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TITLE Tree-Ring Dating of the London Waterfronts

Tree-Ring Dating of the London waterfronts.

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The series of waterfronts excavated recently at Seal House[1] and New Fresh Wharf[2] by the Department of Urban Archaeology provided many fine oak timbers for dendrochronological analysis. The aim was twofold: to date the structures absolutely by the matching of tree-ring sequences, and to evaluate the time relationship, whether relative or absolute, between timbers and between structures on the two sites. This in turn provides a record of the tree growth pattern over the centuries concerned, as a contribution to the reference curve being constructed for this area, and for the dating of timber excavated in the future.

This interim report discusses the results and dating of two sections of Roman waterfront (second century AD) and of three consecutive waterfronts of twelfth and thirteenth century date, by means of dendrochronological examination of the annual rings of the timbers. The methods used are standard for oak in Western Europe; the wood is frozen and surfaced, the annual ring-widths are measured in mm and the values are plotted as a graph for comparison and matching both visually and by computer[3].

1 Schofield, J. 1975 Seal House. Current Archaeology 49 54-57.

2 Schofield, J. & L.Miller 1976 New Fresh Wharf: I The Roman waterfront. London Archaeologist 2 390-395.

3 For further details of the method see:
Baillie, M.G.L. 1974 A tree-ring chronology for the dating of Irish post-medieval timbers. Ulster Folklife 20 1-23.
Fletcher, J.M., M.C. Tapper & F.S. Walker 1974 Dendrochronology - a reference curve for slow grown oaks, AD 1230 to 1546 Archaeometry 16 31-40.

The Roman waterfronts.

Timbers from two sections of the second century waterfront at Seal House and New Fresh Wharf, some 200m apart, were examined both for dating purposes and to confirm the evidence that they both were in fact part of the same structure. A waterfront of similar date at the Custom House site had already been examined and tentatively dated by Fletcher[4], and it was hoped to link this structure also by comparison of the growth rings.

New Fresh Wharf.

Excavation in Area III at New Fresh Wharf exposed a waterfront of horizontal timbers based on a sill-beam and held in place by braces and possibly piles. Cross-sections from thirteen of the major component timbers were sawn and examined, and were divided into two groups on the basis of average width and number of growth rings.

The first group of six large timbers included sill-beams and first-row beams as well as one cradling timber, most of which were oak trunks split in half and trimmed to a rectangular cross-section. They came from mature trees with 100 to 220 growth rings of 1-2mm average width. The ring-width patterns of all six could be synchronised and their relationship is shown in Fig. 1, each block representing the time span in arbitrary years covered by the growth rings of each timber (sample numbers can be related to the axonometric plan, Fig. 3, in the published report[5]), and hatching indicates the presence of outer sapwood, which is discussed below.

4 Fletcher, J.M. 1974 The Dendrochronology. in Excavations at the Custom House Site, City of London, 1973. T. Tatton-Brown Trans. LAMAS 25 211-215.

5 Schofield & Miller, 1976 op.cit. Fig. 3.

Several of the tree-ring sequences showed such a close correspondence in growth pattern that it is concluded they probably originated in the same tree or at least from trees growing adjacently. The two sill-beams 311 and 378 and first-row beam 236 may have come from the same tree; if so, the tree must have reached a diameter of over 800mm and an age of more than 260 years with a clear bole some 13m long, and the ring-widths and sensitivity suggest it must have grown under forest conditions on well-drained land.

Two of the timbers in this group have some sapwood remaining. Sapwood is the outer active zone of the tree, distinguishable by colour and structure in oak, and quite predictable in a mature tree at a width of about 25 rings. So even if only one sapwood ring remains on the wood, it is possible to estimate the year in which the tree was felled. Both timbers 378 and 321 retain almost their entire sapwood zone, that of the former being unusually wide, so the date of their final measured rings will fall very close to the year of felling.

The corresponding ring-widths for each year in the six timbers were averaged to give a mean curve of 262 years, part of which is shown in Fig. 2.

The second group of seven timbers consisted of complete trunks hewn to square cross-section, from younger and faster-grown oaks. These acted mainly as piles and braces, for which strength rather than size was required. The timber came from trees up to 100 years in age (i.e. relatively immature) and about 400mm in diameter, with ring-widths of 2-5mm. The differences in age and ring-width can make comparison with the mature timber difficult, and it is for this reason that they are separated.

Only three of the seven ring-width sequences could be matched together to provide a mean curve of 92 years, which also matches the longer mean curve between arbitrary years 190 and 281 (timbers 279, 326 and 386). A fourth was tentatively placed (timber

243 in Fig. 1). Three of these timbers have sapwood remaining, and the heartwood-sapwood transition lies in a similar position in all of them, indicating felling in the same year (the vertical dotted line in Fig. 1).

The remaining three tree-ring sequences matched neither with those mentioned or each other; the axonometric plan[6] shows that all three (timbers 190, 212 and 213) are vertical piles immediately behind the quayfront beams, which are only found at the west end of Area III, and are thus thought to serve some special function perhaps of supporting a four-bay building or crane on the edge of the quay. The tree-ring evidence confirms that they are not contemporary with the waterfront timbers and are not therefore an integral part of the waterfront; since they do not appear to be contemporary to each other, they probably represent random reused timbers inserted at a later date. A C14 date determined on timber 213 at AD 320 ± 70 (HAR 1421) tends to confirm this. The quality and length of their tree-ring sequences are likely to preclude absolute dating.

The New Fresh Wharf oak timbers thus provided a record of tree growth patterns over 262 years as well as determining relationships between individual timbers.

Seal House.

The second century waterfront was also briefly examined at the Seal House site[7] north of the three medieval fronts discussed in the second half of this paper. While the structure could not be recorded on this occasion, several timbers were collected and examined; subsequent building operations revealed a further 20m of the front

6 Schofield & Miller, 1976 op.cit. Fig.3.

7 Schofield, 1975 op.cit.

and showed it to be similar in construction to that at New Fresh Wharf with horizontal beams, scattered piles and braces[8].

Four out of five timbers provided long tree-ring sequences of up to 294 years, the oldest having some sapwood remaining. The three without sapwood (751 and 752, sill-beams, and 753, a third-row beam) matched well together, giving an average curve of 244 years; subsequent comparison with the 262 year New Fresh Wharf curve showed that both groups of timber had come from the same forest, for their growth patterns were almost identical (Fig. 2). However, in the absence of sapwood, it was impossible to prove that the two sections of waterfront were built in the same year; the key lies with timber 693 which is much slower-grown, and its growth pattern does not match well. It is tentatively placed in the best visual position in Fig. 1, which suggests that the two groups of timber were felled at the same time.

The correspondence of the New Fresh Wharf and Seal House curves (computer comparison gives Student's t = 9.96) allowed the averaging of all nine tree-ring sequences involved into a 282 year mean curve.

Dating of the Roman waterfront.

The next stage was to attempt to apply calendar dates to each growth ring of the trees involved, to find out the date of their felling. The presence of sapwood, at least on the New Fresh Wharf timbers, allows an accuracy in dating of about $\pm$ 5 years; there is no evidence of seasoning (distortion, dryness cracks), so it may be assumed that the wood was worked in a green condition, and there is thus little time lapse between felling and construction.

There are several methods of dating a floating tree-ring chronology; it can be compared to reference curves of the same period

8 Schofield, J. 1976 Seal House. London Archaeologist 2 401.

from other areas, or to floating or dated curves from the same area. If no correspondence is found by these means, or if dubious dating requires further confirmation, C14 dating of several wood samples from known intervals in the tree-ring sequence can be accurate to within several decades.

The waterfront curve was first compared to that for the Custom House timbers established by Fletcher[9], but only slight agreement could be found between the two, and it may be concluded that while they are probably of similar date, the sources of timber may be widely different. A tentatively dated mean curve exists for a well at Wederath in Belgium[10] covering the period AD 39-245 (while a complete reference curve has been established back to before 700 BC in Germany, a definite tree-ring link in the fourth century AD is proving difficult, and the absolute dating is based on the recorded construction date of the Cologne bridge in AD 310; it may therefore vary by several years.[11] The data of the reference curve has not yet been published.), and a possible match between the two (t = 4.03) may place the final ring of the New Fresh Wharf/Seal House curve in AD 151, or thereabouts, thus spanning the approximate period 130 BC to AD 150. With a small allowance for possible missing sapwood, the absolute date for the timbers may be AD 155 $\pm$ 5, which corresponds to the date of AD 150-180 based on archaeological evidence. However, it must be emphasised that this date can only be confirmed by comparison with the full German data and with further contemporary wood from the London area.

In the meantime, several radiocarbon samples have been cut from the timbers to provide a check on the dating of this waterfront and that at Custom House. Four samples come from 50 year intervals

9 Fletcher, 1974 op.cit.

10 Hollstein, E. 1972 Dendrochronologische Datierung von Hölzern aus Wederath (Belginum). Trierer Zeitschrift 35 123-5.

11 Hollstein, E. 1967 Jahrringchronologien aus vorrömischer und römischer Zeit. Germania 45 70-84.

(as shown by brackets at the base of Fig. 1) of the tree-ring sequence; knowing the time intervals between each sample and between the samples and the date of felling, it will be possible to estimate a much more accurate date for the waterfront than for one C14 date alone on wood of unknown age[12].

Complete details of the wood samples and the tree-ring curve will be published when the C14 results are available.

12 Fletcher, J.M. & R. Switsur 1973 North Elmham: the dating. Current Archaeology 36 25-28.
Ferguson, C.W., B. Huber & H.E. Suess 1966 Determination of the age of Swiss Lake Dwellings. Zeitschrift für Naturforschung 2 A 1173-1177.

The Medieval Waterfronts.

Three successive waterfronts of twelfth and thirteenth century date were excavated at Seal House[13], the latest being the southernmost and best preserved. These provided many fine oak timbers for dendrochronological analysis which enabled two of the waterfronts to be dated closely and the third to within decades.

Waterfront III.

This latest waterfront, dated archaeologically to the early or mid thirteenth century, consisted of sill-beams holding horizontal planks and supported by diagonal braces[14]. Seventeen of the timbers were examined, consisting of vertical posts, planks and braces. Two timbers (441 and 478) from an associated drain had already been examined by Fletcher[15], and showed exceptional dating qualities; they showed almost identical growth patterns to the German reference curve[16] between 1019 and 1193 (Fig. 3 and 4).

A further seven timbers from this waterfront could be dated by means of the German curve, and the years spanned by each are shown in Fig. 3. Two of the horizontal planks (387 E and D) came from the same tree, but otherwise there was enormous variety in average ring-width and sensitivity, suggesting that the timbers came from various sources. Two had some sapwood remaining; on one (568) it is possible that the outermost annual ring is preserved, which represents the year in which the tree was felled. The calendar year for this ring is 1219. However,

13 Schofield, 1975 op.cit.

14 Schofield, 1975 op.cit.diagram on p.56

15 Details kindly supplied.

16 Hollstein, E. 1965 Jahrringchronologische Datierung von Eichenholzern ohne Waldkante. Bonner Jahrbuch 165 12-27.

the felling date of the timbers for Waterfront III is given as 1220 ± 5 to allow for the possibility that this is not the case. All nine timbers appear to be contemporary, despite the loss of sapwood and up to 30 heartwood rings during manufacture.

Waterfront II.

The second waterfront, dated archaeologically to the late twelfth or early thirteenth century, was damaged and robbed, but probably consisted of oak planking slotted into vertical timbers[17]. Sections of 10 timbers were collected, including several wide planks with up to 184 growth rings. Four of the timbers had some sapwood remaining.

Again five of the timbers could be dated by means of the German reference curve (Fig. 3); the ring-width curve for one (497D) is shown in Fig. 4 in its synchronous position. The final rings of each timber cluster in date between 1135 and 1145, and the two with sapwood remnants suggest that the felling date and the year of construction of the waterfront can be estimated at 1160 ± 5.

Waterfront I.

The northernmost waterfront had been demolished, but sufficient remained to indicate sill-beam construction with vertical boards, dating to the mid twelfth century[18]. Seven sampled timbers included planks and the sill-beam, with up to 225 rings, but only one young example retained some sapwood.

Therefore, despite dating three of the timbers (Fig. 3), no accurate felling date could be obtained in the absence of sapwood. The last ring of the latest timber (609) falls in 1100, and to allow for

17 Schofield, 1975 op.cit. diagram on p.55
18 Schofield, 1975 op.cit. diagram on p.55

the complete sapwood zone, the timbers must have been felled after about 1125, probably soon after judging from the number of rings, the decreasing ring-widths and the date of Waterfront II.

Finally, a stray twelfth century timber (629 in Fig. 3) was also examined and dated; with its final ring formed in 1054, it must have been felled after c. 1080.

Discussion.

Eight corresponding tree-ring curves from individual timbers of all three waterfronts were averaged to provide a mean curve spanning the period AD 950 to 1193. The mean curve shows excellent agreement with the west German reference curve[19] (t=5.90), with the south German reference curve[20](t=7.76) and with a London curve derived from Westminster Abbey chests[21] (t=8.50), thus providing additional corroboration of the tree growth pattern over this period.

While conditions of growth must have been very similar both in south and west Germany and in south-east England over these centuries, there are significant differences in isolated years, when a wide ring in one curve may be replaced by a narrow ring in another. The two most obvious differences are in 1117, when the German curves show a wide or average ring and the English curves a narrower ring, and in the 1160's when a very deep trough (5 years of very slow growth) in the German curves is much reduced in the English curves.

However, the otherwise close correspondence between the growth patterns of oak in Germany and in England, and the absolute dating of the Seal House waterfronts as a result, is encouraging since it enables us to hope for equally good cross-dating in other periods and the quicker

19 Hollstein, 1965 op.cit.

20 Huber, B. & V. Giertz-Siebenlist 1969 Unsere tausendjährige Eichenchronologie durchschnittlich 57(10-150)fach belegt. Sitz. Österr. Akad. Wiss. 1 178 37-42.

21 Details kindly supplied by Dr. J.M. Fletcher of Oxford.

construction of an English reference curve extending back into Roman and prehistoric contexts.

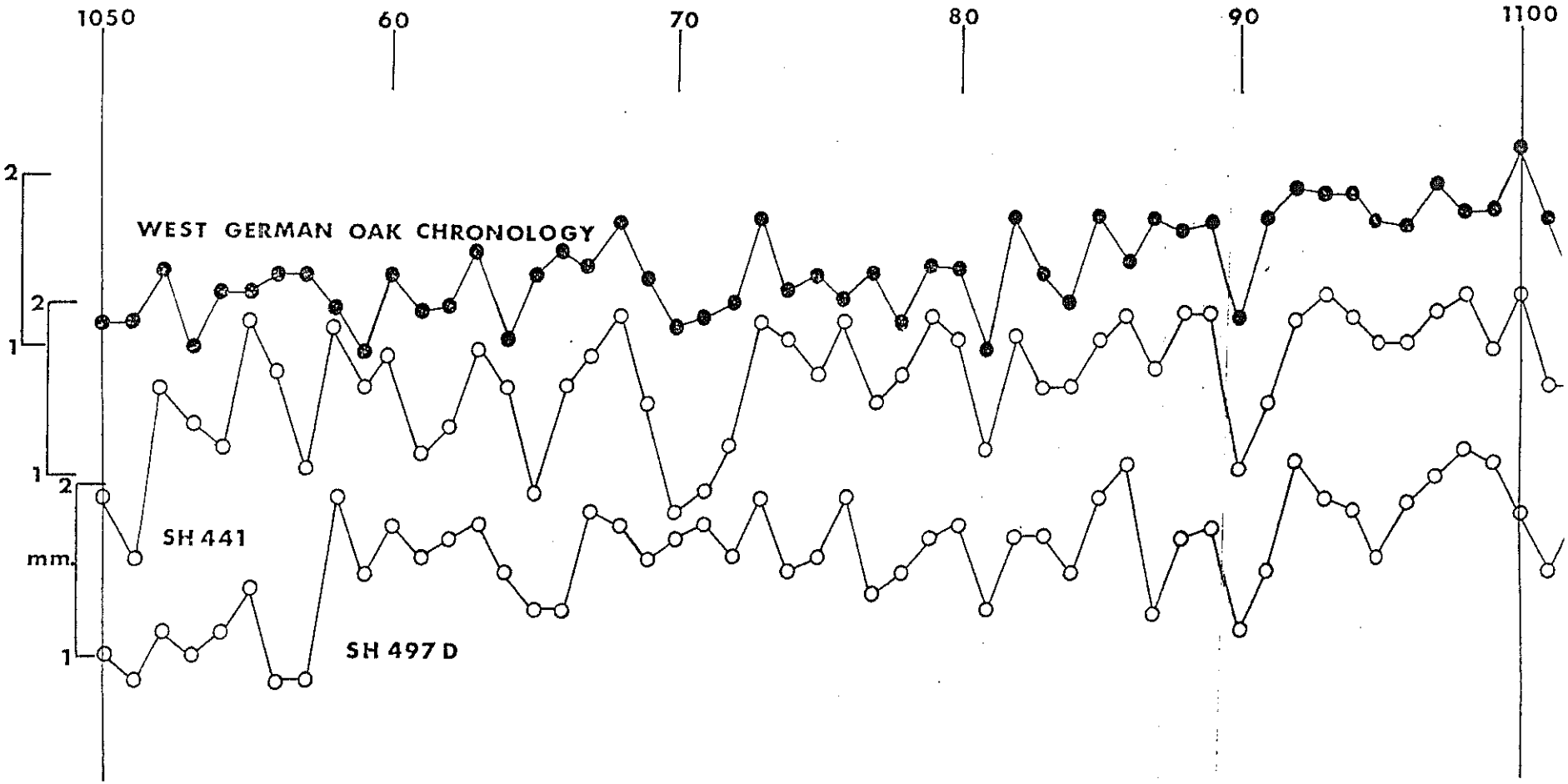
Legends to the figures:

Figure 1 — Block diagram showing the arbitrary years spanned by each timber of the Roman waterfronts at New Fresh Wharf and Seal House. Hatching indicates the presence of sapwood which allows an estimation of the felling date (vertical dotted line) and construction date. The scale in arbitrary years may correspond approximately to 130 BC to AD 150; dating is being checked by four C14 dates from positions shown by brackets at the base.

Figure 2 — Part of the mean tree-ring curve for the New Fresh Wharf timbers (open circles) and for the Seal House timbers (solid circles) between arbitrary years 139 and 204. The scale is logarithmic in mm.

Figure 3 — Block diagram showing the calendar years spanned by each timber of the three Seal House waterfronts with estimated construction dates on the right, based on sapwood remains on several timbers.

Figure 4 — The west German oak chronology, built up by Hollstein, between 1050 and 1172 compared to the growth pattern of timber 441 (Waterfront III) and 497D (Waterfront II).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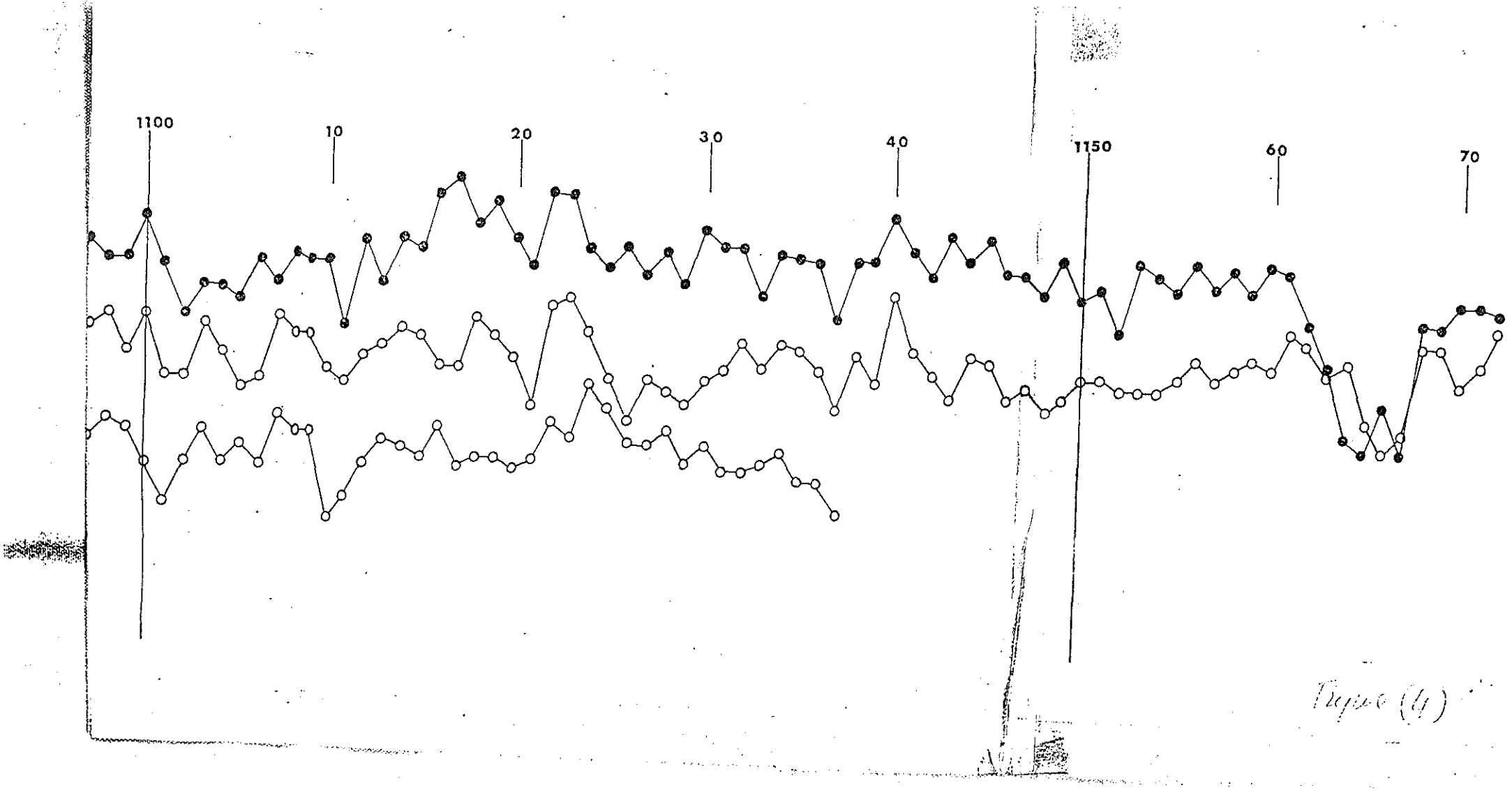
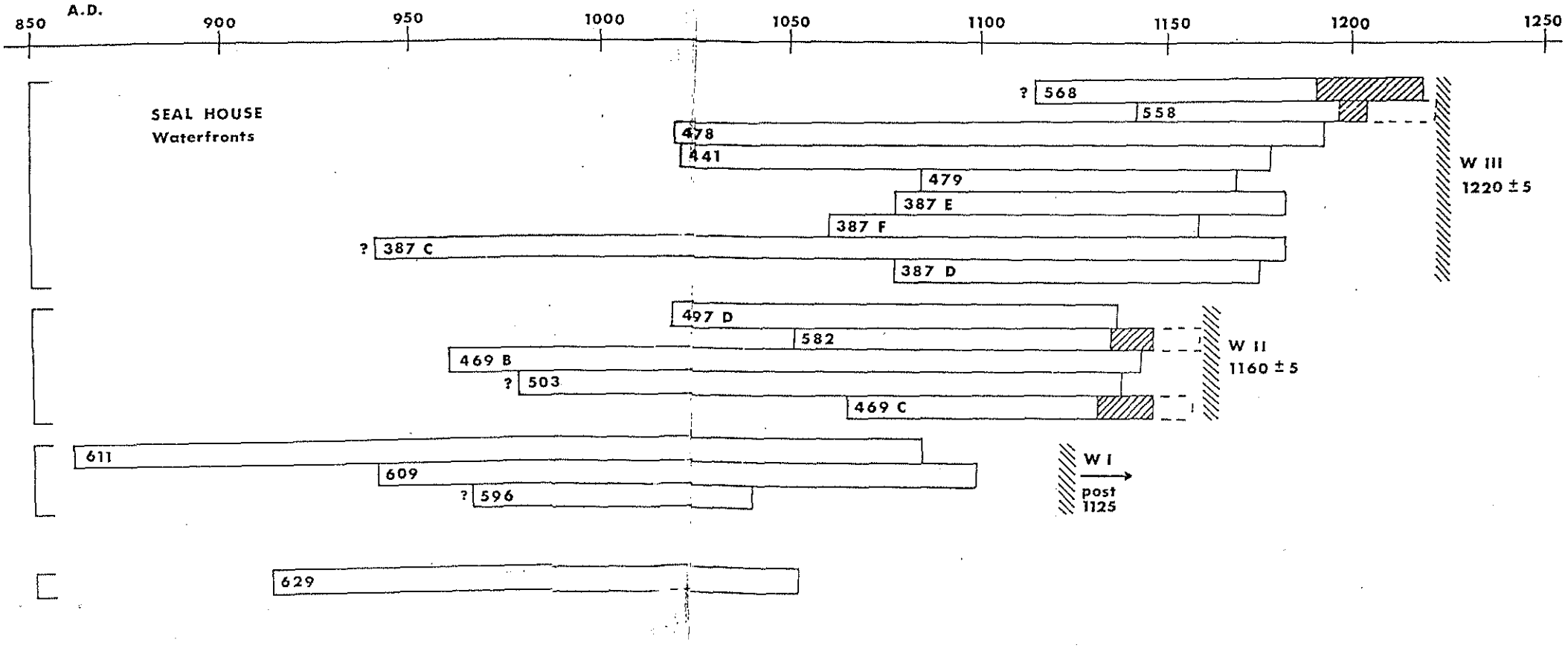


Figure (4)


A.D.
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Waterfronts
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479
387 E
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W III
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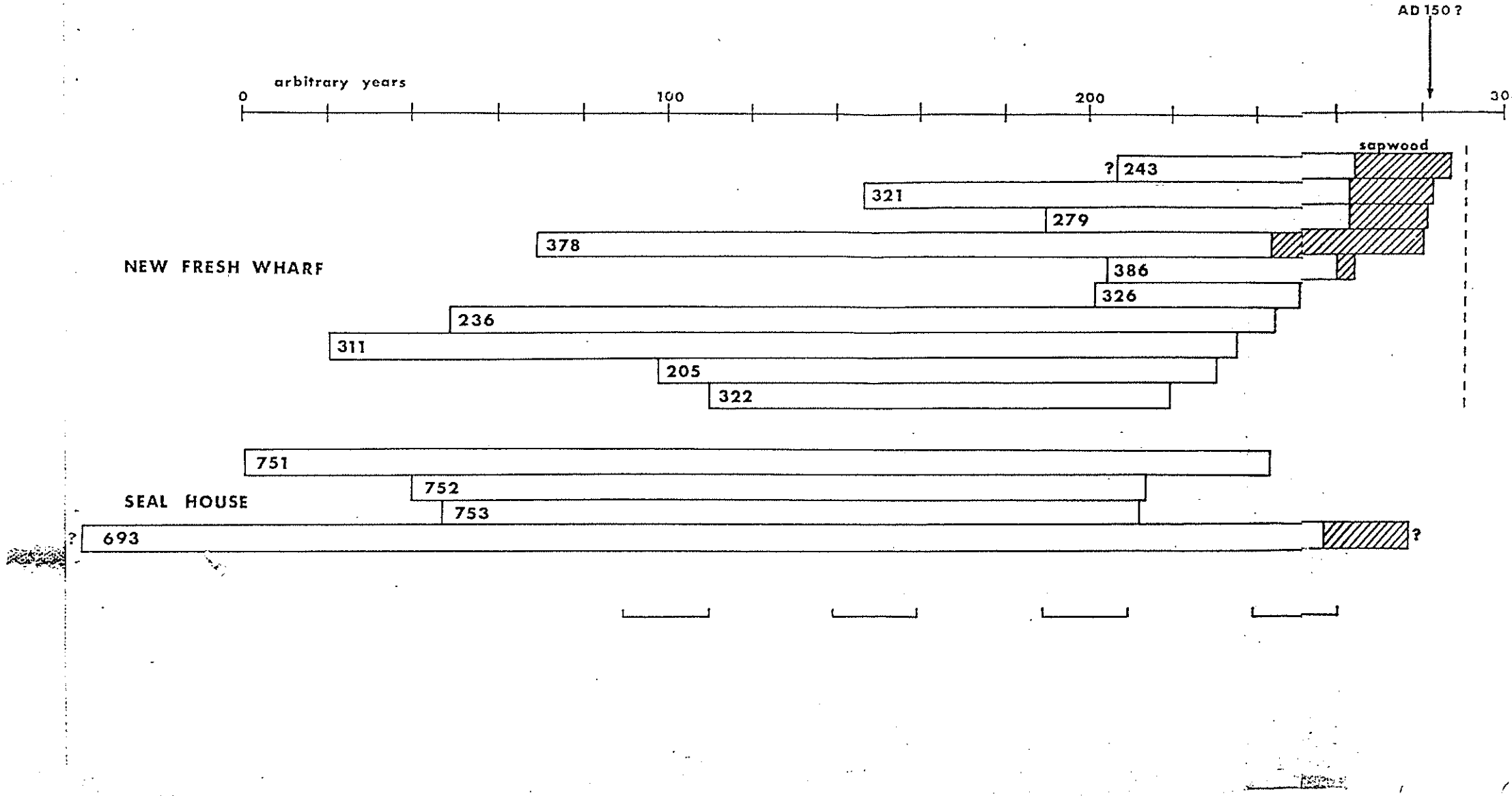
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SEAL HOUSE
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Figure 2)