values for their comparison with the German reference curve (Hollstein, 1965), a curve for the London area (now REF 6 in Fletcher, 1977) or, in the case of later comparisons, with the first Seal House mean curve (see below). The same information is given in diagrammatic form in Fig. 4, each block representing the years spanned by the growth rings of each timber; hatching indicates sapwood and dotted lines suggest the extent of zones of very narrow rings which were not measured.

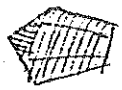
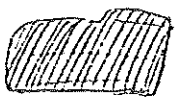
The alterations in Fig. 4 compared to Fig. 4 in Morgan (1977) include the removal of the four tentative matches (timbers 503, 558, 568 and 609); timbers 387C and 596 now have no query beside them; further rings of timber 582 could be measured and it has been placed in its correct position in Waterfront I; timber 640 has now been dated; and finally timbers 433, 455, duplicate 469 and 497D, 637, 685 and 686 measured and dated by Jennifer Hillam have been included.

479*	Brace	86	-	18 x 16 radius 17		1-2
480	Brace	28	-	21 x 21 radius 16		2-7
533	Horizontal support	27	10	15 x 14 radius 15		5+
555	Plank	133	-	17 x 3		.5-2
558	Post	64	8	12 x 12 radius 8		1-2
568	Post	100	26	22 x 12 radius 14		1-2

Waterfront II

469*	Post	91	16	18 x 15 radius 19		1-5
469 B*	Upright plank	184	-	15 x 3		.5-1.5
497 C	Plank	114+	-	36 x 3		1-3
497 D*	Plank	137	-	21 x 4		1-2
503	Plank	160	-	23 x 3		1-2
515	Brace	23	2	27 x 13 radius 12		wide
527	Brace?	25	3	17 x 13 radius 11		wide
528	Post (re-used?)	95	-	20 x 14 radius 22		1-3

Waterfront I

582*	Stake	131	18	12 x 9 radius 13		.5-1.5
596*	Sill-beam	77	-	25 x 20 radius 24		1-4
605	Brace	41	6	19 x 10 radius 13		2-4
609	Plank	157	-	19 x 7		1-2
611*	Brace	225	-	21 x 9-13		.5-2

615	Brace?	74	-	13 x 4		1-2
626	Plank	141+	-	15 x 5		.5-1.5
637*	Brace (secondary?)	74	-	12 x 3		1-2
640*	Plank	77	-	18 x 6		2-3
685*	Brace	58	÷	15 x 6		2-3
686*	Brace	125+	2	18 x 6		.5-1.5
Twelfth century stray						
629*		141	-	20 x 12 radius 22		1-2

Table 1. Details of all the oak timbers examined from the excavations at Seal House.

Table 2

Sample no.	No.of rings	No.of sapwood rings	Years spanned AD		't' value (Belfast program) with means (see text)
Waterfront III					
387 C	154	-	1030-1183		6.92
387 D	99	-	1078-1176	same tree	4.91
387 E	106	-	1078-1183	same tree	4.91
387 F	100	-	1061-1160		4.22
433	170	30	1033-1202		4.51 (1033-1107)
441	159	-	1021-1179		6.90
455	(191)168	-	999-1166(1189)		9.76
478	175	-	1019-1193		2.94
479	86	-	1085-1170		4.81
Waterfront II					
469	91	16	1073-1163		2.97
469 B	184	-	960-1143		4.11
497 D	137	-	1001-1137		8.47
Waterfront I					
582	131	18	1003-1133		5.73
596	77	-	966-1042		4.80
611	225	-	862-1086		4.65
637	74	-	1049-1122		4.73
640	77	-	963-1039		5.27

685	58	-	1032-1089	2.71
686	125+	2	+982-1106	3.53
Twelfth century stray				
629	141	-	914-1054	7.86

Table 2. Details of the oak timbers from the Seal House waterfronts for which absolute dates could be established.

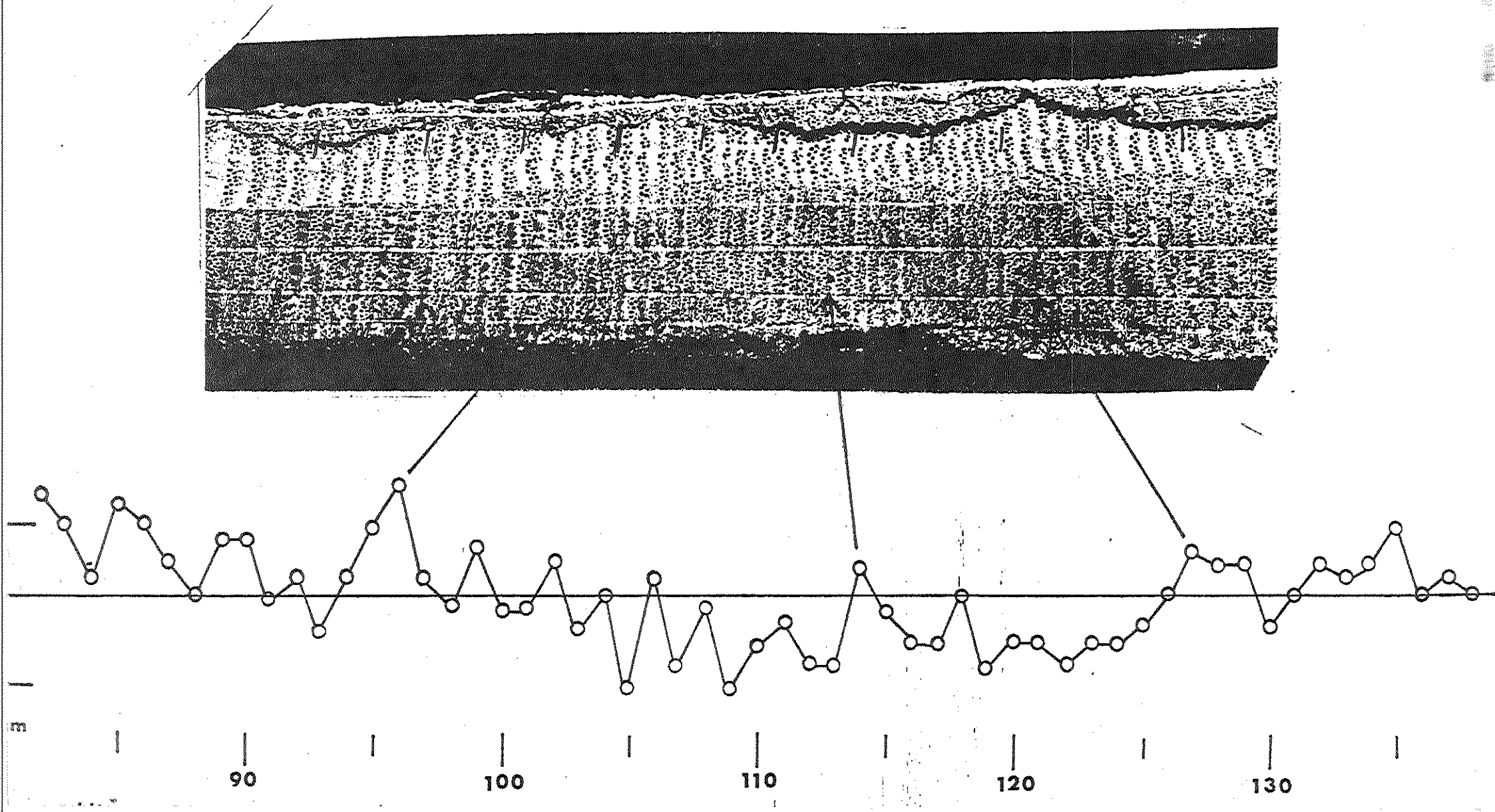
	0	1	2	3	4	5	6	7	8	9	T
950	11.5	10.5	13.0	14.0	13.5	14.0	12.5	12.5	9.5	12.5	2
960	10.0	11.5	10.0	11.5	13.0	12.0	16.5	14.0	14.0	11.5	2
970	11.5	12.5	10.5	10.5	8.0	10.0	10.5	15.0	12.0	13.5	2
980	15.5	14.0	13.0	14.0	13.7	12.7	9.3	10.0	10.0	12.3	3
990	10.7	12.7	12.0	11.3	12.0	11.0	10.7	12.0	10.7	13.5	4
1000	12.2	11.4	11.8	10.6	13.2	9.8	12.4	12.2	10.4	11.0	5
1010	8.2	10.0	13.6	12.2	8.6	9.6	8.0	9.8	8.6	8.2	6
1020	8.7	11.3	9.9	11.1	9.7	8.6	11.3	11.3	10.1	9.7	7
1030	12.6	9.3	9.1	10.5	9.9	12.4	11.4	12.4	10.9	11.0	8
1040	14.6	14.4	14.0	12.2	10.9	12.0	12.5	12.7	11.1	11.9	8
1050	11.0	10.6	12.6	11.1	9.9	14.1	12.7	8.7	15.9	13.1	7
1060	12.3	12.1	12.7	13.8	13.2	9.4	12.1	16.1	16.9	14.0	9
1070	12.9	12.1	11.4	15.1	13.4	12.6	14.3	13.6	14.4	14.1	9
1080	14.2	10.4	12.9	13.0	10.8	13.2	13.4	12.2	13.6	15.9	10
1090	10.1	11.7	13.9	14.4	13.9	13.0	13.5	16.4	15.8	13.0	9
1100	16.3	11.0	12.4	15.9	12.9	12.5	12.5	14.7	14.6	14.9	8
1110	11.4	12.7	12.9	14.4	15.3	14.7	14.0	13.3	14.0	13.4	8
1120	14.3	11.4	16.3	18.0	20.0	13.5	12.7	13.2	15.0	12.5	7
1130	13.7	13.2	14.3	15.7	15.7	14.0	11.7	11.0	12.8	9.8	6
1140	15.6	14.2	12.2	11.6	13.2	12.4	12.0	12.2	11.0	12.6	6
1150	12.6	12.4	11.2	13.8	11.3	11.2	16.0	14.6	13.0	14.6	6
1160	15.6	14.2	15.5	14.2	18.0	14.0	11.7	13.7	17.7	17.0	4
1170	16.0	16.7	16.7	19.7	15.3	13.7	15.0	11.7	14.0	17.3	4
1180	12.5	15.5	15.0	15.5	10.0	11.0	18.0	15.0	8.0	12.0	1
1190	13.0	14.0	11.0	12.0							

Table 3. Annual ring-width values (0.1mm) for the mean curve based on 12 Seal House timbers (see text). The curve spans the period A.D. 950 to 1193. T = number of samples (probably all but two from different trees) involved in each decade.

Fig. 11. Transverse section of [illegible] showing [illegible] which together form a channel [illegible]. The variation in width from year to year is expressed as a curve, as shown below, the marked rings corresponding to the 5 and 10 year intervals of the scale. The growth pattern for this timber could not be dated with certainty. Radially cut boards such as this are of great value for tree-ring dating.

SEAL HOUSE board 503

WII



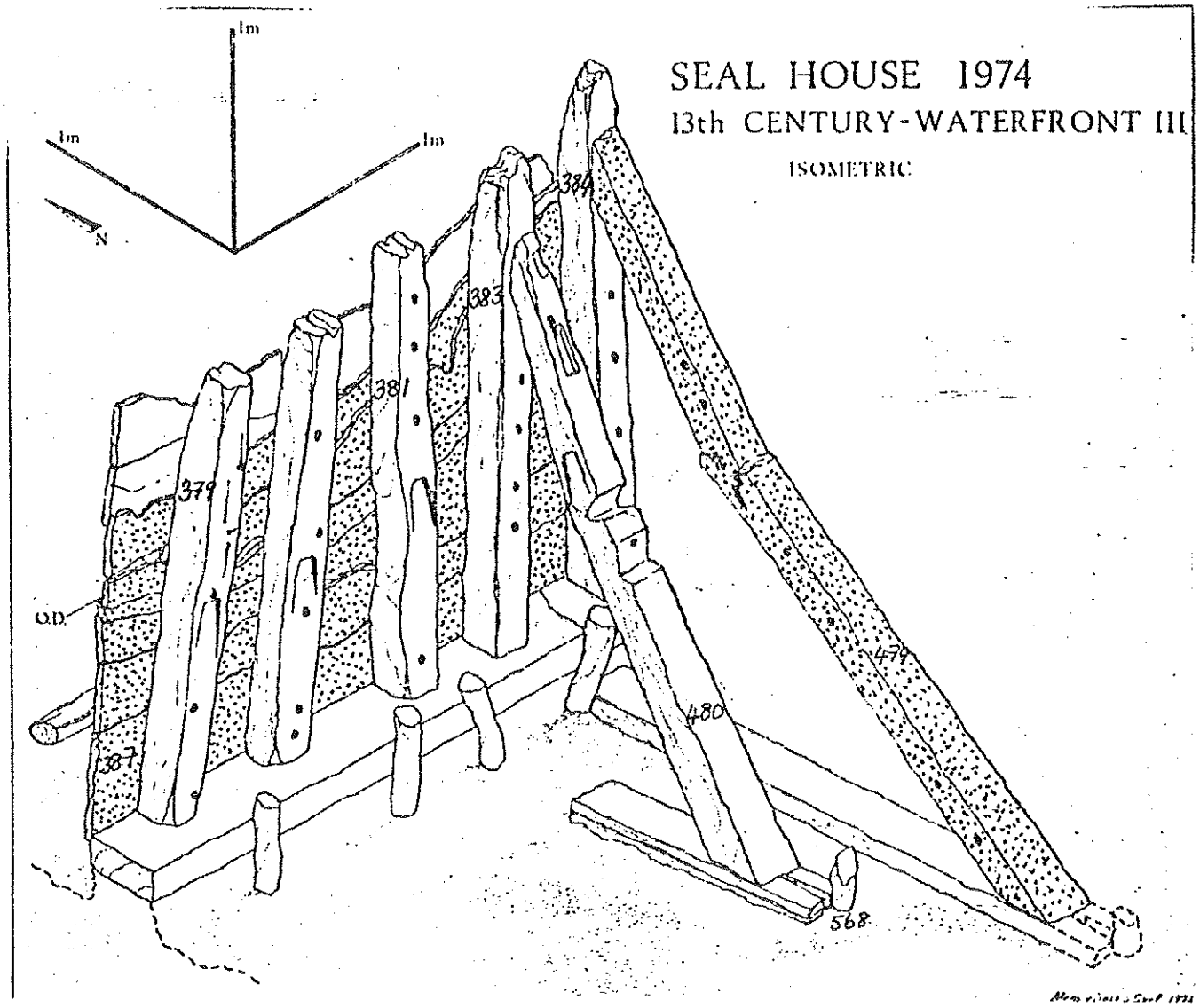


Fig. 2 Isometric diagram of Waterfront III showing the timbers which could be dated. The vertical posts were from young fast-grown trees of no value for dendrochronology.

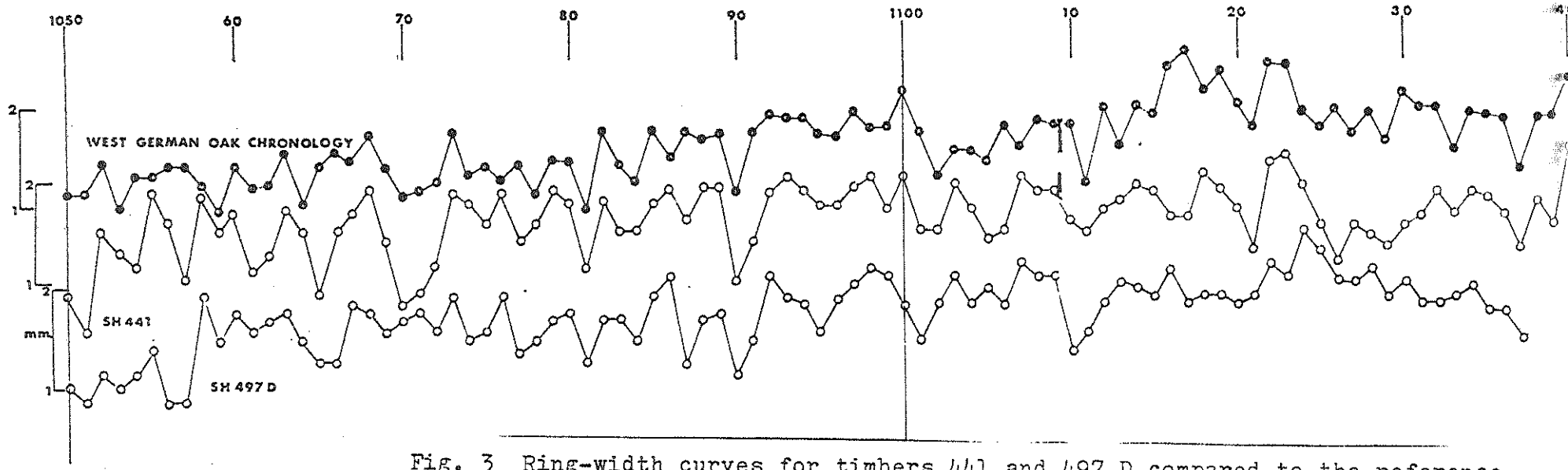


Fig. 3 Ring-width curves for timbers 441 and 497 D compared to the reference curve for Germany west of the Rhine (Hollstein, 1965), by which they were dated. The patterns cover the period 1050 to 1172.

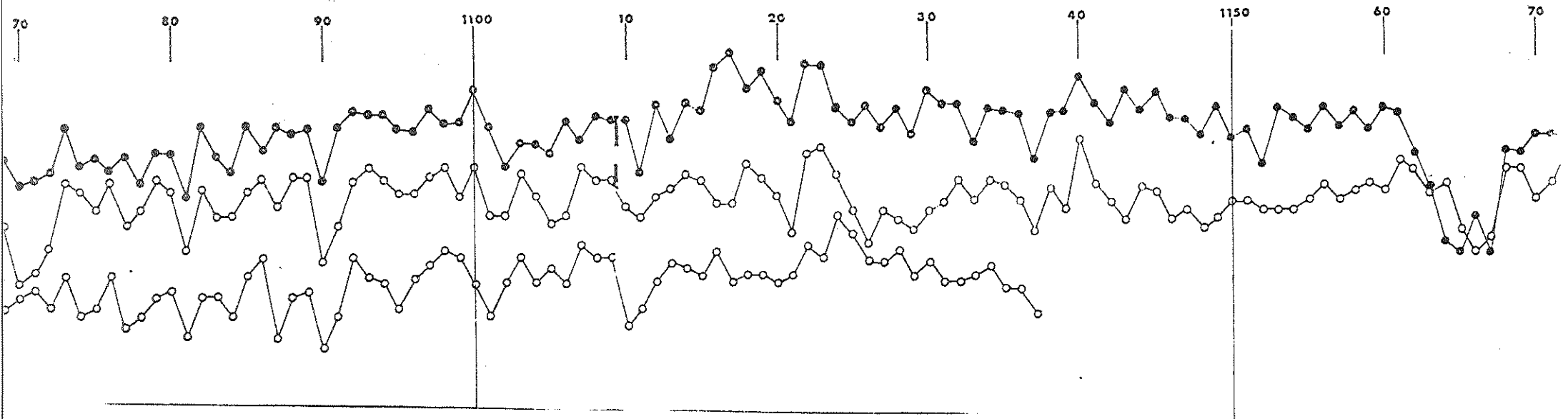
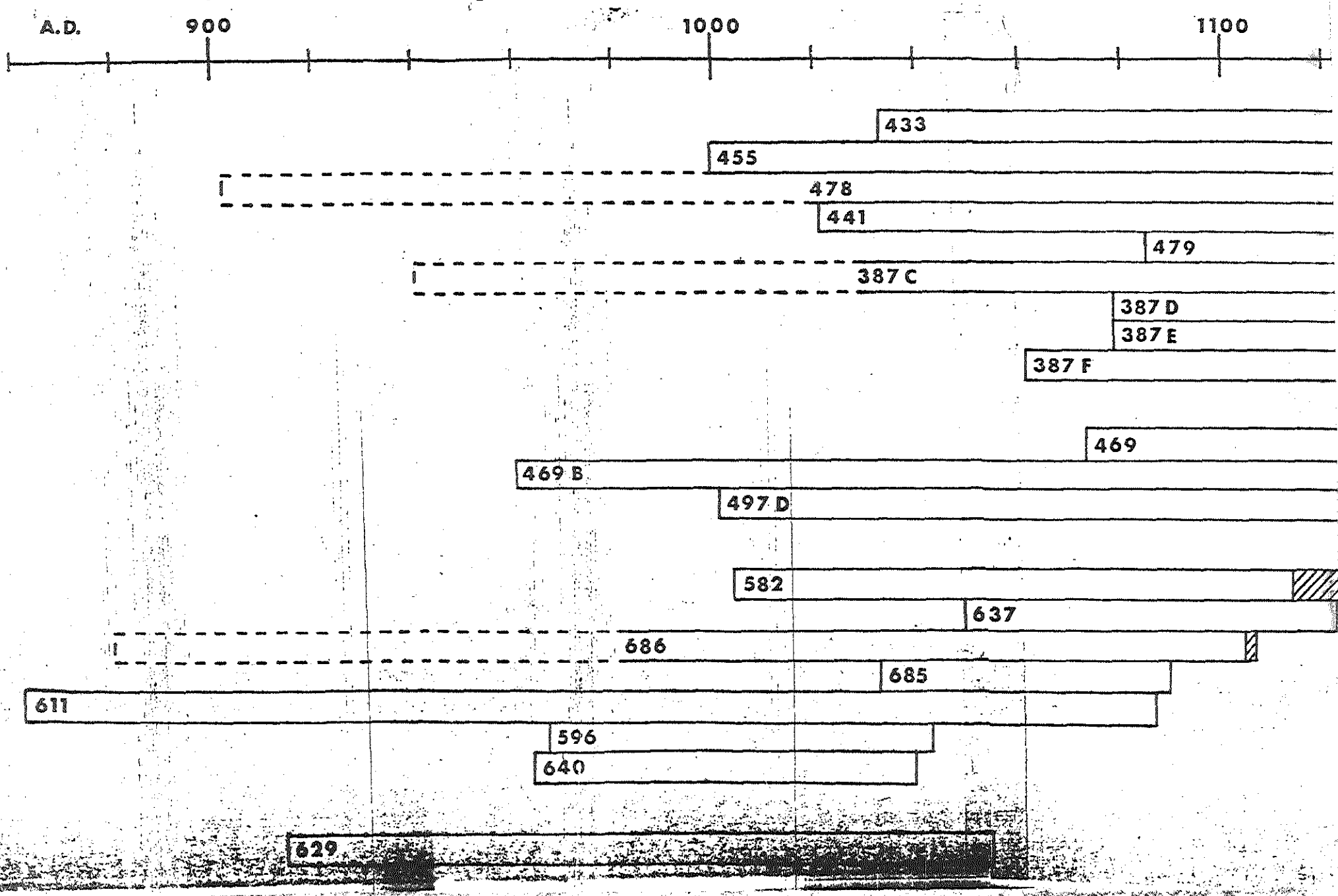
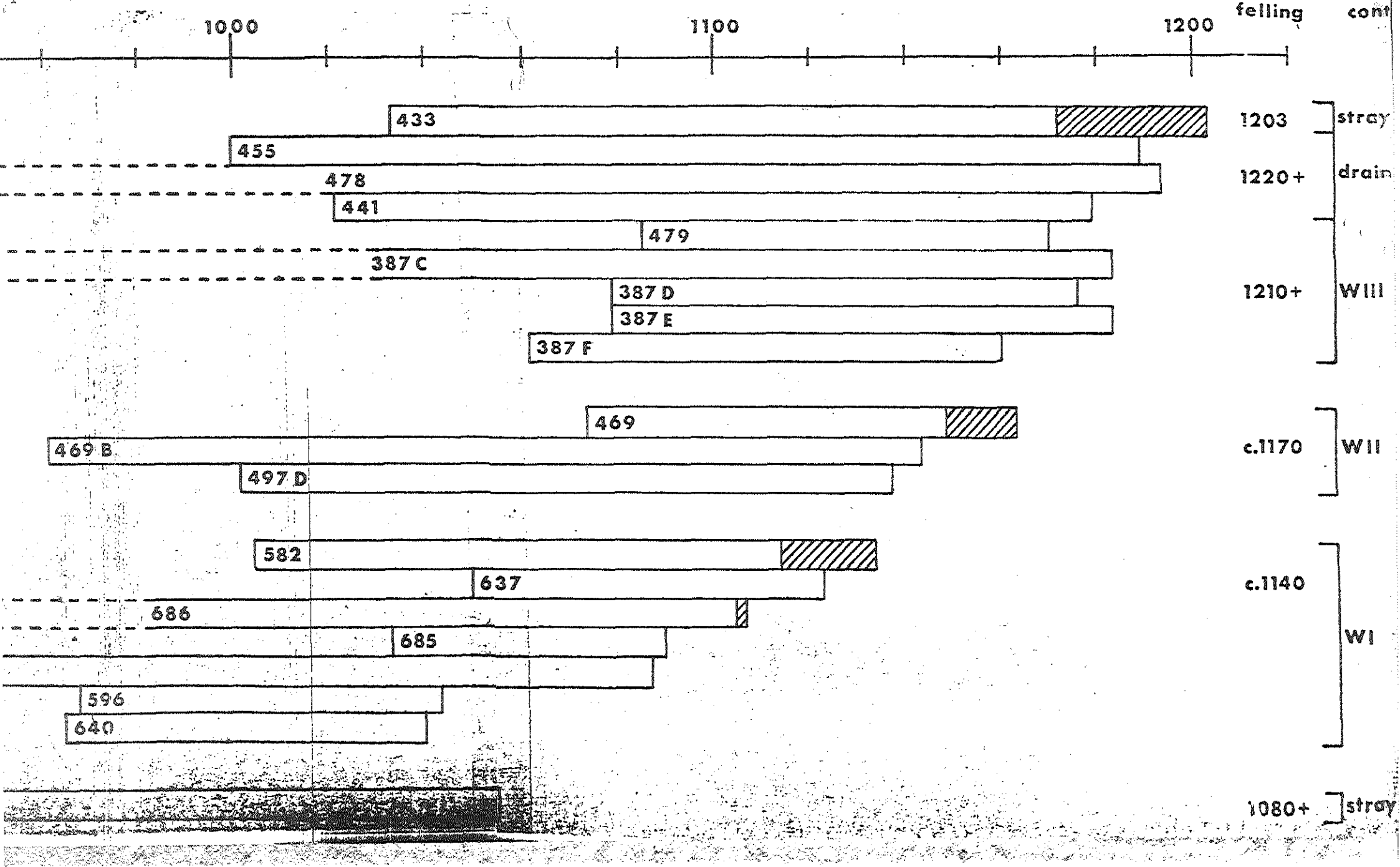


Fig. 3 Ring-width curves for timbers 441 and 497 D compared to the reference curve for Germany west of the Rhine (Hollstein, 1965), by which they were dated. The patterns cover the period 1050 to 1172.

Fig.4 Block diagram illustrating the relationship in date between the rin curves from timbers of each waterfront, with their suggested felling/const dates. The blocks represent the heartwood rings, while dotted lines indic the approximate extent of very narrow unmeasured rings, and hatching repre sapwood.



ig.4 Block diagram illustrating the relationship in date between the ring-width urves from timbers of each waterfront, with their suggested felling/construction ates. The blocks represent the heartwood rings, while dotted lines indicate he approximate extent of very narrow unmeasured rings, and hatching represents apwood.



Appendix. Ring-width values (0.1mm) for all the Seal House timbers which were measured. Each block of data follows a format:

e.g. SH387C = sample number
WIII = waterfront
C 1030-1183 = date where appropriate
154 = number of rings measured and listed below
8 7 9 8 6 15 15 etc. = width of each individual ring

SH 854
14C
78
25 14 28 22 22 18 32 30 20 52 47 44 24 32 35 35 42 45 35 55 55 50 40 33 38
30 28 25 34 48 32 52 37 45 40 37 53 31 35 55 44 38 38 45 62 52 47 47 34 43
29 29 37 31 23 21 29 24 23 19 27 30 27 30 27 17 21 14 14 15 16 10 24 25 25
30 24 25

SH 875
14C
59
30 45 24 13 21 42 50 33 45 38 35 26 17 25 29 30 32 36 24 29 40 37 32 30 22
38 27 29 27 22 20 24 22 15 20 18 12 8 12 14 22 15 14 11 10 17 16 17 20 17
20 20 23 25 28 22 18 16 19

SH 878
14C
73
60 85 45 48 33 39 42 50 42 32 40 34 21 19 19 28 33 29 25 20 14 13 20 31 24
23 35 42 39 23 27 42 37 45 48 21 32 42 34 20 22 24 34 27 34 25 27 23 20 24
24 27 24 28 29 25 33 37 32 25 26 38 35 36 35 40 27 45 33 52 48 32 28

SH387C
WIII
C 1030-1183
154
8 7 9 8 6 15 15 20 18 20 26 35 44 30 15 13 11 12 19 17 8 10 12 9 10
13 14 12 23 22 21 34 25 19 17 12 12 16 19 18 15 15 12 15 17 14 17 16 19 15
18 14 13 24 13 17 20 15 15 9 6 9 12 15 12 13 13 13 17 13 14 9 7 13 11
11 8 10 9 9 9 11 9 11 12 13 10 8 9 10 8 7 7 8 12 10 10 10 12 7
11 9 13 13 15 12 10 8 9 9 12 12 14 12 11 10 12 13 12 13 17 16 17 20 13
17 25 21 17 18 17 15 13 9 9 10 13 13 17 20 14 16 14 19 22 22 26 16 23 23
17 11 14 12

SH387D
WIII
C 1078-1176
99
48 48 50 42 46 62 49 53 41 28 17 31 18 25 10 9 12 17 13 23 17 17 19 15 17
17 18 14 10 8 8 10 12 18 17 22 24 22 18 21 27 29 43 26 39 42 38 23 25 25
24 23 24 22 29 33 33 28 15 19 15 11 19 25 19 26 20 17 27 28 30 32 27 25 23
30 22 22 24 25 18 32 32 17 24 22 26 25 19 19 10 26 22 25 20 33 24 19 17

SH387E
WIII
C 1078-1183
106
42 29 35 20 35 36 25 28 20 18 11 20 8 14 12 14 15 14 15 23 17 16 24 15 17
23 18 14 18 17 24 26 26 26 18 18 21 28 16 21 13 22 26 16 28 35 35 16 19 23
22 15 14 17 17 22 20 17 9 11 12 8 14 13 13 13 12 14 19 17 15 20 18 19 14
24 16 14 18 18 16 19 23 12 12 15 23 18 16 17 21 16 17 19 20 19 14 12 18 13
16 18 15 15 16 17

SH387F
WIII
C 1061-1160
100
20 18 17 14 14 16 20 20 15 17 14 15 16 21 17 17 23 19 19 15 11 12 18 14 17
14 11 12 17 14 12 12 17 15 12 16 15 19 14 19 11 11 13 12 13 11 15 15 14 13
13 12 13 14 14 13 10 11 10 9 8 9 7 15 11 13 9 9 11 13 12 14 14 13 11
10 10 12 9 13 15 13 10 8 10 8 9 8 8 8 7 7 9 9 7 10 11 9 10 12

SH 433
WIII
C 1033-1107

30 28 25 34 48 32 52 37 45 40 37 53 31 35 55 44 38 38 45 62 52 47 47 34 43
29 29 37 31 23 21 29 24 23 19 27 30 27 30 27 17 21 14 14 15 16 10 24 25 25
30 24 25
SH 875
14C
59
30 45 24 13 21 42 50 33 45 38 35 26 17 25 29 30 32 36 24 29 40 37 32 30 22
38 27 29 27 22 20 24 22 15 20 18 12 8 12 14 22 15 14 11 10 17 16 17 20 17
20 20 23 25 28 22 18 16 19
SH 878
14C
73
60 85 45 48 33 39 42 50 42 32 40 34 21 19 19 28 33 29 25 20 14 13 20 31 24
23 35 42 39 23 27 42 37 45 48 21 32 42 34 20 22 24 30 27 34 25 27 23 20 24
24 27 24 28 29 25 33 37 32 25 26 38 35 38 35 40 27 45 33 52 48 32 28
SH387C
WIII
C 1030-1183
154
8 7 9 8 6 15 15 20 18 20 26 35 44 30 15 13 11 18 19 17 8 10 12 9 10
13 14 12 23 22 21 34 25 19 17 12 12 16 19 18 15 15 12 15 17 14 17 16 19 15
18 14 13 24 13 17 20 15 15 9 6 9 12 15 12 13 13 13 17 13 14 9 7 13 11
11 8 10 9 9 9 11 9 11 12 13 10 8 9 10 8 7 7 8 12 10 10 10 12 7
11 9 13 13 15 12 10 8 9 9 12 12 14 13 11 10 12 11 12 13 17 16 17 20 13
17 25 21 17 18 17 15 13 9 9 10 13 13 17 20 14 16 14 19 22 22 26 16 23 23
17 11 14 12
SH387D
WIII
C 1078-1176
99
48 48 50 42 46 62 49 53 41 28 17 31 19 23 10 9 12 17 13 23 17 17 19 15 17
17 18 14 10 8 8 10 12 18 17 22 24 22 18 21 27 29 41 26 39 42 38 23 25 25
24 23 24 22 29 33 33 28 15 18 15 11 19 23 19 26 20 17 27 28 30 32 27 25 23
30 22 22 24 25 18 32 32 17 24 22 26 25 19 19 19 20 23 25 20 33 24 19 17
SH387E
WIII
C 1078-1183
106
42 29 35 20 35 36 25 28 20 18 11 20 8 14 12 14 15 14 15 23 17 16 24 15 17
23 18 14 18 17 24 26 20 26 18 18 21 23 12 21 13 22 26 16 28 35 35 16 19 23
22 15 14 17 17 22 20 17 9 11 12 8 14 13 13 13 12 14 19 17 15 20 18 10 14
24 16 14 18 18 16 19 23 12 12 15 23 18 16 17 21 16 17 19 20 19 14 12 18 13
16 18 15 15 16 17
SH387F
WIII
C 1061-1160
100
20 18 17 14 14 16 20 20 15 17 14 15 10 21 17 17 23 17 19 15 11 12 18 14 17
14 11 12 17 14 12 12 17 15 12 16 15 10 14 19 11 11 13 12 13 11 15 15 14 13
13 12 13 14 14 13 10 11 10 9 8 9 9 15 11 13 9 9 11 13 12 14 14 13 11
10 10 12 9 13 15 13 10 8 10 8 9 8 8 8 7 7 8 9 7 10 11 9 10 12
SH 433
WIII
C 1033-1107
75
20 14 24 19 23 21 16 21 20 24 22 23 20 15 16 14 21 23 27 20 23 16 21 23 14
20 19 14 12 6 7 8 6 9 14 15 13 17 15 9 19 18 14 18 17 18 18 20 12 11
11 7 11 13 9 8 10 8 9 10 13 10 17 11 9 6 6 8 9 8 7 4 3 3 3
SH 441
WIII
C 1021-1179
159
16 9 18 13 10 17 16 15 15 20 13 8 17 7 10 12 19 11 9 17 18 20 17 19 14
13 12 10 11 9 7 14 12 11 19 15 20 18 15 16 11 12 16 14 9 14 16 19 13 8
9 11 18 17 15 18 13 15 19 17 11 17 14 14 17 20 15 11 19 19 13 15 20 18 17
17 19 20 16 20 14 14 19 16 13 14 20 18 13 15 14 16 17 19 18 15 15 21 13 16
12 22 23 19 14 11 14 13 12 14 15 18 15 14 17 15 12 17 14 24 17 15 13 17 14
13 14 12 13 15 15 14 14 16 15 17 15 17 17 16 9 18 16 17 12 10 11 19 19 15
17 21 22 17 15 16 16 17 22
SH 455

159
16 9 18 13 10 17 16 15 15 20 13 8 12 7 10 12 19 12 10 17 18 20 17 10 14
13 12 10 11 9 7 14 12 11 18 15 10 18 14 16 11 12 16 14 9 14 16 19 13 8
9 11 18 17 15 18 13 15 19 17 11 17 14 14 17 20 15 19 19 10 13 18 20 18 17
17 19 20 16 20 14 14 19 16 13 14 20 18 18 15 14 16 17 19 18 15 15 21 18 16
12 22 23 19 14 11 14 13 12 14 15 18 15 18 17 15 12 17 14 24 17 15 13 17 16
13 14 12 13 15 15 14 14 14 15 17 15 16 17 16 20 18 16 17 12 10 11 19 19 15
17 21 22 17 15 18 16 17 22
SH 455
WIII
C 999-1166
168
16 12 12 12 11 17 13 17 17 10 10 7 7 8 8 5 5 5 6 6 7 9 13 12 13
14 9 11 13 11 9 14 8 9 8 7 12 10 8 8 7 7 8 8 9 8 9 13 12 10
13 10 12 12 11 9 14 11 9 16 10 9 6 11 10 10 5 7 9 12 11 9 8 6 10
8 7 9 9 11 10 14 12 13 14 10 11 15 11 13 14 8 9 13 12 10 10 12 13 12
12 14 8 10 12 9 9 9 11 10 10 7 10 10 11 13 13 12 11 9 9 9 7 9 8
12 9 9 6 12 8 8 9 7 11 10 8 8 8 7 7 5 10 8 6 9 10 5 6 5
6 5 5 4 4 4 4 7 7 7 5 7 4 9 9 6 9 1
SH 478
WIII
C 1019-1193
175
4 6 4 3 4 5 4 4 5 6 9 5 5 6 4 7 7 8 7 7 13 14 14 11 9
10 8 12 15 11 10 8 10 15 9 9 15 16 8 16 12 10 6 10 8 10 5 10 11 13
10 10 8 10 13 12 8 8 9 13 9 8 7 8 9 7 10 7 5 8 10 6 6 7 8
7 7 5 8 11 7 10 9 8 9 8 7 8 6 9 12 7 7 6 7 8 7 8 7 7
7 6 7 7 7 7 5 4 5 7 6 7 6 6 8 7 9 8 7 14 10 19 12 9 10
16 11 11 10 8 10 13 13 13 15 13 12 25 19 16 16 16 17 17 13 25 14 9 12 14
14 13 11 9 11 10 11 10 6 9 12 10 16 14 14 10 11 18 15 8 12 13 14 11 12
SH 479
WIII
C 1085-1170
86
25 25 23 33 34 33 28 47 54 36 36 23 25 47 24 38 25 17 19 23 18 12 12 15 21
17 16 22 15 18 22 14 15 19 17 17 10 16 25 11 11 10 13 12 14 11 12 10 12 17
17 14 15 16 15 30 42 30 15 10 14 9 6 13 10 11 12 7 8 9 9 12 12 10 13
13 13 9 11 15 12 16 13 16 10 11
SH 555
WIII
133
11 11 28 20 16 13 12 18 14 13 12 14 37 33 28 23 23 25 17 23 25 28 6 5 6
6 10 18 18 18 25 26 38 27 15 7 11 13 14 16 12 9 6 4 8 10 12 11 13 13
10 6 8 7 10 11 10 12 15 10 10 9 6 6 5 7 6 6 9 8 8 8 13 11 7
4 5 5 4 5 7 8 9 9 9 9 10 12 5 8 9 11 1 11 10 9 7 7 6 7
10 10 13 10 11 15 14 15 12 9 17 11 20 15 20 13 10 11 11 12 14 11 14 12 14
12 16 13 14 17 18 17 15
SH 558
WIII
64
15 13 11 10 13 17 15 11 10 13 18 17 9 13 13 13 14 16 12 12 13 14 13 13 11
13 16 18 18 7 8 10 10 9 7 9 11 8 8 10 11 13 12 16 13 15 15 10 10 15
21 11 10 18 19 9 15 17 14 12 19 16 19 16
SH 568
WIII
100
27 30 23 21 23 15 20 12 8 10 7 8 6 8 10 8 9 9 13 21 12 14 13 10 18
13 10 9 12 18 17 14 21 19 14 17 19 19 16 20 16 20 13 14 11 15 13 13 16 8
8 7 8 13 15 17 12 9 18 13 14 13 10 7 10 11 13 12 12 15 16 10 9 9 11
10 15 15 15 14 12 11 9 8 12 16 14 13 16 9 14 14 16 9 11 14 14 13 13 14
SH 469
WII
C 1073-1163
91
22 15 11 11 13 24 29 27 24 30 20 24 20 16 12 14 16 17 19 19 23 15 14 11 14
20 15 27 23 12 8 7 8 8 7 8 7 12 19 21 43 34 45 44 57 50 27 27 20 24
40 31 27 17 15 18 16 21 13 12 13 16 14 11 8 7 9 12 14 11 8 7 9 9 8
12 9 10 8 7 9 8 7 9 13 9 12 13 11 15 15
SH469B
WII

12 9 10 8 7 9 8 7 9 13 9 12 13 [illegible] 15 15
SH469B
WII
C 960-1143
184
13 7 6 9 7 7 8 8 10 8 8 8 9 7 7 7 9 12 11 12 8 8 7 6 5
6 8 9 9 10 9 8 7 8 8 8 6 7 9 9 6 7 7 8 10 7 6 9 10 12
11 10 10 10 8 8 9 9 7 10 9 10 9 11 7 7 8 9 9 6 9 6 5 5 5
6 6 7 7 6 6 7 6 7 7 6 7 7 9 6 5 5 5 6 4 5 7 6 5 5
4 5 5 6 5 5 5 8 7 6 6 5 5 7 7 7 10 11 10 7 8 8 12 9 10
10 7 8 9 9 8 8 10 9 8 7 8 12 12 15 11 9 9 7 9 9 11 9 11 13
11 10 13 11 13 14 10 13 14 11 10 8 8 [illegible] 10 9 9 [illegible] 11 10 9 12 11 11 11
9 13 15 11 12 11 13 15 12
SH497D
WII
C 1001-1137
137
13 16 9 15 8 11 11 11 15 10 10 14 11 [illegible] 10 12 13 11 [illegible] 8 10 10 9 10 9
14 13 12 10 18 13 12 10 12 12 10 14 [illegible] 12 14 15 11 13 11 14 11 13 11 12 11
11 12 11 11 13 11 9 20 14 19 18 17 17 15 13 13 19 18 15 17 17 14 20 14 15
18 14 15 16 18 11 17 17 15 19 21 12 16 16 11 15 23 19 18 15 17 20 23 21 22
14 18 23 17 21 19 25 23 22 12 14 19 22 22 20 23 22 19 17 16 18 23 21 30 23
20 21 23 19 21 18 18 19 20 17 17 14
SH 503
WII
160
7 9 8 10 12 16 15 20 17 13 14 14 [illegible] 1 8 8 13 [illegible] 13 12 10 12 13 9 9
10 8 7 7 6 8 12 9 11 9 13 13 12 12 10 11 12 11 13 19 20 17 22 14 18
16 15 14 15 14 17 20 21 16 14 15 19 24 2[illegible] 18 12 17 22 19 13 18 20 15 21 14
22 23 19 20 19 27 23 26 16 22 20 17 15 19 19 15 16 17 16 20 24 16 14 18 14
14 17 13 15 10 16 11 14 10 12 13 11 [illegible] 17 14 12 12 15 11 12 12 11 12 12 13
15 18 17 17 13 15 17 16 17 20 15 16 15 [illegible] 19 15 16 [illegible] 19 20 15 15 17 14 15
14 15 17 15 16 15 17 15 20 14
SH 528
WII?
95
28 24 25 25 24 30 36 30 35 34 32 34 [illegible] 27 25 23 24 22 24 22 14 21 18 13 12
12 14 18 17 11 17 14 14 12 12 14 2[illegible] 17 [illegible] [illegible] 12 14 13 13 17 14 11 13 12 [illegible]
13 16 14 21 20 16 12 5 5 5 4 5 8 [illegible] 11 8 12 11 14 17 17 19 21 22 25
19 19 19 20 18 21 23 37 29 22 21 15 [illegible] [illegible] 8 8 7 [illegible] 14 9
SH 582
WI
C 1003-1133
131
9 9 10 6 10 11 10 8 11 10 9 8 8 [illegible] 10 10 6 6 10 7 7 6 9 9 9
6 6 10 7 9 5 7 7 10 9 7 10 8 [illegible] 5 7 7 [illegible] 6 8 5 7 4 6 4
4 7 12 13 10 14 14 13 11 10 11 11 9 8 12 12 10 6 8 10 13 10 18 15 14
9 8 10 7 7 12 14 17 13 11 11 13 7 [illegible] 12 13 11 [illegible] 9 12 13 11 10 9 8
15 15 13 14 18 10 23 10 9 11 14 14 [illegible] [illegible] 13 15 [illegible] [illegible] [illegible] 6 [illegible] 13 [illegible] 6 8
8 8 10 9 9 6
SH 596
WI
C 966-1042
77
40 38 32 33 31 23 21 12 8 7 10 12 8 [illegible] 15 14 12 [illegible] 14 19 19 19 13 20 16
16 15 19 19 20 15 17 20 19 18 18 16 [illegible] 2[illegible] 22 19 26 3[illegible] 4[illegible] 36 50 75 67 28 32
24 23 35 36 23 21 22 30 25 19 33 33 [illegible] 25 42 [illegible] 32 2[illegible] 31 [illegible] 22 28 22 23 27
31 31
SH 609
WI
157
15 14 18 17 17 15 5 5 5 5 7 [illegible] [illegible] [illegible] 7 [illegible] 7 [illegible] 7 12 14 12 10 17 19
24 14 7 7 9 [illegible] 14 14 [illegible] 9 12 8 [illegible] [illegible] 24 14 14 [illegible] 15 16 14 14 15 7 8
18 9 10 10 17 16 15 18 19 7 9 [illegible] [illegible] [illegible] 13 [illegible] 15 [illegible] 5 7 5 9 8 10 15
13 6 6 10 16 [illegible] 15 14 14 11 [illegible] 17 [illegible] [illegible] 14 11 13 2 [illegible] 15 [illegible] [illegible] 16 13 15
15 13 11 14 8 [illegible] 10 8 7 6 6 7 8 [illegible] 10 11 9 [illegible] [illegible] [illegible] 8 7 12 14 14
14 11 10 11 10 13 12 [illegible] 13 11 13 20 [illegible] [illegible] 14 [illegible] 13 [illegible] [illegible] 9 14 [illegible] 17 13 [illegible]
16 10 16 12 13 [illegible] 12
SH 611
WI

16 19 16 12 13 12 12
SH 611
WI
C 862-1086,
225
8 9 8 8 9 9 7 8 8 6 10 12 10 14 11 9 9 16 11 9 8 10 10 11 11
10 9 9 7 7 11 7 8 8 8 7 6 6 9 9 9 10 8 9 10 11 12 9 9 10
12 8 6 8 7 9 11 9 11 11 8 7 7 13 7 10 10 9 7 9 8 7 9 7 10
9 10 11 9 10 8 5 6 8 9 10 9 8 9 7 9 8 5 5 5 6 7 7 7 8
8 10 8 6 9 11 13 8 8 8 8 9 8 12 11 17 11 12 14 12 16 15 12 14 13
14 14 18 14 17 15 17 20 15 17 20 15 18 14 15 14 16 17 12 19 17 17 13 10 14
17 18 11 12 6 12 11 9 13 14 18 17 10 10 12 11 8 7 11 7 9 8 9 12 12
12 11 12 19 15 14 9 9 11 10 13 11 11 9 11 10 10 8 13 9 6 13 12 11 13
11 11 9 8 7 12 13 12 9 9 9 10 10 10 11 11 12 9 11 7 9 10 8 11 8
SH 615
WI
74
20 19 21 20 12 14 18 15 13 15 10 14 16 8 21 26 23 12 17 17 12 13 10 12 12
17 30 36 7 10 9 7 14 12 14 15 7 9 13 18 19 17 17 12 12 16 10 11 12 16
13 17 17 9 13 14 17 17 12 18 18 15 20 31 19 20 15 17 14 9 13 9 10 9
SH 626
WI
141
19 18 13 12 7 5 5 5 6 7 10 9 8 8 10 10 8 11 9 12 8 11 10 12 11
12 11 11 10 11 9 12 21 14 16 13 12 12 9 10 8 10 12 12 12 11 11 10 10 12
8 11 13 8 10 9 11 10 10 15 13 9 10 11 9 10 7 11 12 12 10 11 9 8 9
10 9 12 11 16 11 12 9 9 10 10 8 9 9 7 9 8 1 9 9 9 9 9 8 10
8 10 13 8 11 10 8 7 11 9 12 10 7 11 10 11 9 8 8 7 7 7 8 8 7
8 5 8 7 6 7 6 6 6 7 6 6 5 5 5 5
SH 637
WI
C 1049-1122
74
22 29 20 33 25 18 37 35 40 35 49 26 41 17 25 22 15 16 23 24 21 15 12 16 14
10 13 14 11 12 13 10 7 16 13 10 9 12 8 14 11 10 9 14 13 10 9 10 14 11
9 12 10 11 12 10 9 8 11 11 10 7 9 11 11 9 10 10 7 11 8 10 7 11
SH640B
WI
C 963-1039
77
28 22 19 27 36 33 34 42 33 33 36 30 29 34 32 23 27 29 18 25 32 22 29 21 12
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28 24 23 16 23 28 18 17 25 27 32 22 20 9 19 22 21 24 17 19 14 14 26 17 22
19 19
SH 685
WI
C 1032-1089
58
15 24 36 34 32 32 27 21 25 15 26 17 25 21 20 21 29 21 19 29 21 21 26 30 30
20 25 22 29 16 25 14 32 20 33 33 34 28 21 22 25 28 21 19 26 26 33 31 31 22
25 31 21 30 21 13 25 27
SH 686
WI
C 982-1106
125
8 15 14 8 5 5 7 8 5 6 7 5 6 6 6 7 8 6 7 6 5 6 6 7 7
6 4 7 4 6 6 7 6 11 8 8 8 8 7 11 8 9 8 9 10 6 10 12 11
11 11 12 14 10 7 7 8 8 9 9 11 7 10 14 14 15 11 12 7 6 6 5 5 7
5 8 11 7 11 12 13 17 10 17 21 18 16 16 17 13 13 11 14 16 15 17 14 15 16
13 11 12 14 12 14 18 21 15 13 17 16 23 8 17 10 13 8 11 7 10 10 13 14 17
SH 629
STRAY
C 914-1054
141
19 15 23 30 40 30 30 24 24 22 24 12 21 15 15 14 10 6 24 19 17 16 12 13 14
23 15 20 11 19 23 20 20 26 17 15 13 13 12 20 21 22 10 10 12 18 13 15 12 13
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9 10 9 10 7 14 6 11 9 8 3 9 13 5 10 8 8 11 11 11 8 10 9 10
10 17 16 13 10 6 6 9 8 8 8 8 8 12 7 10