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SUPPLEMENT 47

ISTANBUL AND WATER

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TABLE OF CONTENTS

THE SOCIAL IMPACT OF WATER IN OTTOMAN TIMES

THE AESTHETICS OF WATER

OF HARBORS AND TREES: THE MARMARAY CONTRIBUTION TO A 2367-YEAR OAK-TREE-RING CHRONOLOGY FROM 97 SITES FOR THE AEGEAN, EAST MEDITERRANEAN, AND BLACK SEAS

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INTRODUCTION

This report presents the partial results of thirty-eight years of effort at building a continuous oak tree-ring chronology for the Aegean and neighboring regions. So far, since we collected our first samples there in 2005, the excavations of the Marmaray Project have yielded 1461 years' worth of oak tree-ring chronologies from 35 units shown in the date list below, in reverse chronological order, with their numbers and captions in bold font (most of them *iskele*s [docks] at Yenikapı). They cluster in three long sequences: six chronologies from AD 1205 to 1808 (603 years), twenty-six chronologies from AD 410 to 911 (501 years), and three chronologies from AD 51 to 382 (331 years). Interspersed among these sequences we also include chronologies from 62 other sites which overlap the gaps between these groups so that we are able to present the Marmaray material as part of a continuous 2367-year oak chronology. As of June 2011, of the more than 2100 samples measured from the Marmaray Project alone, 295 have been dated. As the measuring continues, no doubt many more Marmaray pieces and the units from which they were retrieved will be dated, too. Thus, this paper must be considered a preliminary date list, subject to modification, interpretation, and refinement as the work progresses.

The Marmaray Project — a massive 5-billion-dollar, 39-kilometer-long transit system, designed to relieve the congestion caused by millions of daily commuters in modern-day

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The datasets presented in this paper represent the cumulative efforts of some hundreds of students over the last three decades, and some 50 have collected, prepared, measured, and analyzed the Marmaray samples. We gratefully acknowledge that this text would not have been possible without their contributions. In particular, we thank LeAnn Canady and Kayla Altland who between them have measured over 1000 radii on Marmaray project samples alone, Doğan Perinçek whose tsunami hypothesis inspired much fevered tree-ring measuring, and Maryanne Newton, Hope Kuniholm, and Christine Latini for their work years ago on the non-Marmaray material. We also thank Ariel Aicher, Sam Fuller, Perri Gerard-Little, Jessica Herlich, Ryan Hunter, Brita Lorentzen, Alison Petrucci, Sarah Johnson, Kate Seufer, Sarah Simpson, Xan Stepp, Jennifer Watkins, Becky Wrench, Rebecca Wall, and other members of the project. At the Cornell Lab we thank Mary Jaye Bruce, Peter Brewer, and Sturt Manning. At Yenikapı we thank Zeynep Kızıltan, Mehmet Ali Polat, Filiz Yalçındağ, and Sırrı Çölmekçi. For geological discussions we thank Oya Algan and M. Namık Yalçin.

Istanbul — has unearthed tens of thousands of objects (33,000 registered as of 2007),[1] including many wooden constructions and shipwrecks. Most of these finds have come from the location of the central station for the planned network at Yenikapı, the area of the former Theodosian harbor where, in antiquity, the Lykos River reached the Sea of Marmara.[2] At this location an enormous excavation measuring some 600 by 800 m has been opened on the edge of this city, and 23 m of cultural layers have been excavated, uncovering over 8000 years of Istanbul's past.

Over 2100 wood samples, most commonly pilings from *iskele*s (docks), with excellent potential for dendrochronological dating have been retrieved from the combined Marmaray and Metro Project Excavations at Yenikapı, Üsküdar, Sirkeci, and Vezneciler. Most of the Marmaray timbers were collected in groups representing definite construction units (usually *iskele*s), some very well represented by as many as 28 dated samples, others by as few as a single one.[3] Some of the *iskele*s were built as single constructions, others in as many as four distinct phases over a period of 83 years from 527 to 610. In one notable instance pilings were inserted into an existing *iskele* randomly over a 135-year period in the fourteenth and fifteenth centuries.

The wood samples represent different periods — from fourth-century sea-walls and harbor *iskele*s to nineteenth-century basements of pumping stations — but building activity was not continuous, and natural hazards like earthquakes, storms, and possibly even a tsunami have obliterated many phases of construction. To this is added the fact that use of the harbor decreased and increased in different time-periods; the result is a series of gaps in the material available for continuous dendrochronological dating.

In order to fill these gaps we had to look outside the Marmaray Project timbers to a range of non-Marmaray sites. Some of them were sampled as far back as 1974, but, although long since measured, have remained undated because of the lack of a master chronology to which to attach them.[4] The reader will note that two-thirds of the sites in the following date-list are non-Marmaray (see in **Fig. 14** the bar-graph where non-Marmaray sites are shaded in grey scale). Some are as important as Hg. Sophia or Hg. Eirene, while others are little more than holes in the ground (well-linings or mill foundations or pieces of harbor debris), the latter more often than not unpublished. Thus without the Marmaray contribution, this long, continuous oak-tree-ring chronology could never have been assembled, and *vice versa* — without the previous work, the Marmaray wood could not have been placed in a coherent sequence. Happily for us, it is now all coming together into a tentative chronology, which we present here.[5]

[1] For the most substantial and comprehensive overview to date, see Kızıltan 2007.

[2] For the topmost levels before excavation began, see Müller-Wiener 1994, p. 1, fig. 1, and Pl. 1–4; for the commercial installations including the neighboring *Horrea Alexandrina*, see Magdalino 2000, p. 212; Mango 2000, fig. 4. In contrast, see the photographs of the excavated area in Kızıltan 2007, pp. 11, 167.

[3] Dating single samples — from anything — is always risky since one cannot tell from internal evidence whether the wood is primary, reused, or a repair.

[4] Kuniholm and Striker 1987. This report was a listing of sampled sites and approximate numbers of rings counted, but with no dates before 1297.

[5] We accompany as many of our 97 data sets as possible with a skeletal, explanatory bibliography. A fully detailed consideration of the architectural or historical significance of these dates must wait for a later time, after the Marmaray wood is completely measured and all placements are confirmed.

When the work is complete, and after we have had a chance to go over the electronic plans with the excavators and the architects, it should be possible to draw — at least in rough outline — the changing shoreline of Yenikapı or the Theodosian Harbor of Constantinople over the centuries. Although this preliminary report discusses primarily the dated wood elements, the final Marmaray report will have to take into account the thousands of archaeological artifacts that are being studied concurrently by other groups.[6]

In addition to the dating of the specific units listed below, we have already discovered that wood was being imported to Constantinople from all over the Roman/Byzantine Empire, from as far west as Greece or Italy and the Adriatic, and from as far east as the Black Sea — even up the Danube River for at least 100 km, if not further.[7] For the moment we can point out only some of the most obvious examples. The full analysis of timber imports and exports will take much more time (months, if not years) than we have available for this preliminary report.

The Dendrochronological Method

Dendrochronology consists of measuring the annual rings of trees — in this report, oak — and then matching the resulting ring-patterns so that a specific ring can be assigned to a specific calendar year.[8] In highly schematic form the method looks as in **Fig. 1**.

As with all schematic illustrations, some of the details in **Fig. 1** are misleading. The image makes it appear that wood is available in both quality and quantity in all periods. This is not so.[9] Several years ago we had much more wood from the Middle Bronze Age than we had from the Roman period.[10] Moreover, the enthusiasm of the artist makes it seem across the top of the image that we are trying to match rings from different species of trees. Sometimes this is possible, but most of the time it is not. Thus we have tried to keep our sequences separate — species by species, as shown in the bar-graph in **Fig. 2** — until the chronologies are complete.

The procedure in this laboratory has been to make a smooth surface on the cross-section of the wood, either with fine sandpaper or with a razor-blade, so that each ring can be measured under a traversing binocular microscope to the nearest 1/100mm.[11] Each radius from pith to bark (where possible) is measured by at least two workers independently of one another, and then the measurements are reconciled. On some of the more difficult samples

[6] Kızıltan 2007, *passim*, with contributions by 41 authors.

[7] See Kuniholm 2000, pp. 99–100, for an instance where evidence for nineteenth-century timber imports to Istanbul from both the Black Sea and Thrace first came to light at Karaköy — a foreshadowing of what we would find at Yenikapı; see also Kuniholm et al. 2007, pp. 380–381.

[8] For a brief outline of the technique, see Kuniholm 2001. An online copy is available at http://dendro.cornell.edu/articles/kuniholm2001a.pdf

[9] Hollstein 1980, p. 11; Kuniholm and Striker 1987, p. 391. Both the Rhineland and the Aegean have the same uneven distribution of sample quantity in various periods.

[10] Although there are quantities of Roman buildings around the Mediterranean, most are built of stone, and the beam-holes are empty. A casual stroll past the Baths of Caracalla or Diocletian in Rome will reveal vast numbers of beam-beds, now filled with little more than the occasional pigeon nest.

[11] Stokes and Smiley 1968; see also http://dendro.cornell.edu/

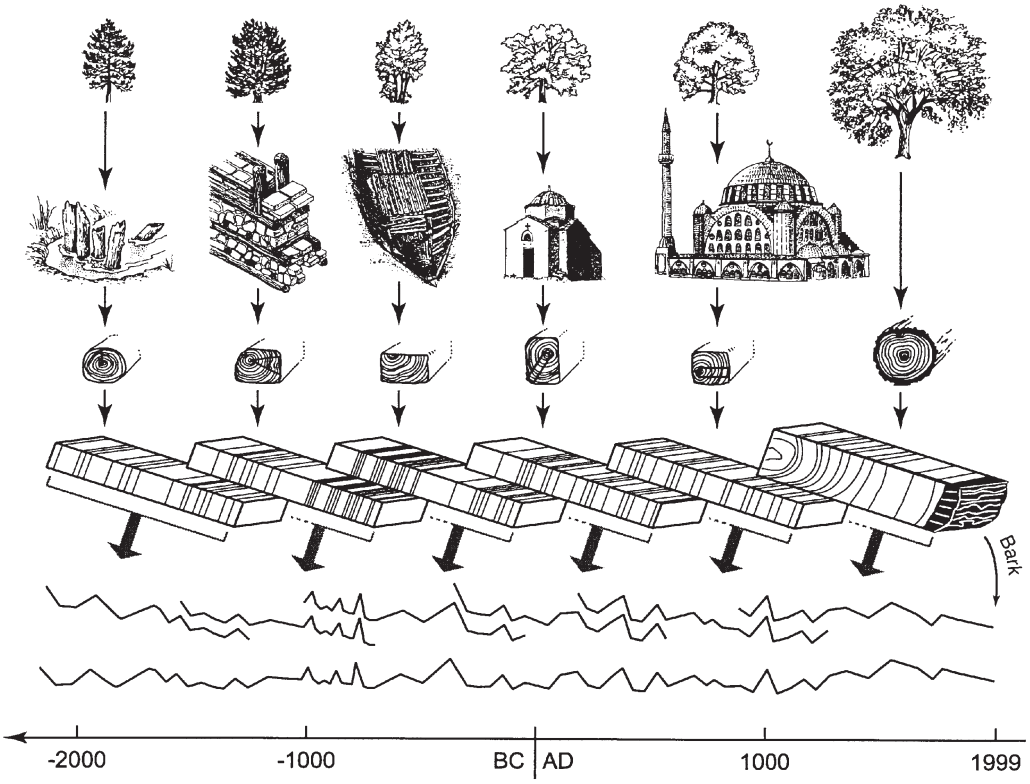


Fig. 1. Schematic drawing of how a tree-ring chronology is built, from a living tree with a known date for its final ring under the bark, back — with overlaps from specimen to specimen — to Antiquity. Source: Aegean Dendrochronology Project.

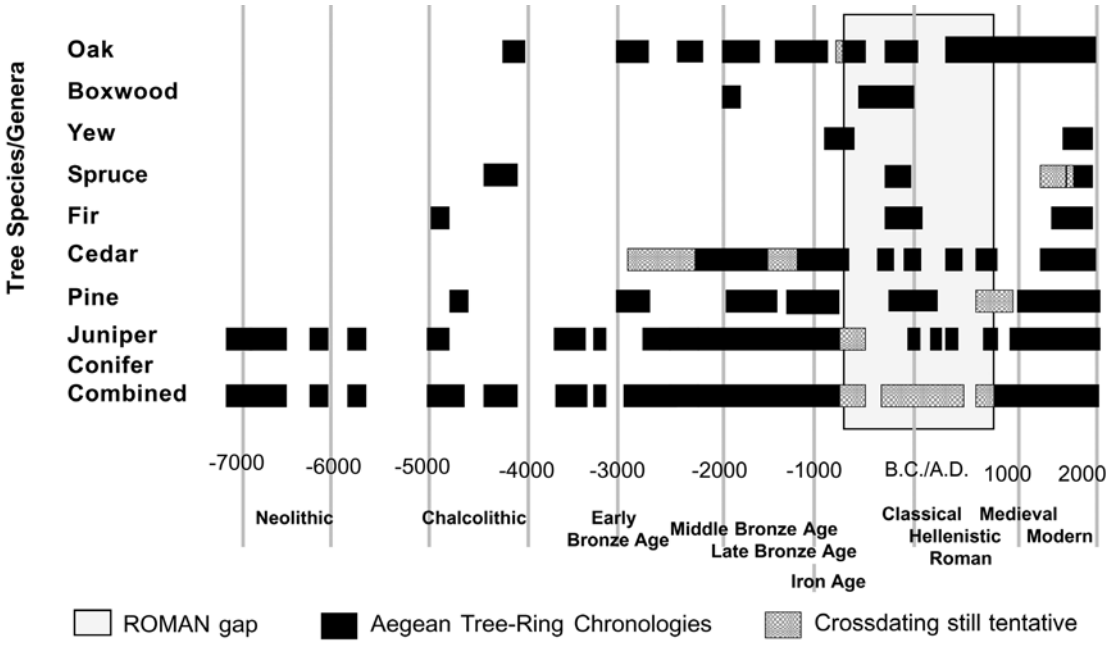


Fig. 2. Bar-graph, broken down by species, of the Aegean Dendrochronology Project's chronologies from the present to the Neolithic. Until the gaps between the early end of an absolute chronology and the beginning of another floating one are filled in, estimates — usually based on radiocarbon wiggle-matching — provide an approximate placement. This paper addresses the oak chronology for the "Roman Gap" shown as a hollow box on either side of the AD/BC transition. Source: Aegean Dendrochronology Project, C. L. Pearson.

as many as four radii have been measured and then combined. The method of crossdating is primarily visual. Thus, raw growth readings have been converted to indices so that the large interior (young) growth rings of one sample may be compared with the small exterior (old) growth rings of another. Visual analysis is cross-checked by a battery of statistical tests, the most useful of which is the so-called Student's *t*-test.[12]

The condition of the exterior of the wood sample is crucial to interpretation. Aegean oaks, which seem to have been the wood of choice for both Byzantine and Ottoman carpenters, have on average 26 +/-9 sapwood rings,[13] but at Yenikapı more usually 16 to 26 sapwood rings, depending on the age of the tree. If the bark is present or the waney edge — an Anglicism for the terminal ring immediately under the bark and noted in our date list as WK (for the German *Waldkante*) — then the cutting year is known. If a number, but not all, of the sapwood rings are present, then an estimate for the cutting date must be made.[14] Fortunately for the purpose of this paper the practice in both the Byzantine and Ottoman Aegean seems to have been to cut the wood and then use it immediately. Where we have inscriptionally or historically dated buildings with wooden elements that include the bark or waney edge (WK) preserved, the maximum elapsed time between cutting the wood and using it is generally one year. On many of the Marmaray samples the ring underneath the bark is complete, indicating that the wood was cut during the winter when there would have been no leaves to impede the work of the woodcutters. At Yenikapı, where the vast majority of our samples are oak pilings for *iskele*s (docks), there would have been no need to season the wood for any length of time. Thus it is a reasonable assumption that the wood was put in place during the summer following the year of cutting.

We present below our preliminary date list of both Marmaray and non-Marmaray samples. The list runs in reverse chronological order and may be navigated via the number and (usually) three-letter site code (*e.g.*, 2: BEK) shown in the bar-graph of the complete sequence in **Fig. 14**.

[12] Baillie and Pilcher 1973. For the trend-coefficient (German *Gleichlaufigkeitswert*), see Hollstein 1980, pp. 17–24. A practical combination of these two tests as a highlighting or exploratory guide is the so-called D-test (Schmidt 1987), used to identify possible crossdates for visual investigation. Correlation coeffients, or *r*, are a standard statistical method. A non-statistical WJ test (*Weiserjähre* or signature years) was a verbal suggestion by F. H. Schweingruber that we should look for years in which the variations in the rings of the sample being analyzed matched the variations in 80 percent or more of the available contemporary samples.

[13] Kuniholm and Striker 1987, pp. 390–391. Well over 99 percent of some thousands of timbers we have sampled from Byzantine, Meta-Byzantine, and Ottoman buildings are oak. See also Griggs et al. 2009, p. 76, fig. 3.

[14] We use the University of Arizona notation convention for wood that is lacking the bark. The letter *v* means there is a subjective reason for thinking that the last preserved ring is near the bark (and that very few rings are missing from the exterior). The letters "vv" mean that an unknown number of rings are missing. Elevations are marked with a ▼ indicating the level of the tops of the pilings above or (-) below sea-level. The sign + means that the last ring, although present, could not be measured.

A 2367-YEAR, 97-SITE OAK CHRONOLOGY[15] FOR THE NORTHEASTERN MEDITERRANEAN FROM AD 2004 BACK TO 357 BC

(1) *Aegean Oak Master Chronology for the Second Millennium*

AEG.OAK.2011: Oak from 9 forests and 62 buildings spanning the better part of ten centuries was selected for this paper from well over 1000 samples representing a total of 22 oak forests and over 232 dated medieval and post-medieval buildings in Turkey, Greece, and the former Yugoslavia. This chronology — represented by a single line in the bar graph at the top of **Fig. 14** and counted as only one chronology in this date list — has been in place, although with many new samples added, for a number of years.[16] It is complete from bark in 2007 back to 1068.

(2) *Samsun, Kavak: Bekdemir Mosque*

BEKS01: 39 samples. The chronology runs from 1089 to 1876Bark. The Bekdemir Mosque, with its extraordinarily long-lived timbers,[17] served as a check on the correctness of the placements of some 61 second-millennium chronologies before 1600.

(3)[18] ***Istanbul, Yenikapı: Five-Sided Structure in Grid Square LM-6-8***

Twelve samples, including YMK-290, 292, 293, 297, 298, 301, 327, 402, 403, 408, 452, 453. This was probably the base of a windmill, as shown in the *Liber Cronicarum*, the so-called Nürnberg Chronicle of 1498 (**Fig. 3**). Terminal rings in several levels (possibly 7 phases) range from 1706 to 1808v. The chronology runs from 1570 to 1809+v, with 25 sapwood rings. Elevations are for level 3 ▼-0.67 m; for level 5 ▼-1.80 m; for level 6 ▼-2.00 to ▼-3.00 m; for level 7 ▼-2.36 m. The samples were collected in 2006.

(4) ***Istanbul: Metro, Vezneciler, Evre III and IV***

Ten samples: VZN-1, 2, 3, 11, 12, 13, 14, 15, 16, 17A, 17B. The chronology runs from 1551 to 1781Bark. We were presented with the Vezneciler wood in two piles, already removed to the side of the excavation, one pile said to be from Phase III, the other from Phase IV. There was no discernible time-difference between the two phases. The samples were collected in 2006.

[15] See the bar-graph (**Fig. 14**) at the end of this report.

[16] See Kuniholm and Striker 1987; Kuniholm 1996; 2000; see also the Annual Reports of the Aegean Dendrochronology Project, available at http://dendro.cornell.edu/reports.php.

[17] Kuniholm 2000, pp. 97–99.

[18] Bold font indicates new findings from the Yenikapı excavations. YMK=Yenikapı Marmaray, YMT=Yenikapı Metro, VZN=Vezneciler, UMK=Üsküdar, SMK=Sirkeci. As of 5 May 2011 we have 36 chronologies, adding up to some 1461 years' worth of chronologies in three large blocks. The dates reported here are so new that we do not yet know how our "news" will be received by the respective excavators and trench masters.

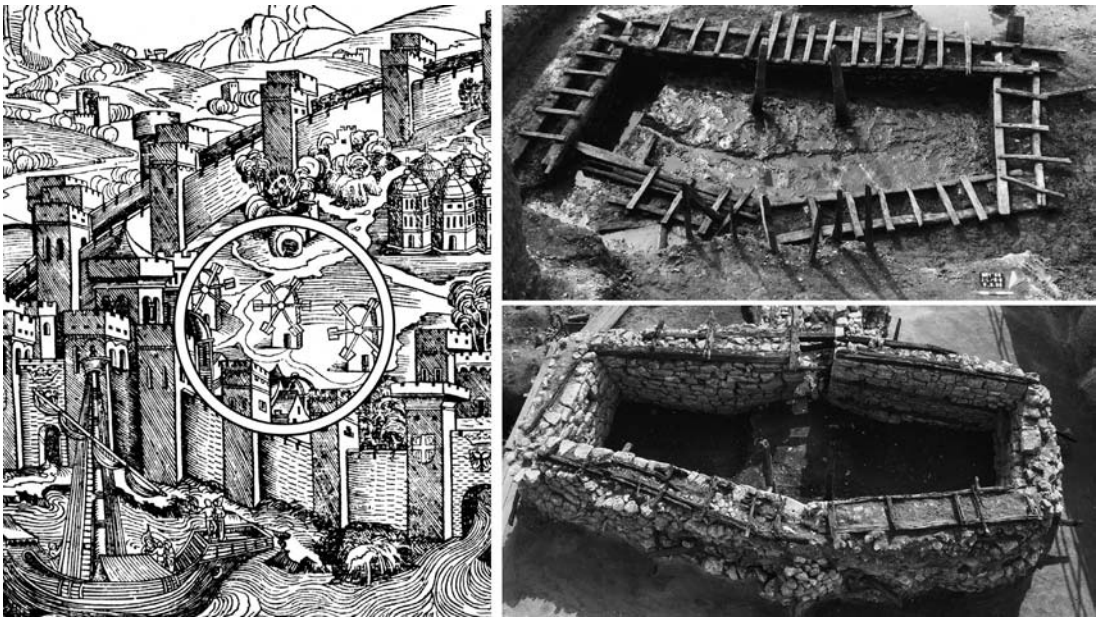


Fig. 3. Windmills at Yenikapı shown in the *Liber Cronicarum* (Nürnberg Chronicle) of 1498 (left), and two later five-sided structures (#3 above and #5 below) in the *Bostan Kuyusu* ("well of the cabbage garden") at Yenikapı, presumably the bases of similar windmills from the eighteenth and nineteenth centuries (right). Source: Aegean Dendrochronology Project, Istanbul Archaeological Museums.

(5) ***Istanbul, Yenikapı: Second Five-Sided Structure in Grid Squares LMN-137-138***

Five samples: YMK-1974, 1976, 1983, 1984, 1986. This was probably the base of another windmill (**Fig. 3**), but in contrast to the multi-phase structure in No. 3 above it was a single build. The chronology runs from 1656 to 1762vv with no sapwood, so one needs to add the usual sapwood increment. Elevations are ▼+0.35 m to▼-0.27 m. The samples were collected in 2009.

(6) ***Üsküdar: UMK-All Elements***

Fourteen samples: UMK-6, 12, 14, 15, 16, 17, 18, 20, 22, 28, 29, 32, 33, 34, from a variety of contexts. The chronology runs from 1205 to 1728+v. The constituent parts are as follows: UMK-15, 16, 17, 18, 20, 22 (1728+v) from a double-box construction abutting an east-west stone wall in grid square A-6/68–70; UMK-32–33 (1717v) from pilings under a late east-west wall in grid square I/69–70; UMK-6 (1694vv) in grid square; I/65; UMK-34 (1658vv) from the foundation of a late northwest-southeast wall approximately 10 m south of the church in grid square B/C-72; UMK-14 (1527+vv) from the east-west Ottoman wall in Grid Square A-6/68; UMK-12 (1404++v), a timber recovered from grid square I/58; UMK-28–29 (1370vv) from the late wall east of the bema of a twelfth-century church foundation in grid squares A/1 to E/66–72.[19] The samples were collected in 2006.

[19] Kızıltan 2007, p. 41, fig. 10. See the dog-legged wall extending east of the northern wall of the naos at the top of the photograph. Some of these Üsküdar samples were presented to us with only their grid squares recorded.

(7) ***Istanbul, Yenikapı: Ottoman Well in Grid Square 2Ic3***

Three samples: YMK-545, 546, and 654. The chronology runs from 1349 to 1545WK.[20] One element has the waney edge in 1531, so the wood was either re-used, or the well has more than one phase. Elevation is ▼-3.00 m for the bottom of the well. The samples were collected in 2007.[21]

(8) ***Istanbul, Yenikapı: İskele in Grid Squares H23, I21, J23, and N2***

Twenty-one posts: YMK-2, 4, 6, 10, 11, 13, 16, 17, 18, 19, 21, 22, 23, 25, 26, 27, 28, 29, 31, 32, 33. Elevations are ▼-0.80 m to ▼-1.25 m. Fifteen posts show a profile from Northern Greece. Five posts show a Black Sea profile. The chronology runs from 1248 to 1446+v. Cutting dates range from 1321 to 1446, showing that the dock was repaired over a 135-year period. One of the posts was driven through the planking of a ship some 3 m beneath, dated on the basis of its naval architecture to around 1000 by Cemal Pulak. The samples were collected in 2005.

(9) *Priština (Kosovo): Gračanica Monastery, Early*

GRAEARLY: 13 samples. The chronology runs from 1073 to 1297vv with possible sapwood beginning at 1286. Supporting information is the inscription on the lintel: we know that the church was built by King Milutin in ca 1321;[22] thus a full sapwood allowance would place the cutting of the wood just before the time of the dedication of the church.

(10) *Trabzon, Kuştul: Şimşirli (Hg. Giorgios Peristereota Monastery)*

KUS-2AB, 6, 10. The chronology runs from 1018 to 1171vv,[23] with no sapwood (see No. 19 below). This would be from the early monastery, predating the removal of the monks in 1203. The foundation date for the monastery is thought to have been 752.

(11) *Bursa, Mudanya: Kurşunlu Kilise (St. Albercius)*

KUR-555, five samples. The chronology runs from 1061 to 1156vv, with 4 sapwood rings; thus there is a need to allow for the missing sapwood component. The church was built during the reign of Manuel I Komnenos (1143–1180).[24]

[20] Wood from the bottom of this well was reported in December 2010 as coming from the eighth century, but this early placement, although it still looks valid, was not confirmed by radiocarbon-dating. Since that time Carol Griggs and Tomasz Ważny have found excellent fits for the well-lining with niche sites in Eastern Thrace.

[21] Parallels for this kind of timber transport are also to be found in the imported Italian Alpine larch that forms the rafters of Hg. Paraskevi in Chalkis, Euboea (Kuniholm et al. 2007), and in repairs to the roof of al-Aqsa Mosque in Jerusalem (Lorentzen et al. in preparation). More recently there is evidence for imported Ottoman oak in the Church of the Nativity in Bethlehem (Bernabei and Bontadi 2012).

[22] Ćurčić 1979, pp. 12–17; 2010, pp. 664–666.

[23] Bryer and Winfield 1985, pp. 271–272; pl. 198.

[24] Ramazanoğlu 1955, p. 441, cites a *typikon* of 1162 for St. Albercius.

(12) *Pherrai: Kosmosoteira, Primary*

Two samples: PHE-8 and 15. Two cores were drilled from the dome window tie-beams.[25] The ring-sequence runs from 1004 to 1121vv with no sapwood. The date given in a Komnenian *typikon* is 1152. Allowance for 26±9 years of missing sapwood would put the bark at that date. For other supporting information, the radiocarbon date for the last ring is 1140±20 at 1 sigma. The overlap with Gračanica is short, but there are confirming dates for earlier structures.[26]

(13) *Istanbul: Pantokrator, West Face of the Center Door from the Narthex to the Naos of the South Church*

PAN-11A. This is from the lunette filling above the marble door frame. The ring-sequence runs from 953 to 1100v, with 28 sapwood rings. This is thought for stratigraphic reasons to be primary, but is sufficiently different from other primary members (PAN-3, 6, and 7) below, so that it has been kept as a separate data set. The dendrochronological date is fine for the primary construction. This was probably an import.

(14) *Istanbul: Kariye Camii (Church of St. Savior in the Chora), Early*

KAR-9, 10, 11, 12. The chronology runs from 922 to 1080Bark. Four unlabeled samples were recovered from the storage room north of the South Parekklesion, presumably left behind by Paul Underwood and his colleagues two generations ago. They are possibly attributable to the work carried out between 1077 and 1081 by Maria Doukaina, mother-in-law of Alexios I Komnenos.[27]

(15) *Istanbul: Pantokrator, Lintel System of Door No. 3 from the North in the South Church*

Three samples: PAN-3, 6, 7. The chronology runs from 977 to 1070vv with two sapwood rings present. The church is thought to have been built between 1118 and 1124.[28] A radiocarbon sample was sent to Heidelberg in December of 2005. We have a confirming date of 953 +/- 17 BP for ring 5.

[25] See Ćurčić 2010, pp. 408–409, fig. 445–447.

[26] For example, a timber in the bema of Panaghia Chalkeon in Thessaloniki (TPX) ends in 1027+bark (*i.e.*, the wood was cut in the winter of 1027/1028). The inscriptional date is 1028. We have excluded TPX from this list because the wood is chestnut (*Castanea*). The usual "cut it and use it" convention for the Aegean applies.

[27] Oates 1961, p. 230. Robert Ousterhout agrees with our interpretation. For an image of some of the eleventh-century marble veneer, see Ćurčić 2010, pp. 539–542, and fig. 613. The window tie-beams visible above the veneer are from the early fourteenth century.

[28] Müller-Wiener 1977, p. 209.

(16) *Ohrid: Sv. Sofija, Primary Chronology*

Eighteen samples: OHS-25, 42–45, 47–50, 60, 63, 69, 71, 73–75, 81, and 82. The chronology runs from 895 to 1052vv, possibly a part of the eleventh-century rebuilding by Archbishop Leo (1037–1056).[29] Ten sapwood rings are preserved. Proveniences include: the south nave arcade; the south aisle door lintel in the esonarthex; the north aisle door lintel; the blocked windows in the east wall of the exonarthex; the stumps of the east-west tie-beams originally spanning the long transverse barrel vault; the east wall soffit system in the exonarthex; the lintel system at the base of the stairs leading to the narthex gallery; the stair tower to the north of the esonarthex; the esonarthex gallery; and the north-south tie-beams in the triple-arched window to the naos. Our existing Balkan oak-tree-ring chronology for the eleventh to fourteenth centuries begins only in 1073. Thus, until the addition of the Yenikapı material to our data base, the Sv. Sofija primary chronology was undatable.

(17) *Enez/Ainos: Hg. Sophia*

Seventeen samples: ENZ-1, 2, 4, 5, 7, 9–20. The chronology runs from 814 to 1050v with 23 sapwood rings plus possibly one unmeasurable ring at the end for 1051. The radiocarbon date for the end ring is 1038±15 at 3 sigma. The recessed-brick masonry is thought to be a feature of the eleventh and twelfth centuries in Constantinople.[30]

(18) *Thessaloniki: Chortiates*[31]

Six samples: TCH-3, 4, 6, 7 (TCH-1 and 2 were left out because their patterns are erratic). The chronology runs from 854 to 1022vv with no sapwood. The radiocarbon date is 1039±70 at 3 sigma for the final rings. There is recessed brickwork as at Enez.

(19) *Trabzon, Kuştul: Hg. Georgios Peristereota Monastery*

KUS-11ABCD. The ring-sequence runs from 803 to 1016vv with no sapwood. This date is also surprisingly early (as in No. 10 above).[32] Bryer and Winfield also refer to a refoundation date of 1393 for the monastic buildings.

(20) *Istanbul: Hg. Sophia-69A, Lunette in the Center Bay of the South Gallery*

SOF-69A: Ring-sequence runs from 849 to 987vv with no sapwood. The tie-beam is found in a modification to the south gallery's center bay, in the lunette above a four-column support that helps counteract the outward splay of the dome. It is possible that these

[29] See Krautheimer 1986, pp. 497–498, with an extensive bibliography. See Ćurčić 2010, pp. 398–400, and n. 122, stating that a definitive study of this monument is much needed.
[30] Mango 1960, pp. 249–250. See Ćurčić 2010, p. 400, and fig. 435B.
[31] Ćurčić 2010, pp. 372–373, and plan in fig. 398.
[32] Bryer and Winfield 1985, pp. 272–273.

were part of the repairs after the earthquake of 26 October 989.[33] Mainstone is not entirely clear whether this unit is part of the sixth-century construction process as the building settled, or whether it had something to do with the work of the Armenian architect Trdat between 989 and 994/995.[34]

(21) *Prespa: Hg. Achilleios*[35]

Six samples: HAP-1, 4, 5, 8, 9, 11. Three more samples crossdate, but are short and erratic. The chronology runs from 825 to 968vv with 12 sapwood rings preserved. All we know about the basilica is that it was built for Tsar Samuel after his conquest of Larissa in 985/986 and that a synod was held here shortly after 1000. As for supporting information, the radiocarbon date for the last ring is 961±23 at 2 sigma.

(22) *Zagreb: City Museum*

Eleven samples: ZCM-3, 4, 6, 7, 10, 15, 23AB, 24, 25, 26, 28. The chronology runs from 849 to 962vv. Aleksandar Durman reports that the samples are from under the foundation of the thirteenth- or fourteenth-century circuit wall; a coin find for the latter refers to the German Emperor Sigismund. The structure, he says, could be as early as the Hallstatt period (sixth century BC), or the second century BC (La Tène), or as late as the ninth to eleventh centuries AD. An equivocal date at 709 BC means that a 14C date might be useful to confirm the present placement.

(23) *Stiris, Phokis: Hosios Loukas, Tie-Beams in the Gallery of the Katholikon*

Four samples: HLK-3, 4, 7, and 8.[36] The chronology runs from 857 to 956vv with no sapwood and an unknown number of missing heartwood rings. The *katholikon* in its present form is thought by Stikas to date from 1042 to 1055.[37] We have juniper samples from the adjoining Theotokos Church — thought to have been built in 946/947 — and from the monastic buildings, but their growth-patterns are so erratic that they probably never will be dated dendrochronologically.

(24) *Tekirdağ: Perinthos*

PRT-1 and 3, not to be confused with nearby Değirmendere (DEG). The chronology runs from 822 to 947vv. The two samples were excavated during a canalization project and

[33] Mark and Çakmak 1992, p. 54. The dendrochronological date for the tie-beams in the support system below this lunette is 910. See No. 27 below.

[34] Mainstone 1988, pp. 96, 92. Fig. 116 shows both the tie-beams (outermost ring is 910) and the lunette above (outermost ring is 987).

[35] See Ćurčić 2010, pp. 311–312, and fig. 328, where some of our sampled timbers may be seen, especially in the bema windows.

[36] See Ćurčić 2010, fig. 416, where the tie-beams may be seen in his photograph.

[37] Stikas 1974–1975, pp. 4, 130.

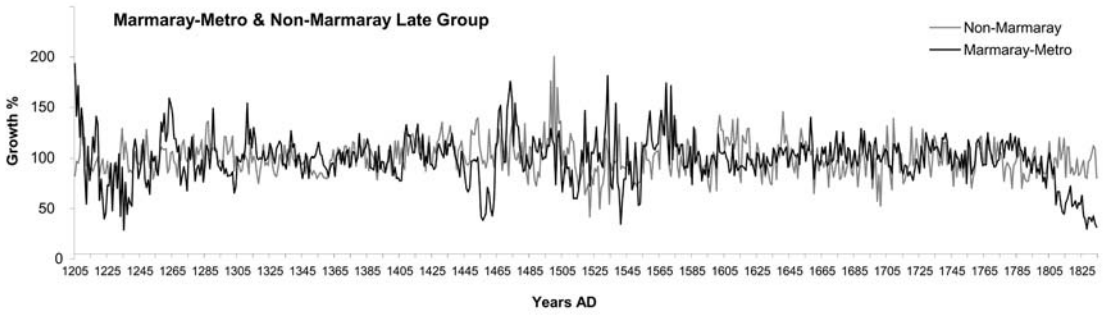


Fig. 4. Graph of the fit between Marmaray Late Group (black line), five data sets from 1205 to 1808, and the 24 non-Marmaray data sets (grey scale). The *t*-score is 8.98, overlap or *n* = 604 years, *r* = 0.34, trend coefficient = 60%, D-score = 89.4, WJ (*Weiserjähre*) = 66% of the 56 available signature years. The dips in the graph reflect adverse growing conditions. Source: Aegean Dendrochronology Project, C. L. Pearson.

found 5 m below present-day ground level in a trench of 5 × 5 m. The director of the Tekirdağ Museum can say only that it should date from the first millennium AD.

(25) *Venice: San Lorenzo*

Two samples: LOROAK.S02. The chronology runs from 835 to 926Bark with 18 sapwood rings present. Two sawn sections were collected from the north of the ninth-century church, from the eastern end of the current building during excavations conducted by the Venetian authorities. This possibly was the *aula* to the north of the ninth-century apse. The samples were collected on 13 June 1995 in our Operation 3.[38]

At this point the Marmaray Late Group, six data sets from 1205 to 1808, ends. Below (**Fig. 4**), we show how well it fits with the 24 non-Marmaray data sets. The *t*-score is 8.98, overlap or *n* = 604 years, *r* = 0.34, trend coefficient = 60%, D-score = 89.4, WJ (Weiserjähre) = 66% of the 56 available signature years. This is encouraging, especially since the geographical distribution of the non-Marmaray data sets ranges from Venice to the Black Sea.

(26) ***Istanbul, Yenikapı: YMK 2006 Repair to Halil's Second İskele[39] in Grid Squares GHIJKLMN 2–3–4–5–6–7–8***

Two samples: YMK-254 and 261. This was possibly a repair to No. 28 below, the primary construction of Halil's second iskele. The chronology runs from 747 to 912WK with

[38] A check of other LOR pieces might produce dates from the twelfth century.

[39] Here and elsewhere in this narrative, in order to provide clarification for the excavation team — since we still do not have all of the relevant plans and sections or the official nomenclature — we have identified the *iskele*s by the trenchmaster's name.

21 sapwood rings present. Elevations are ▼-0.02 m to ▼-0.36 m. Note that the elevations of these pieces in No. 26 are almost a meter higher than those of the first phase. The samples were collected in 2006.

(27) Istanbul: Hg. Sophia, Secondary Tie-Beams in the Center Bay of the South Gallery

Two samples: SOF-2 and 3. The chronology runs from 753 to 910vv with 10 sapwood rings. The tie-beams are found in a modification to the south gallery's center bay (below SOF-69-A; see No. 20 [SOF-69A] above in this list). This is supported by a radiocarbon date of 896±35 for the last ring at 1 sigma. Possibly these were repairs following — by some decades — the earthquake(s) of 869 and thereafter.[40] Although these samples were collected in 1974, not until now did enough *comparanda* exist against which to date them.

(28) ***Istanbul, Yenikapı: Halil's Second İskele in Grid Squares GHIJKLMN–2–3–4–5–6–7–8***

Eleven posts: YMK-464, 484, 622, 623, 626, 629, 633, 635, 641, 642, 648. The chronology runs from 715 to 897+WK. Elevations are ▼-0.47 m to ▼-1.12 m. The samples were collected in 2007.

(29) ***Istanbul, Sirkeci: Late Group (Walls 164 and 189) in Grid Squares BC/4–5***

Six posts: SMK-4AB, 7, 54AB, 130, 131, 133. The chronology runs from 707 to 884WK with 16 sapwood rings present. Elevation is ▼0.08 m. The samples were collected in 2009.

(30) ***Istanbul, Yenikapı: YMT 2007, İskele in Grid Squares 3Ib2–2Ia2***

Six posts (of the thirteen collected): YMT-548, 549, 550, 551, 553, 558. The chronology runs from 694 to 878+1+WK. Twenty-one sapwood rings are present. Elevation is ▼-1.75 m. The samples were collected in 2007.

(31) ***Istanbul, Yenikapı: YMT 2007, İskele in Grid Squares 0Hc4–1Ha4***

Two posts: YMT-490 and 508. The chronology runs from 723 to 877+1+WK with 22 sapwood rings present. Elevations are ▼-2.30 m to ▼-2.50 m. The samples were collected in 2007.

(32) *Kütahya: Castle, Tower 65, Two-Meter thickening of Tower 53 Wall, and Slightly Earlier Pieces from Neighboring Towers*

KUTOAK: Nine samples: KUT-7, 12–15, 19–22. Large oak timbers were used as a binder — inserted into the windows of the first phase of the tower — to keep in place a two-meter thickening to Tower 53; there were also headers and stretchers collected from

[40] Mark and Çakmak 1992, pp. 53–54; Mainstone 1988, pp. 96–97, and fig. 116.

Towers 10, 13, 33, Tower E, and the west curtain wall's second tower to the north of the inner castle (maybe Clive Foss's T10). The chronology runs from 598 to 870Bark. This is supported by a radiocarbon date of 864±4 at 1 sigma. Foss's estimates of the date(s) based on the color of the mortar are not helpful here.[41]

(33) ***Istanbul, Yenikapı: İskele in Grid Squares HIJKL 1–3***

Four posts: YMK-1843, 1845, 1846, 1847. The chronology runs from 725 to 868WK with 23 sapwood rings present. Elevations are ▼-0.08 m to ▼-1.45 m. The samples were collected in 2009.

(34) ***Istanbul, Yenikapı: Metro, İskele Next to (East of) Mürvet's in Grid Square 4Ib2***

Three posts: YMT-1184, 1186, 1194 (two radii from each). The chronology runs from 718 to 856vv, and no sapwood is present. Elevations are ▼-1.20 m to ▼-1.24 m. Compare Günşıl's *iskele* (one late post) at AD 829 (see No. 38 below). The samples were collected in 2008.

(35) ***Istanbul, Yenikapı: YMT 2007, İskele in Grid Squares 2Hd1–3Hb4***

Seven samples: YMT-547-550 (possibly the same tree), 551, 553. This is the same *iskele* (or at least with the same orientation) as No. 34 above — that is, the *iskele* east of Mürvet's dock — but from its very south portion, and ending at least seven years earlier than the posts in No. 34. The ring sequence runs from 700 to 849+vv. Eighteen sapwood rings are present. Elevation is ▼-2.30 m. Note that the elevations are over 1 m below those of the *iskele* in No. 34. The samples were collected in 2007.

(36) *Bozburun Ship*

The ship yielded 20 oak samples, of which the best 11 are included in the chronology. The chronology runs from 599 to 830Bark with 34 sapwood rings present. Supporting evidence for the end date is a radiocarbon determination of 820±22 at 1 sigma. The amphorae date from the ninth century.[42] Although the ship sank at Bozburun near Bodrum, its place of origin is unknown. The dendrochronological fits with other regional sub-sets of our chronology are not good enough to for us to propose one.

[41] For the phasing, see Foss 1985, pp. 64–74; for the reinforcement to Tower 53 which he assigns to his Period II, see pp. 42–43, and fig. 39–44.

[42] Harpster 2005, p. 1; 2006, p. 95. His original assessment was late ninth century. Ours was at first a tentative 874, now requiring revision after the addition of the Yenikapı samples across a formerly weak point in the chronology, to 830.

(37) *Afyon, Emirdağ: Amorium, Repair to Triangular Tower in Trench AB*

Four samples: AMO-12, 15, 43, 44. The chronology runs from 689 to 829(+3)vv. Sapwood, if present, cannot be identified. The tower may possibly be part of Emperor Zeno's wall construction project between 474 and 491.[43] The primary wall and tower construction, therefore, seem to be of the late fifth century. A coin of Arcadius (late fourth to early fifth century AD) has been identified. Long-lived cedar samples from Trench AB — as yet undated — may represent the (fifth-century) primary phase. The tower is believed to have been destroyed in the Arab attack of 838. Hence, these four oak pieces are not from the primary build. The outer portions were too badly burned to be useful, although we tried our best. One of the Amorium samples was observed to have its bark at the time of collection; however, it ends before the other pieces. Thus, repairs to the tower seem to have continued over a period of decades, if not centuries.

(38) ***Istanbul, Yenikapı: Metro, Günşıl's İskele No. 1 Late (= Metro İskele 24), in Grid Squares 4Eb1 to 4Ea3***

YMT-236. The ring-sequence runs from 698 to 829vv, plus two unmeasurable sapwood rings. This sample was noted in the field to post-date an unusual chaotic sediment layer, dark in color and comprising materials found both on land and in the sea (**Figs. 7–10**), interpreted by Perinçek as a "tsunami deposit" (his Level 4),[44] and by Algan and Yalçın as a "chaotic layer" (within their Unit P5).[45] This layer will be given further consideration as appropriate within the list, particularly in No. 61–64 below. Elevations are ▼-2.20 m to ▼-4.22 m. The sample was collected in 2008.

(39) ***Istanbul, Yenikapı: İskele in Grid Squares JKLMN–1–2, Phase II***

This *iskele* has a total of 43 dated posts, of which 26 belong to this second phase, and 17 to an earlier phase. Phase II includes YMK-1850, 1854, 1859, 1863, 1868, 1871–1873, 1875–1878, 1885–1888; and also YMK2008: 768, 770–772, 774, 782, 783, 789, 790, and 791. The chronology runs from 690 to 819WK with 23 sapwood rings present. Elevations are ▼-1.41 m to ▼-1.79 m. Phase I of this *iskele* in 786 is discussed in No. 44. A note

[43] Böhlendorf-Arslan 2007, pp. 274–275. These pieces of charcoal are from a different lot than the one cited there; see Witte-Orr 2007, p. 297; see also Gill 2002, p. 12. The fifth-century fragments cited there are not included in the present date list.

[44] Perinçek (2008) makes an impressive argument for a tsunami; for even more impressive photographs of the stratigraphy and what the authors call a "high-energy deposit," see Bony et al. 2011, especially fig. 1b and 3.

[45] Algan et al. (2009, pp. 457–461) report that the level is abnormal and definitely chaotic. While they do not rule out the possibility of a tsunami deposit, they offer alternate hypotheses for the unusual stratigraphy, such as a change in the depositional environment following the construction of a harbor wall, or after storms and concomitant flooding from the Lykos River. Since the Annual RCAC Symposium in December 2010 we have also learned from the Yenikapı trenchmasters that coins post-dating the one published Justinianic *solidus* in that layer (Kızıltan 2007, p. 176) have now been found and identified (many in a continuous, non-disturbed stratigraphic sequence at the top of this level). Therefore, it seems there may be more to this sedimentary unit than just a single catastrophic event.

concerning the crossdating: this does not fit with Hg. Eirene in the way in which the timbers of the Phase I *iskele* do, but rather with YMT 0Hc4–1Ha4 (No. 31 above), YMT 3Ib2–2Ia2 (No. 30 above), and YMK HIJ 3–4 (No. 28 above). Elevations are ▼-1.41 m to ▼-1.79 m.[46] The samples were collected in 2008 and 2009.

(40) ***Istanbul, Yenikapı, Metro: Günşıl's İskele No. 3 in Grid Squares 4Eb1 to 4Ea3***

Two samples: YMT-309, 310. YMT-305, 307, and 308 also fit, but are erratic and have therefore been omitted here. The chronology runs from 736 to 807WK. The sapwood is hard to count because the heartwood/sapwood transition zone has highly-compressed rings. As with No. 38 above, the stratification of this *iskele* was noted at the time of collection as belonging to the "post-chaotic layer." Elevations are ▼-0.76 m and ▼-0.83 m. The sample was collected in 2008.

(41) *Istanbul: Hg. Eirene, Tie Beams in the South and North Nave Arcades (Tertiary)*

Seven samples: IRN-1, 2, 3, 5, 6, and 7 from the south arcade (**fig. 5**), and IRN-8 from the north arcade. The chronology runs from 643 to 799v with a maximum of 25 sapwood rings. The radiocarbon date for the end ring is 796±19 at 1 sigma. Urs Peschlow believed that this construction was a result of the earthquake of 740.[47] This assumption now needs to be rethought. It is difficult to imagine that the second church in Constantinople remained unrepaired for 60 years. Was there some other problem with the church about which the chronicles do not tell us?

(42) *Mudanya, Trilye: Fatih Cami, Tie Beams*

Three samples: TIR-1, 3, 4. The chronology runs from 655 to 793vv with no sapwood. Trilye has always crossdated splendidly with Hg. Eirene. The radiocarbon date for TIR-2 (whose ring-sequence runs from 655 to 777, but has been left out of this calculation because of its erratic nature) is 718–803 at 2 sigma. Robert Ousterhout thinks that the building dates to the early ninth century. Thus our adding a full sapwood component should tie in perfectly to what the architectural historians believe.

(43) *Istanbul: Hg. Sophia, Stretcher in the North Wall of the So-Called "Baptistery"*

SOF-31B. The ring-sequence runs from 610 to 790vv. No sapwood is present, and so an early-ninth-century date is likely.[48]

[46] Once the plans are complete, the excavators need to check whether there is an elevation difference between the posts of Phase I and Phase II.

[47] Peschlow 1977; Kuniholm and Striker 1977, pp. 229–240.

[48] Kuniholm and Striker 1985. The "baptistery" was used as a *türbe* for the Ottoman sultans Mustafa I and Ibrahim and their families. The last-preserved tree ring in the porch (*revak*) is 1616.

(44) ***Istanbul, Yenikapı: İskele in Grid Squares JKLMN–1–2, Phase I***

This sample includes 17 posts: YMK-1853, 1856, 1858, 1861, 1865, 1867, 1880, 1881, 1882, 1883, 1889, and 1890, and also YMK2008–761, 764, 766, 779, and 785. The chronology runs from 681 to 786WK with 23 sapwood rings present. Elevations are ▼-1.48 m to ▼-1.79 m. This is Phase I of the *iskele* in No. 39 above (collected in 2009). This *iskele* fits remarkably well with Hg. Eirene, Hüseyin's "lighthouse," and the *iskele* in IJKL, as well as YMT 0Hc4–1Ha4 and YMT 3Ib2–2Ia2. Since Phase II of this *iskele* dates to 819, 33 years elapsed between the cutting of the posts for Phase I and Phase II. The samples were collected in 2008 and 2009.

(45) ***Istanbul, Yenikapı: Hüseyin's "Lighthouse" (Now Believed to Be an İskele) in Grid Square 4A2a1***

This is quite different from all the other *iskele*s at Yenikapı in that it is a stone construction rather than an *iskele* supported on oak posts. Four samples were collected from parallel boards (**Fig. 5**) set vertically around the foundation and filled with hydraulic clay, presumably to prevent the undermining of the wall: YMT-245, 246, 247, 248, and 250. The chronology runs from 657 to 786vv. There are 9 sapwood rings on YMT-247, so construction is estimated at around the turn of the eighth to the ninth century. Elevations are ▼-1.10 m to ▼-1.20 m. The fit with the Hg. Eirene tree-ring graph (**Fig. 5**, see also No. 41 above) is so good (*t*-score 7.55, n=130 years, r=0.55, trend coefficient 73%, D-score=172.6, WJ=72% of 61 available years) that we believe the timbers originated in the same forest. The samples were collected in 2008.

(46) *Afyon, Emirdağ: Amorium, Trench TT*

This includes two charcoal samples, AMO66 and 68, possibly from the same tree. The ring-sequence runs from 681 to 780vv. No sapwood is identifiable. The excavator's estimated date is late ninth century.[49] The best fits are with Hg. Eirene, Trilye, and Hüseyin's "lighthouse" at Yenikapı. Are the last three sites, therefore, built with wood from the Anatolian interior? The group stands out from all the other (probably coastal) samples in this list.

(47) ***Istanbul, Yenikapı: İskele in Grid Square IJKL–122–124***

This includes 21 samples: YMK-1918, 1924r–1928r, 1930–1932r, 1934r, 1937r, 1938, 1939B, 1940r, 1942, and 1944. The chronology runs from 646 to 765WK with 34 sapwood rings present. Elevations are ▼-1.00 m to ▼-1.32 m. This is a single-phase *iskele*. It has a superb fit with the Hg. Eirene tertiary (see No. 41 above) and possibly stems from the same forest. The samples were collected in 2008.

[49] Gill 2002, pp. 16–17.

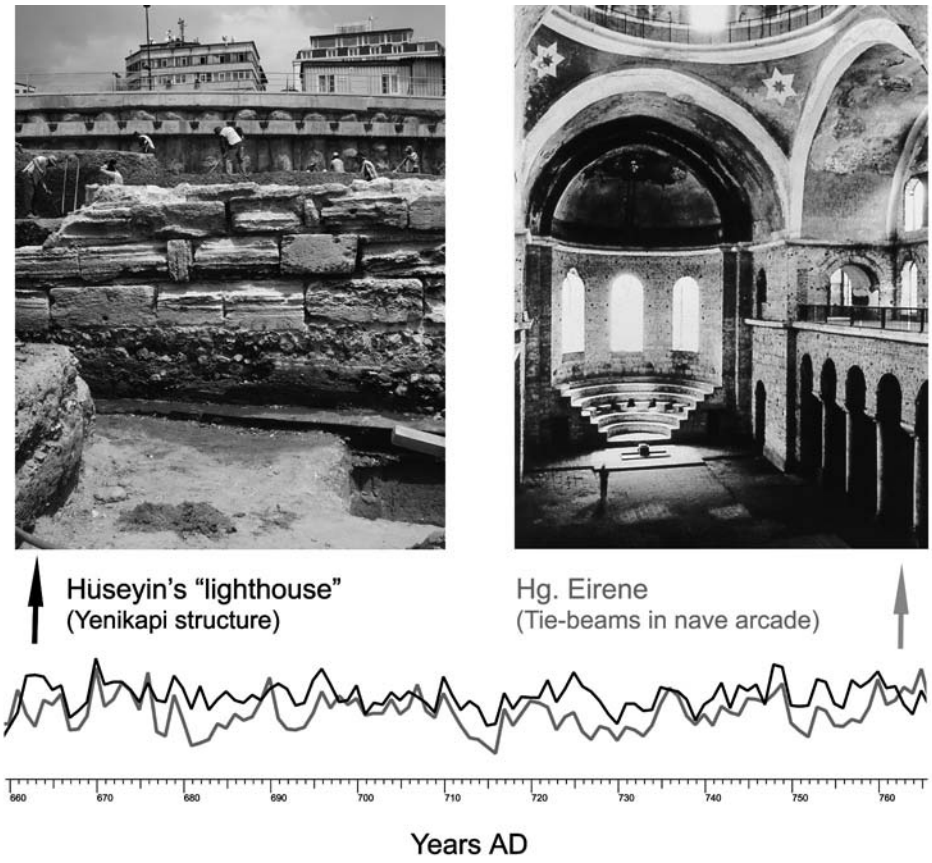


Fig. 5. Graph of the fit between the tree-rings of Hüseyin's *iskele* (photo left, graph below in black) and the south nave arcade of Hg. Eirene (photo right, graph below in grey scale). Both the visual fits and the statistical test results are so good (*t*-score 7.55, n=130 years, r=0.55, trend coefficient 73%, D-score=172.6, WJ=72% of 61 available years) that we believe the timbers originated in the same forest.
Source: Aegean Dendrochronology Project; graphs by C. L. Pearson; photograph left by P. I. Kuniholm, photograph right by T. Matthews.

(48) *Vize/Bizye: Hg. Sophia (Küçük Ayasofya)*

VIZ-3 and 4 combined. The chronology runs from 583 to 747v. VIZ-3 (from the pilaster to the north of the central door, on the west wall exterior, with 31 sapwood rings) ends in 747. VIZ-4 (from the south arcade in the naos, the east-west tie-beam sawn from the west reveal of the pier in the westernmost arch of four, no sapwood) ends in 726. It also fits on the right-hand edge of Bernd Kromer's 14C wiggle-match. Uwe Haeussner had reported to us a 14C date from J. Gorsdorf in Berlin (2064 BP +/-27), which made no sense.[50] This was superseded by Kromer's Heidelberg determinations which suggest an end date near 769+/-25. One other long element (VIZ-1, not in this catalogue, a tie-beam from the triple window in the west wall of the naos) ends in 821, but with no sapwood.

[50] E-mail communication with Uwe Haeussner, September 2003.

(49) *Milan: Castel Seprio, Santa Maria*

Two sets of cored samples: SEP-1ABC and 2A. The chronology runs from 670 to 744vv with no sapwood. This building has always crossdated well with Sv. Donat. The first radiocarbon dates (first century!) were many centuries too early, possibly because the samples were taken from the creosoted roof. Subsequently another radiocarbon date of the late eighth to the mid-tenth century (778–952) was reported by Paula Leveto-Jabr.[51] We are not certain of the relation between the cores she sent us and the 14C samples.

(50) *Zadar: Sv. Donat, Floor Joists (?) of the Gallery*

Eight samples: DON-1AB–9. The chronology runs from 583 to 743v with 25 sapwood rings. Sv. Donat has long been thought to be contemporary with Charlemagne's Palatine Chapel at Aachen, but not too many sapwood rings can be added after 743 in our tree-ring series.[52] Is 743 therefore slightly early, or is Aachen a copy of Sv. Donat in its present form? A relatively recent archaeological re-interpretation cited by Goss (for which we have no further details other than verbal and e-mail communications) places the first one-story construction of Sv. Donat in the second half of the eighth century, which would accord well with the dendrochronological evidence.[53] Samples were sent to Heidelberg in December of 2005. The radiocarbon date is 1450 +/-20 BP = 572–645 at 2 sigma for the first ten rings; thus one can set a date of 733–806 for the end on the basis of the Heidelberg 14C alone.[54]

(51) *Afyon, Emirdağ: Amorium, AMO98 LC6 (Gateway Rooms)*

Four carbonized samples: AMO-96, 115, 120, 134. The chronology runs from 560 to 714vv with an unknown number of exterior rings missing. AMO-120 was sealed under an eleventh-century pavement with a coin of Theophilus (829–831).[55] The radiocarbon date for carbonized scraps from context 19 from this trench was 671–783 at 2 sigma.

[51] Leveto-Jabr 1987, pp. 17–18. Something is amiss with the arithmetic in her report.

[52] Goss 1987, p. 39, and fig. 20, 4246; Ćurčić 2010, pp. 340–343.

[53] Gvozdanović (1972) attributes a modification to a Bishop Peter around 780. We noted at the time of collection that the undersides of the beams we sampled, presently embedded in the gallery floor, had carved and painted decoration (see Gvozdanović 1972, fig. 52–53), suggesting that in yet an earlier phase the beams, before the floor was modified, were visible from below. Prof. Durman's e-mailed report of a conversation with Vežić is as follows: "He says that first the older, middle part was built inside Sv. Donat, and then the surrounding gallery and spolia (both stone and wooden) were added to the older one." This suggestion of an early date is supported by both the radiocarbon determinations and the dendrochronology.

[54] Srdoč et al. (1973, pp. 437–438) report similar results of 695+/-55. Their assumptions about the expected life of the trees, however, were inaccurate by about 40 years and were revised in a paper published in Croatian by Pavuša Vežić in 1985 (unavailable to us). When this adjustment is taken into account, the Rudjer Bošković results are much closer to Heidelberg's.

[55] Gill 2002, p. 13; Böhlendorf-Arslan 2007, p. 282, Fig. 8. Our charcoal fragments have an earlier end-date than the latter citation — based on the coin finds — indicates.

(52) *Vergina (Greece): Arapis Riverbed*

One piece: BCO-6. The ring-sequence is 624 to 706vv. This is the result of a fieldtrip by the late Bernd Becker, Bernd Kromer, and Yannis Maniatis in an unsuccessful search for pre-glacial wood. This piece (BCO-6) has never crossdated with the Fotada pieces (BCO-7, 8, 9), collected on the same trip, which are several centuries earlier.

(53) *İznik/Nicaea: City Wall, Upper-Level Stretcher of Tower 106*

Tower 106 is also known as the Kız Kulesi (Maiden's Tower) and is possibly the so-called "Corner Tower" mentioned by the Crusaders. One piece: IZW-5A. The ring-sequence is 633 to 702vv,[56] with no sapwood preserved. Schneider and Karnapp date the bastion and curtain wall in front of it to 1097 on the basis of Seljuk inscriptions, but they make no comment on the date of the tower itself.

(54) ***Istanbul, Yenikapı: YMT, Osman's İskele in Grid Squares 3Aa2–4A1b3***

Three crossdated posts (of ten): YMT-237, 239, 240. The chronology runs from 631 to 702vv, with approximately 17 to 19 sapwood rings. The remaining samples are short and/or erratic. YMT-242 may be as late as the ninth century. Elevations are ▼-1.73 m to ▼-2.80 m. The samples were collected in 2008.

(55) *Ephesos: Harbor, Pilings Retrieved in Dredging Operation*

Two samples: EPH-12 and 15. The chronology runs from 591 to 681vv with no sapwood. Zabehlicky has published a compendium of the literary and epigraphic evidence for the use of the harbor and the periodic need to dredge the channel from the harbor to the sea, as it gradually silted in during the early centuries AD.[57]

(56) *Spina (Italy): Unnumbered Plank from the Cemetery, Retrieved from the Basement of the Ferrara Museum*

One sample: SPI-3. The ring sequence runs from 502 to 671vv. No sapwood is preserved, thus a cutting date around 700 is likely. This plank was found among a number of similar planks that had been lying in the basement of the Ferrara Museum for half a century, most of them with their labels having fallen off.[58] The radiocarbon date is 674±80 at 2 sigma. This late date was a major surprise. The Ferrara Museum officials had guessed that these tombs were likely to date from the late fourth/early third century BC on the basis of the imported Attic pottery groups from the cemetery. We had noticed the good AD fit at

[56] Schneider and Karnapp 1938, pp. 34–35, 41–43, pl. 49.

[57] Koester 1995, pp. 201–215; see also Kraft et al. 2007, pp. 137–145, and fig. 11–14, including a schematic drawing of the location of one of the posts.

[58] Alfieri and Arias 1958, pl. A–M.

the outset, but dismissed it as a false positive until the radiocarbon date made us look again at the seventh century AD.

(57) *Kastamonu: Ilgarini Cave, Sarcophagus from a Robbed Tomb*

Four samples: ILG-1–4. The chronology runs from 323 to 648vv. Thirteen exterior rings are either sapwood or degraded by rot. These boards were collected and kindly sent to us by Ünal Akkemik and could be from any period in history. His sketch and explanation are the only documentation we have.

(58) ***Istanbul, Yenikapı: Marmaray, YMK-Halil's and Kaya's Region III, in Grid Squares IJKL-74–1, İskele Kazı (Marmaray İskele 1), Phase 4***

Thirteen samples: YMK-3390, 3410, 3420, 3430, 3440, 3450, 3460, 3580, 3590, 3690, 414, 416, 427. The chronology runs from 475 to 610Bark, almost certainly imported from Romania (Capidava), or at least the Black Sea. The elevations of the posts from this level (which ought to be post-chaotic) are relatively even — within 11 cm of one another — compared with the helter-skelter elevations for Phases 1, 2, and 3 (which ought to be pre-chaotic). Elevations are ▼-0.54 m to ▼-0.65 m.

This *iskele* (**Fig. 6**) in its four phases was more difficult for us to interpret and date than anything else at Yenikapı. Although building a 175-year sequence from it was not a problem, placing it in time was impossible for several years. Attempts at radiocarbon wiggle-matching were unsatisfactory, pointing very crudely toward a seventh-century date. Tomasz Ważny found the key to the date when he visited Capidava, a Justinianic site about 100 km up the Danube from the Black Sea coast. As we explored this likelihood further, we realized that the city walls of Sinop, a number of posts at Yenikapı in a variety of *iskele*s, as well as wood from the primary phase of Hg. Sophia and an early phase of Hg. Eirene all had probable Black sea origins (see below). These samples were collected in 2006, before the chaotic layer, visible in the scarp in the back of **Fig. 6**, had been identified as such. In this area of the Yenikapı excavations, protected by the sea-wall, the accumulation of this layer is not as deep as elsewhere in the harbor. Note that the elevations of the tops of the posts in Phase 4 are considerably higher than those in the preceding phases.

(59) *Venice: Torcello, Basilica*

Three samples: TOR-1, 2, 3. The chronology runs from 520 to 606vv with 4 sapwood rings. (TOR-2 with 7 sapwood rings might be 15–20 years earlier than TOR-1 and 3.) TOR-1 is from the interior of the basilica, the north side, or "fourth nave."[59] The post was found in a vertical position in the north section of a deep sounding in the basilica and is thought by Albert Ammerman to date to ca 400–800 AD. TOR-2 was sawn from a post *in*

[59] Grandi 2005, p. 4. See shaded area in **Fig. 2**. TOR-2 and 3 are from the shaded area just north of the north wall of the basilica.

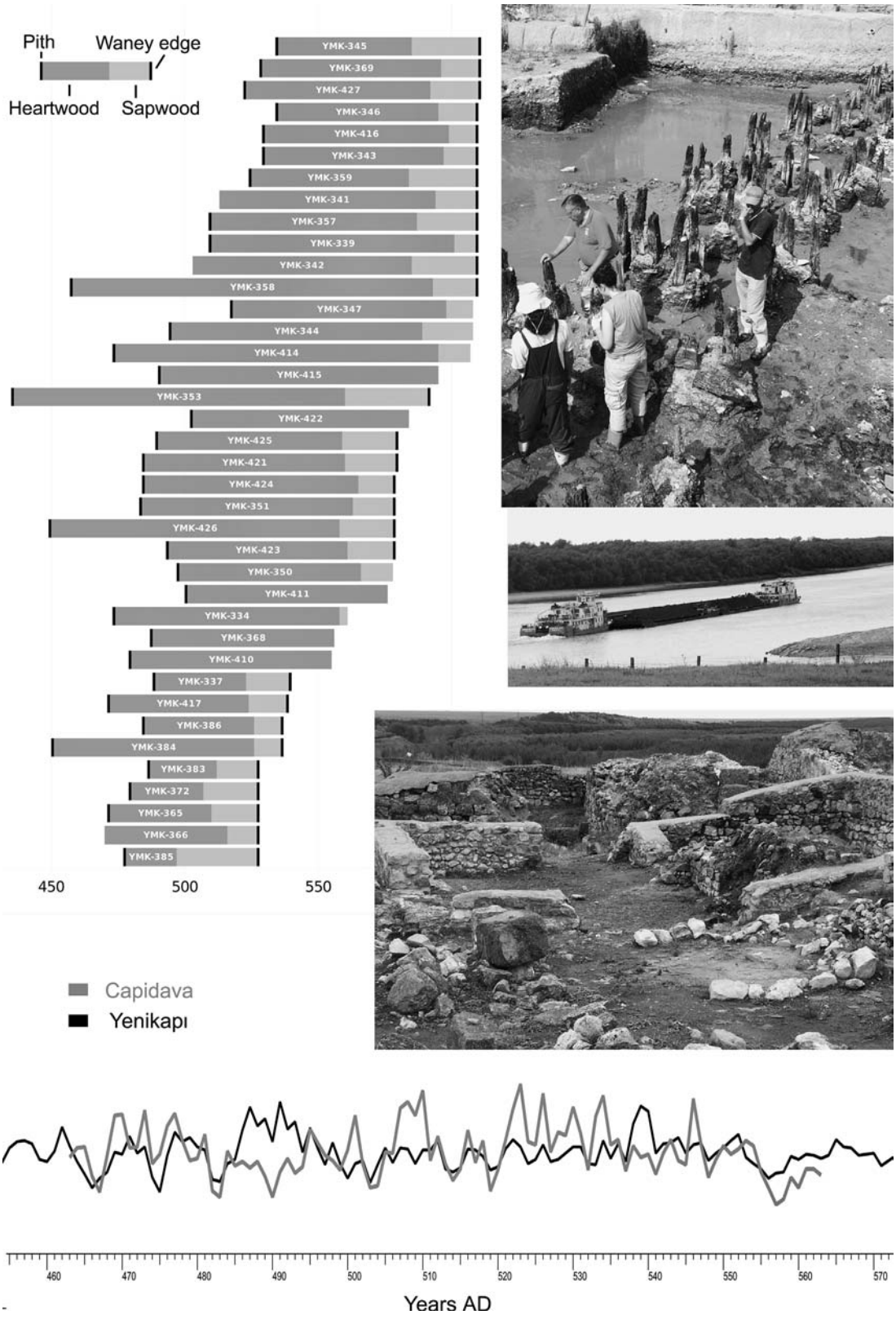


Fig. 6. Four-phase *iskele* at Yenikapı (photograph top right and graph left) and the Justinianic site of Capidava 100 km up the Danube on its right bank (photographs on the right). The graph below shows the quality of the fit between the two. Until Capidava was visited, the Yenikapı *iskele* remained undatable. The wood in Phase 1 of the *iskele* was cut in 527, Phase 2 in 539, Phase 3 in 579, Phase 4 in 610. Source: Aegean Dendrochronology Project; graphs by C. L. Pearson; photographs by K. J. McDonnell and T. J. Ważny.

situ, immediately north of the basilica's north wall. TOR-3 was sawn from a post already removed from the ground, 1.13 m north of TOR-2, but the hole from which the post had recently been extracted was still visible. The exterior samples lie adjacent to a cobbled paving in the trench. A wiggle-matched radiocarbon estimate is that the series ends at 576 ± 33 AD (1 sigma), 589 ± 55 AD (2 sigma).

(60) ***Istanbul, Yenikapı: Marmaray, YMK-Halil and Kaya's Region III, İskele Kazı, in Grid Squares IJK 74–81, Phase 3.5***

Two posts: YMK-353 and 411. The chronology runs from 436 to 591WK, with 31 sapwood rings present. This fits between Phases 3 and 4 and seems to represent a separate repair to Phase 3. Elevations vary widely in contrast to Phase 4: ▼-0.55 m to ▼-1.15 m. The samples were collected in 2006.

(61) ***Istanbul, Yenikapı: Marmaray, Merve's İskele (= Marmaray İskele 3) in Grid Squares GHIJK 140***

Six samples: YMK-1895, 1896, 1897, 1900, 1904, 1911. The chronology runs from 432 to 588WK. This is the final pre-chaotic layer *iskele* (Perinçek's Unit 4,[60] Algan and Yalçın's chaotic layer within P5) (**Fig. 7a–b and 8**).[61]

At the 2010 Annual RCAC Symposium, we incorrectly associated this *iskele* and its companion *iskele*s with the December 557 earthquake and proposed an associated tsunami that might have been connected to the partial collapse of the dome of Hg. Sophia in 558.[62] The linkage proposed at that time of the chaotic layer to the December 557 earthquake which caused a partial collapse of the dome of Hg. Sophia no longer exists, since the Yenikapı dates have been moved 31 years down in time (toward the present). An earlier phase of this *iskele* probably ends in 541. Elevations are ▼-2.04 m to ▼-2.60 m. The samples were collected in 2008.

The black layer — in some places 1 m thick, filled with extraordinary amounts of debris from both land and sea (shown as Level 4 in **Fig.** 7) — is an anomaly at Yenikapı. Perinçek names it Level 4 and interprets it as the result of a "tsunami." Algan and Yalçın interpret it as a chaotic layer within their level P5, which may have resulted from a series of bad storms, flooding, or a change in sedimentary regime. This is not the place to argue the cause — we leave that to the geologists — but if the layer were to represent a tsunami or some equally serious event(s) in 588 or later, we have at least six *iskele*s associated with the chaotic layer at Yenikapı which may be useful in further interpretations. We list these as follows (with the minimum length of time each *iskele* was in place before the deposition of the layer):

[60] See n. 44.
[61] See n. 45.
[62] Mark and Çakmak 1992, pp. 51–53.

Fig. 7a. The "chaotic layer" just above the line of white dots (P.5. in the terminology of Algan and Yalçın), or "tsunami layer" (Level 4 in the terminology of Perinçek), at Yenikapı. At least six *iskele*s were destroyed in this event in or shortly after AD 588.

Fig. 7b. A more "chaotic" view of the chaotic layer. Source: Photographs by D. Perinçek.

Fig. 8. Merve's *iskele* in grid squares GHIJK-140, Yenikapı. These posts, cut in 588, are from the latest *iskele* to be destroyed in the "chaotic event" that followed shortly thereafter. Note the accumulated debris between the remaining vertical pilings and under the scattered horizontal members. Source: Istanbul Archaeological Museums.

Merve's *iskele*, No. 61, in grid square GHIJK 140	588WK (0 years)
Günşıl's second *iskele*, No. 62, in grid square 4Eb1-4Ea3	587vv (1 year)
Mürvet's *iskele*, No. 64, in grid square 2Ja1 to 3Jc3	581WK (7 years)
Halil and Kaya's *iskele*, Phase 3, No. 65, in grid square IJKL-74–81	579B (9 years)
Züleyha's *iskele*, No. 66, in grid square 3Cc1	568B (20 years)
Günşıl's first *iskele*, No. 69, in grid square 3Ea4	553B (25 years)

After this remarkable event — whatever its cause — we have yet to find anything at Yenikapı built during the next 22 years until 610, the year in which the İskele Kazı, Phase 4 (No. 58 above) was built, aside from the two pieces of the so-called Phase 3.5 (No. 60) cut in 591. (The event[s] which produced the chaotic layer could, of course, have been after 591.) This gap makes little sense for a major port in such a metropolis. Fishermen need to fish; seamen and merchants need to come and go. Either this is an odd circumstance of our sample retrieval, or perhaps it is evidence that seafarers chose other ports either in the Golden Horn or along the Marmara shore for some two decades following the event(s) of 588 or 591 (certainly a logical possibility if the harbor had been damaged by

some sort of catastrophic event).[63] Work is under way to pursue the proper stratigraphic interpretation of these *iskele*s with the excavators, geologists, and architects as part of our future analysis.

(62) ***Istanbul, Yenikapı: Marmaray, Günşıl's İskele No. 2, in Grid Squares 4Eb1–4Ea3***

Four samples: YMT-298, 299, 300, 301. The chronology runs from 410 to 587vv, with no sapwood discernible. In the opinion of the excavator, this *iskele* also pre-dates (and was destroyed at the time of) the chaotic layer. Allowance for sapwood would push the date for the chaos closer to the turn of the century. The samples were collected in 2008.

(63) *Celano, Abruzzo: Water-Mill (Mulino Paludi)*

Five samples: CEL-5A, 5B, 6, 10, 11. The chronology runs from 420 to 584v, with 39 sapwood rings present. Excavator Vincenzo d'Ercole thinks it dates to the late sixth/early seventh century.

(64) ***Istanbul, Yenikapı: Metro, YMT-Mürvet's İskele (= Metro İskele 3) in Grid Squares 2Ja1 to 3Jc3***

Thirty-four posts: YMT-263B, 264, 267BC, 273A, 275BC, 278BCD, 280, 281, 283BC, 284BC, 285ABCE, 286, 287BCD, 290, 292EF, 1409, 1410, 1416, 1417, 1420, 1421, 1424, 1425, 1426, 1427, 1428, 1429, 1508, 1509, 3558, 3559, 3560, 3562, 3643. The chronology runs from 423 to 582WK, with 25 sapwood rings present. Most of the posts were cut in the years 580 and 581. One piece was cut 11 years earlier. Some pieces were definitely imported from the Danube region or nearby, a fact that we noticed as soon as the Capidava wood had been measured. We shall not be able to dissect this *iskele* into its constituent parts of presumed origin until next year, but the exercise should be instructive. Elevations are ▼-1.62 m to ▼-2.70 m. In **Fig. 9**, there can be seen the 15 or so timbers, all of them chestnut (*Castanea*), which stick up above the set of shorn-off oak pilings and which seem to represent a half-hearted attempt at repair. None of them can yet be dated.

(65) ***Istanbul, Yenikapı: Marmaray, YMK-Halil and Kaya's Region III, in Grid Squares IJKL-74–81, İskele Kazı, Phase 3***

Six samples: TYMK-421, 424, 425, 426, 3500, 3510. The chronology runs from 450 to 579Bark. This is probably another pre-chaotic-layer *iskele* (implied from the levels), with the wood almost certainly imported from the area around or up the Danube from Capidava (Romania) or the Black Sea. Elevations are ▼-0.55 m to ▼-1.15 m. The samples were collected in 2006.

[63] Magdalino (2000, pp. 218–219) notes shifts in the population distribution in Constantinople to and from the Marmara shore over time, proposing that the plague might have had something to do with the sixth-century shift. On pp. 215–216 and pp. 217–219, he notes the tradition of the filling in of the Harbor of Eleutherios with construction debris from the Forum of Theodosius. Might both the population shifts and the filling-in have followed this tsunami or chaotic event? In several instances we have noted that the later phase of an *iskele* is considerably higher than its predecessor.

Fig. 9. YMT-Mürvet's *iskele* in grid squares 2Ja1 to 3Jc3, Yenikapı. This is the best-represented *iskele* at Yenikapı with 34 dated samples. Most of the wood was cut in 580 and 582 and destroyed in the "chaotic event" of 588 or shortly after. Note how the tops of the pilings are sheared off at about the same height. The taller timbers (like the ones identified by white arrows), all chestnut and so far undatable, seem to represent a half-hearted attempt at a repair. Source: Photograph by P. I. Kuniholm.

(66) ***Istanbul, Yenikapı: Metro, YMT-Züleyha's İskele in Grid Square 3Cc1***

One sample: YMT-228. This sample dates to the pre-chaotic layer. The ring-sequence runs from 481 to 568WK. The heartwood-sapwood boundary is not clearly identifiable. Two additional samples, YMT-220 and 222, probably imported, are not included here, nor is YMT-225 (chestnut which does crossdate). Elevation is ▼-3.03 m to ▼-4.30 m. The sample was collected in 2008.

(67) *Capidava (Romania): Justinianic Level*

The chronology of the two pieces runs from 463 to 563vv. This data set, as noted above (see **Fig. 6**), is important for demonstrating the Black Sea or Danubian origin of some of the Yenikapı and other sixth-century samples.[64]

[64] James Crow has commented: "I noted that since Capidava is in the Dobrudja, a region notorious for the absence of trees, timbers were likely to have come from elsewhere. One of the key shipping routes in late antiquity apparent from the 4th c. AD were the supply routes for the garrisons on the lower Danube supplied from the Aegean and Hellespont. This pattern is revived in the 6th c. by Justinian in a system known as the *Quaestor*

(68) *Istanbul: Hg. Eirene, Forebay (Secondary) on the South Side of the Naos*

IRN-4ABC (see the photograph on the right in **Fig. 12**). The ring-sequence runs from 451 to 561vv with 2 sapwood rings preserved. An allowance for several more sapwood rings point to a felling date not long after 561. IRN-4 has never fit with the rest of the IRN pieces from the nave arcades and is probably from the restoration by Justinian in 564 and following after the narthex and atrium were destroyed by fire.[65] It is not from the primary phase as we had long surmised. For supporting evidence we have a radiocarbon date of 560±30 at 2 sigma for the last ring.

(69) ***Istanbul, Yenikapı: Metro, Günşıl's İskele No. 1 (= Metro İskele 24) in Grid Square 3Ea4***

Five samples: YMT-229, 230, 232, 233, 235. The chronology runs from 466 to 553vv with 6 sapwood rings. Elevations are ▼-3.20 m to ▼-4.48 m. This is from the pre-chaotic layer (**Fig. 10**). The samples were collected in 2008.

(70) *Perinthos, Değirmendere: Mill Foundation*

DEG-1 and 2, not to be confused with PRT. The chronology runs from 387 to 551WK. This site (its Turkish name means mill-stream) had been, according to the mayor of the town, a sandy stream bed for all his life. The winter before we collected the wood, a storm had washed away all the sand, thereby exposing the oak timbers in their brick beds. The radiocarbon date is 219±6 at 1 (or 246 ±13) at 2 sigma, so the dendrochronological date and the 14C are not in agreement. The museum director in Tekirdağ had estimated the mill-construction to date to the fifth/sixth centuries.

(71) ***Istanbul, Sirkeci: Trench A/6, Örnek 4***

The ring-sequence of SMK 659 runs from 449 to 546vv. No sapwood is present. The elevation is ▼-0.29 m to ▼-0.44 m. This is well above the early Sirkeci material reported below. The sample was collected in 2007.

(72) *Aydın, Karacasu: Aphrodisias, North Agora*

APH-9AB. The ring sequence runs from 473 to 545vv with 13 sapwood rings present. The excavator believes it to be from the seventh/eighth century. It was found in the same

Exercitus. Lots of amphorae from the Aegean, etc., are found along the Danube forts and settlements, but not inland to any extent. It would follow that this would be a maritime/river trade and my suggestion was that this was the process that timbers made their way back on the return leg to Constantinople. The sources could vary but an obvious one is the forested Haemus/Balkan mountains which come down to the sea north of Messembria Nessebre, alternatively higher up the river from around the Iron Gates, but I know this region less well. This mechanism could explain how you have similar timbers from Capidava and Yenikapı." E-mail message from James Crow, 16 December 2010.

[65] Mathews 1976, pp. 102–103.

Fig. 10. Günşil's *iskele* #1 in grid square 3Ea4, Yenikapı. The wood was cut shortly after 553 and destroyed in the "chaotic event" of 588 or shortly after. Note the evidence for the "chaotic layer" by focusing on the amphora just at the top of the posts in the center of the photograph, and then following the line of debris as it sags down to the right. The tall post on the right, clearly a replacement, was cut a decade or two after 829. Source: Photograph by P. I. Kuniholm.

general context as APH-7, a 208-year piece — the longest-lived oak sample at Aphrodisias — which remains undated.

(73) ***Istanbul, Yenikapı: Marmaray, YMK-Halil and Kaya's Region III, İskele Kazı in Grid Squares IJKL 74–81, Phase 2***

Four samples: TYMK-3370, 384a, 386a, 417a. The chronology runs from 451 to 539Bark. The wood was almost certainly imported from Romania (Capidava) or the Black Sea. Elevations are ▼-0.25 m to ▼-1.02 m. The samples were collected in 2006.

(74) *Istanbul: Hg. Sophia, Primary*

Ten samples: SOF-10, 14, 26, 50, 52, 53, 58, 66, 88, 105. The chronology runs from AD 418 to 536 (but WK is present at AD 534 on SOF-14, a tie-beam on the ground floor

Fig. 11. Cutting a tie-beam (SOF-14) on the Ground Floor, SE Bay, of Hg. Sophia. The waney edge or *Waldkante* (WK) is present, so the felling date for the timber was after October 534 (but before April 535), not long after construction began in early 533. Source: Photograph by R. Hadley.

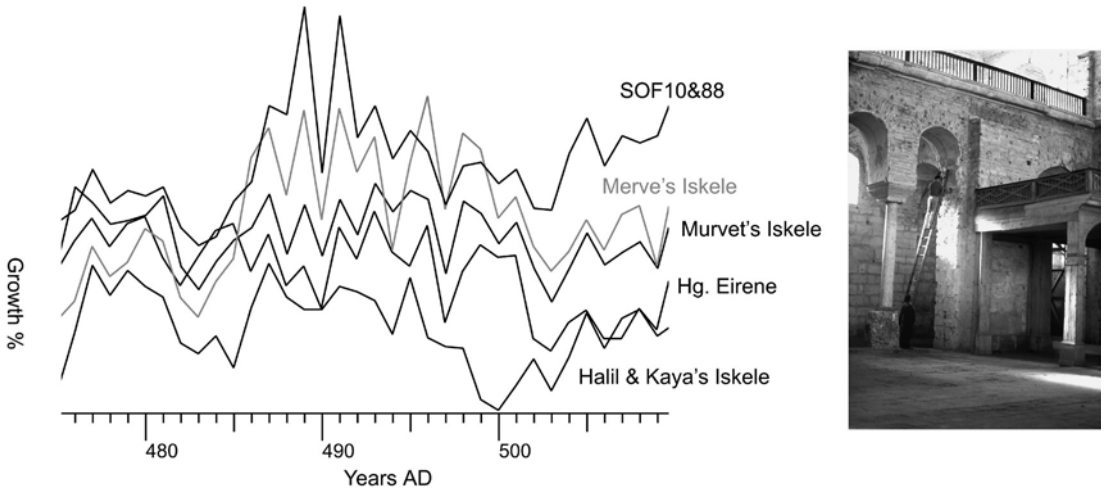


Fig. 12. A unique set of signatures from 481–502, originally nicknamed "Mürvet's spider" because of the dangling dips in the graph representing years with adverse growing conditions, first noticed in her *iskele*, then in Merve's *iskele*, Capidava, the Sinop Castle walls, Halil's and Kaya's four-phase *iskele* (IJKL 74-81), some of the Hg. Sophia pieces, and the Hg. Eirene forebay (photograph on the right). Nowhere else — in Central Anatolia, in Greece, or in Italy — do we see this, and it seems to be a Black Sea (or environs) peculiarity. Source: Aegean Dendrochronology Project, C. L. Pearson; photograph by C. L. Striker.

in the southeast bay, **Fig. 11**).[66] Twelve sapwood rings are present. The radiocarbon date for the group is 518±33 at 1 sigma. This fits in perfectly with the Justinianic construction date of 532–537 given by Procopius. There is no reason to doubt him. SOF-50 and 52 (ending in 535) are from tie-beams in the four-column insert in the north gallery's center bay — closer in time to the primary construction than we had originally thought.[67] We are still working on SOF-5, 7, 15, 49, 55, 63. These and other tie-beams should be primary. Some samples are undoubtedly from the Black Sea, explaining why we have had so much trouble sorting out our 179 samples from this extraordinary building. Three radiocarbon dates support the placement of this data set.

At this point a comment on the Black Sea imports is in order. **Fig. 12** shows a curious set of signatures from 481–502, originally nicknamed "Mürvet's spider" because of the dangling nature of the years with adverse growing conditions, first noticed in her *iskele* (see No. 64 above) and then also found in Merve's *iskele*, Capidava, the Sinop Castle walls, Halil and Kaya's four-phase *iskele* in grid squares IJKL 74–81, some of the Hg. Sophia pieces, and the Hg. Eirene forebay (see inset to the right in **Fig. 12**). Nowhere else — on the Anatolian mainland, in Greece, or in Italy — do we see this, and it seems to be a Black Sea (or environs) peculiarity, likely to be of the greatest future use in doing dendroproveniencing.[68]

(75) ***Istanbul, Yenikapı: Marmaray, YMK-Halil and Kaya's Region III, İskele Kazı in Grid Squares IJKL 74–81, Phase 1***

Four samples: TYMK365a, 366a, 383a, 385a. The chronology runs from 470 to 527Bark. This wood was almost certainly imported from Romania (Capidava) or the Black Sea. Elevations are ▼-0.27 m to ▼-0.84 m. The samples were collected in 2006.

At this point the Marmaray Middle Group (27 data sets from AD 410 to 911) ends. Below we show how well it fits with the 46 non-Marmaray data sets (**Fig. 13**). The *t*-score is 9.74, overlap or n = 502 years, r = 0.40, trend coefficient = 62%, D-score = 121.6, and WJ = 66% of 186 available years. This is even more encouraging than the comparison, made earlier, for the late material. Not only does the geographical distribution of the non-Marmaray data sets range from North Italy to the Black Sea, but the earlier matches in this series also include some sites which are practically unknown, and there is less corroborating evidence to support the dendrochronological placement.

[66] For a graphic estimate of the probable progress of construction, into which estimate our Hg. Sophia primary samples are now fitting, see Mainstone 1988, p. 186.

[67] Note that they are much earlier — by centuries — than the corresponding tie-beams in the south gallery of the center bay (No. 27 above), which date from 910.

[68] S. W. Manning first noticed that the originally proposed fit (forced by an estimated — and, as it turned out, unnecessary — allowance for 10–20 missing sapwood rings on the exterior) was not in accord with the radiocarbon results. Subsequently, Ważny identified the waney edge (WK) on SOF-14, which allowed us to adjust the rest of the chronology to its proper position.

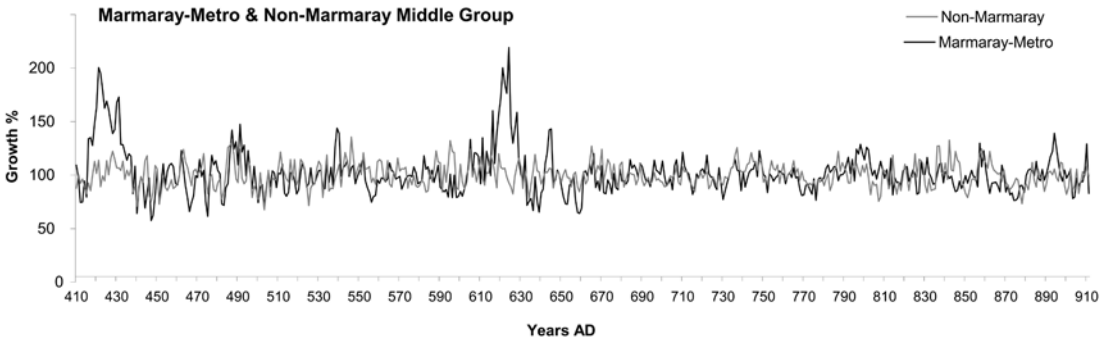


Fig. 13. Graph of the fit between the Marmaray Middle Group (black line: 27 data sets from AD 410 to 911) and the 46 non-Marmaray data sets (grey scale). The *t*-score is 9.74, overlap or *n* = 502 years, *r* = 0.40, trend coefficient = 62%, D-score = 121.6, and WJ = 66% of 186 available years. The geographical distribution of the non-Marmaray data sets ranges from North Italy to the Black Sea, as most probably do the Marmaray data sets. The dips in the graph reflect adverse growing conditions. Source: Aegean Dendrochronology Project, C. L. Pearson.

(76) *Aydın, Karacasu: Aphrodisias, North Terrace Trench*

APH-5 (multiple radii). The ring-sequence runs from 394 to 499vv. This sample is from an unlabelled box found in the Aphrodisias depot by Martha Singer. The top of the box was marked "N. Terr. Trench 2, SE2, Trench 8, 12 August 1965" and contained 16 partly burned fragments with Late Antique pottery, green glaze, and bones (information from the ticket on the box).

(77) *Ephesos: Harbor*

Samples EPH-25 and 26. The chronology runs from 417 to 488vv with no sapwood. Zabehlicky has published a compendium of the literary and epigraphic evidence for the use of the harbor and the periodic need to dredge the channel from the harbor to the sea as it gradually silted in during the early centuries AD.[69]

(78) *Ephesos: Hanghaus II, Unit 7, West Wall of Room 32C*

These samples, EPH-74 and 75, in several fragments, are from a bag of burned oak sections, from the interior of the wall (possibly part of the framing).[70] The chronology runs from 286 to 471vv. This is much later than the third century's "great changes after the earthquake of 262,"[71] about which we were told at the time of collection,[72] but well before the early-seventh-century destruction (second decade) noted by Vetters,[73] and more recently

[69] See Koester 1995, pp. 201–215; Kraft et al. 2007.
[70] Krinzinger 2002, p. 155, Taf. 1.
[71] Ladstätter 2002, pp. 24–29. We were not able to determine at the time of collection whether our samples were primary or from a late intervention.
[72] Rather later than the dates proposed in Parrish 1999, pp. 507–514.
[73] Vetters 1977, p. 24.

by Ladstätter in her analysis of the coinage.[74] There is no discernible sapwood since the wood is completely carbonized.

(79) *Ephesos: Harbor*

Samples EPH-20 and 24. The chronology runs from 383 to 455vv. There is no sapwood. The overlap with the other harbor pieces is too short to combine them into one sequence. Zabehlicky has published a compendium of the literary and epigraphic evidence for the use of the harbor and the periodic need to dredge the channel from the harbor to the sea as it gradually silted in during the early centuries AD.[75]

(80) *Sinop: Sea Wall between Towers 24 and 25 on the North Side of the City*

SIN-2 and 4. These are the best of four sawn oak stretchers from the interior of the wall. The chronology runs from 374 to 434Bark with 22 sapwood rings present. All were in the section of wall between Bryer and Winfield's Tower 24 and 25.[76] The sequence has "Mürvet's spider" signature.

(81) *Ajdovski Gradec (Croatia): Late Roman Well-Lining*

AJD-1, 3, 11, 12, 19, 21, 27, 28, 30. The chronology runs from 272 to 390vv, with 8 sapwood rings. Aleksandar Durman estimates that it ought to be Late Roman.

(82) ***Istanbul, Yenikapi: Marmaray, "Theodosian" Wall in Grid Square H/71***

Four samples: YMK-436, 444, 445, and 446. The chronology runs from 200 to 382WK. These radially-split boards are from an oak veneer on the east face (that is, the harbor-side) of the wall, north of the new pit and west of the İskele Kazı (see note in No. 88 below). Russell Meiggs has published a photograph of an identically-veneered wall in Ostia.[77] The best fits are with Italian sites. The samples were collected in 2008.

(83) *Garigliano: River B (Pilings where the Appian Way bridges the Liris River)*

The chronology runs from 232 to 382vv. The samples were collected decades ago from several sets of bridge supports — with an underwater chainsaw — by excavator Dominic Ruegg,[78] and then studied by the late Bernd Becker who kindly provided us with the master chronology. The radiocarbon dates are 245–279±50 or 335–369±20, somewhat different from those reported by the excavator in his dissertation.

[74] Ladstätter 2002, p. 17.
[75] Koester 1995, pp. 201–215; see also Kraft et al. 2007.
[76] Bryer and Winfield 1985, pp. 76–79; see plan on p. 88. These towers have Bryer and Winfield's "M"-type of masonry which they think should be late. Our samples are from the interior core of the wall.
[77] Meiggs 1960, Pl. XIX; for this wall, see also Kızıltan 2007, p. 171 and 172, fig. 5.
[78] Ruegg 1995, pp. 103–111.

(84) *Thessaloniki: Hg. Sophia, Early*

THS-Early: 16, 17, 18. These are the tie-beams from the primary construction on the north side of the naos. The chronology runs from 264 to 380vv.[79] The dendrochronological date is in the middle of the range suggested by a single 14C date of 1723+/-20 BP, or a radiocarbon range for the last ring (82 years later than the decade from which the radiocarbon sample was cut) on THS-16 of 321–486.[80]

(85) ***Istanbul, Sirkeci: Metro, Deep Sounding***

No further information is available. These are from multiple contexts in this deep sounding. SMK-Master (24 samples: SMK-4(1), 9, 10, 11, 12, 13, 18, 22, 27, 37, 40, 44, 48, 92, 109 [with 21 sapwood rings], 112, 127, 128, 130, 131, 133, 136 [with 7 sapwood rings], 140, 265). The chronology runs from AD 51 to AD 364vv. Elevations are ▼-3.00 m. The innermost ring on this data set is so far our oldest dated ring from the Marmaray Project. The samples were collected in 2010.

(86) *Enez/Ainos: Roman Grave No. 3*

Two samples: ENR-1 and 3. The chronology runs from 282 to 351WK. The graves that according to the excavator Sait Başaran are "identical to Grave 3" have Roman imperial coins dating from 240–250.

(87) *Venice: San Francesco del Deserto, Channel Revetment*

Single Sample: SFD-11. This is one board with a ring-sequence running from 257 to 346vv and with no apparent sapwood. The radiocarbon date is 348±60 at 2 sigma. Albert Ammerman notes that this helps demonstrate Roman attempts to channel the water flow in the Venetian lagoon at this very early period.[81]

[79] Theocharidou (1988, p. 13) notes that there are more coins in the rubble of the surrounding area from the time of Theodosius I (383–392), Arcadius (395–402), and Honorius (393–395) than any other. See also pp. 167–168.

[80] Mango (1978, pp. 89–90) calls it an eighth-century church of "unoriginal sixth century design." Ćurčić (2010, pp. 258–260) remarks on the late-fifth- and early-sixth-century capitals. We have no explanation for the discrepancy between these judgments and the late-fourth-century date for the tie-beams. It seems implausible that reused wood should have been employed in such an important building, unless somehow the wood is spolia from the destroyed basilica directly underneath. See Ćurčić 2010, p. 105, fig. 99, where the north wall of the Hg. Sophia's naos — from where these samples were taken — lies directly on top of the north wall of the early basilica underneath.

[81] Grandi 2007, p. 5; see fig. 3 for a schematic rendering of these subaqueous revetments. This particular context is shown in fig. 3 as (9056-A).

(88) ***Istanbul, Yenikapı: Marmaray, 100 ADA (Region II), Site 7A in Grid Square L65, West Face of the East Wall Near the "Theodosian" Wall***

Single sample: YMK-439. The ring-sequence runs from 132 to 281vv. The sample was collected from Room 7A in L65 near the opposite side (on the west) of the wall from No. 82 above. YMK-439 from Room 7A — Mehmet Ali Polat in an e-mail commented that "this is the plank which was taken from under the Constantinian wall" — and YMK-446 from the east face of the "Theodosian" wall were cut from the same tree. The cutting date (AD 382) for the wall veneer on the latter is to be judged by the waney edge (WK) present on both YMK-436 and 445, but not on YMK-446. No sapwood is present on this sample (YMK-439), however. The absolute placement is not supported by radiocarbon, unless the earlier of the two Heidelberg dates is wrong. There is an excellent fit with an unpublished oak chronology from Hungary, as well as a good fit with Roman Enez. The samples were collected in 2008.

(89) *Zhitosvyat (Bulgaria): Cremation Tumular Grave*

Single sample: CTG-1. This is from an unpublished grave in Zhitosvyat, near the town of Karnobat in Southeastern Bulgaria. The ring-sequence runs from AD 86 to AD 182vv. The sample consists of charcoal with no discernible sapwood, thought by the excavator Roumyana Georgieva to be from the second/third century AD.

(90) *Sisak/Siscia: Roman Pilings Chainsawed from the Kupa River Bed*

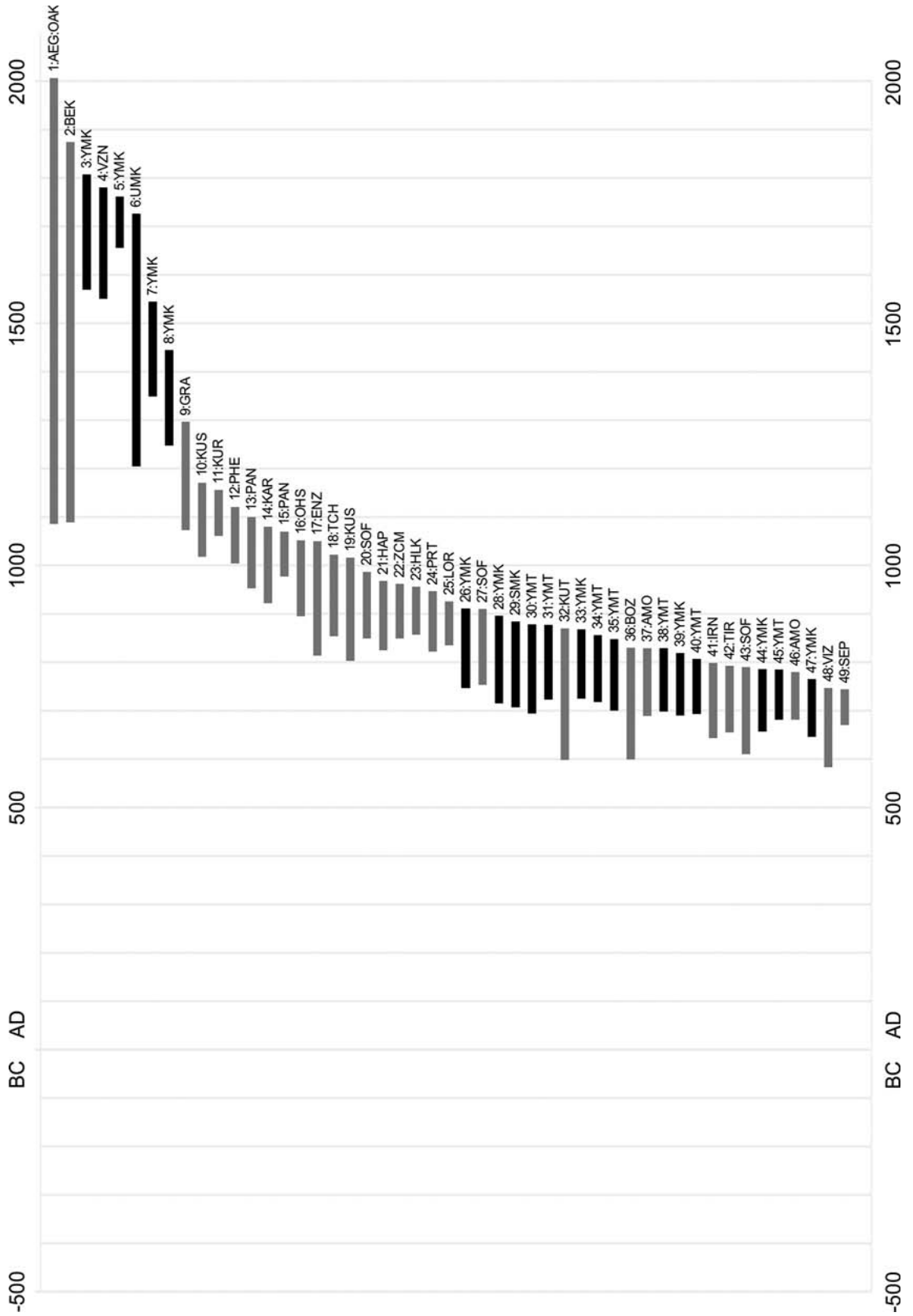
Twenty-one posts: SIS-2, 9–12, 14–17, 19–20, 23, 26–29, 31–32, 44, 55, 59. The chronology runs from 204 BC to AD 159. The samples were collected with Aleksandar Durman. All posts were re-measured and re-confirmed by Tomasz Ważny. They are thought to be from a smith's shop (*šindra*). Over 1000 first-to-third-century Roman coins give an indication of the approximate date of this site. More specifically, a coin of Tiberius discovered in one of the iron shoes (nailed over the point of SIS-7), supports this placement. All other earlier Sisak chronologies and associated radiocarbon dates need to be re-examined, since it is now clear that other building activities went on both before and after the Roman period.

(91) *Okuje/Otok (Croatia): Lining of Roman Well No. 3*

Four sawn vertical planks: BRO-311, 312, 313, 314. The chronology runs from 4 BC to AD 98WK. Eighteen sapwood rings are present. The well is several meters below present-day ground-level. The best fit is (not surprisingly) with Sisak, only 38 km away.

(92) *Fotada River (Greece): Logs Found During Dredging Operations in the River Bed*

BCO-789. The chronology runs from 33 BC to AD 97vv. The radiocarbon date is 95±20. These riverine oaks were collected, along with BCO-6 mentioned above, by Becker,


2000
1500
1000
500
BC AD
-500
1:AEG:OAK
2:BEK
3:YMK
4:VZN
5:YMK
6:UMK
7:YMK
8:YMK
9:GRA
10:KUS
11:KUR
12:PHE
13:PAN
14:KAR
15:PAN
16:OHS
17:ENZ
18:TCH
19:KUS
20:SOF
21:HAP
22:ZCM
23:HLK
24:PRT
25:LOR
26:YMK
27:SOF
28:YMK
29:SMK
30:YMT
31:YMT
32:KUT
33:YMK
34:YMT
35:YMT
36:BOZ
37:AMO
38:YMT
39:YMK
40:YMT
41:IRN
42:TIR
43:SOF
44:YMK
45:YMT
46:AMO
47:YMK
48:VIZ
49:SEP

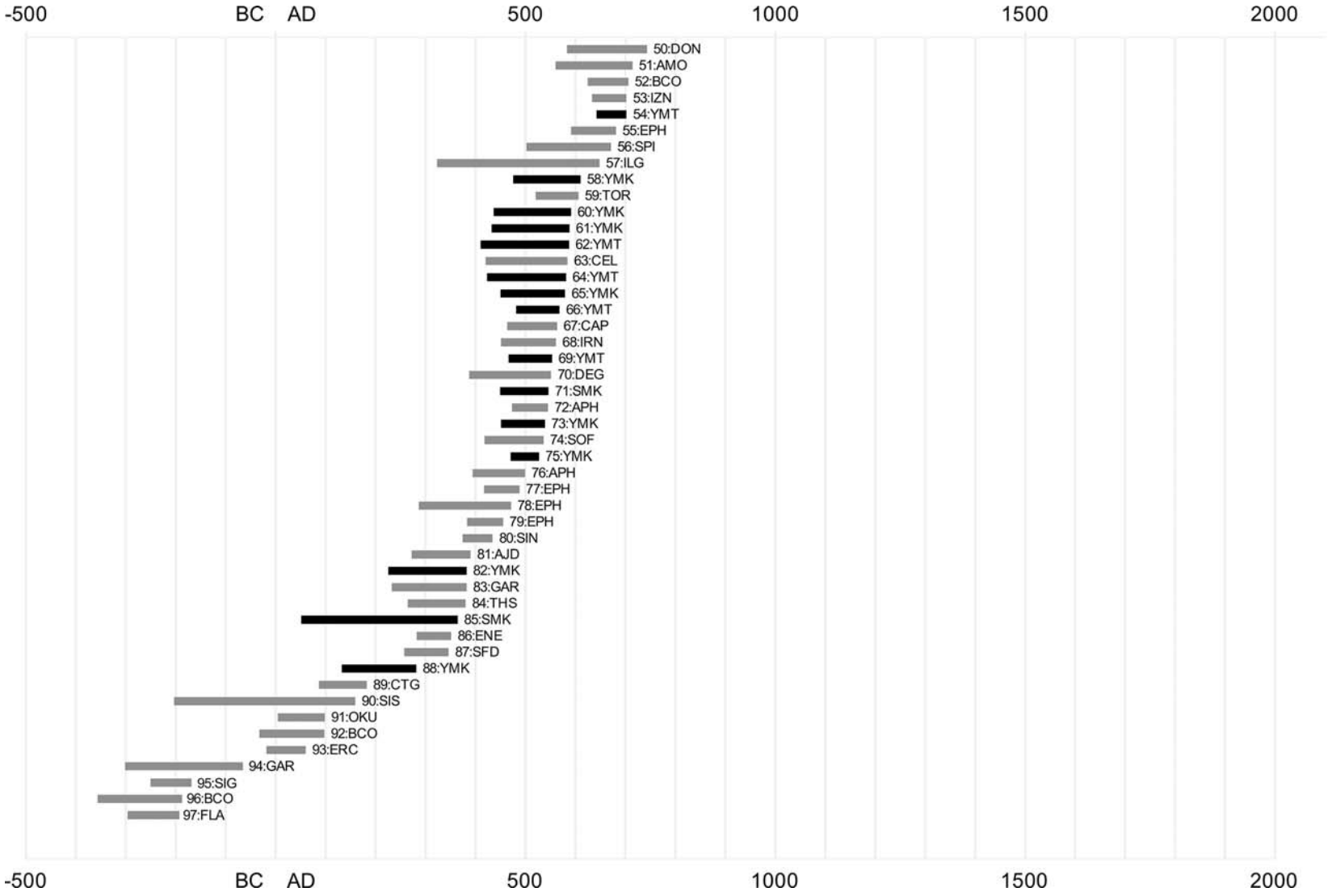


Fig. 14. Bar-graph of the 97 oak tree-ring data sets in this report spanning the last 2367 years. Marmaray Project data sets are shown in black; non-Marmaray data sets are shown in grey scale. Numbers on the right refer to the relevant paragraph in the date list. Source: Aegean Dendrochronology Project, C. L. Pearson and P. Brewer.

Kromer, and Maniatis in 1986 in their attempt to find pre-glacial material. The Aegean Dendrochronology Project continues to revisit these and other Balkan rivers annually as we search for sub-fossil wood.

(93) *Ercolano/Herculaneum: Scavi Novi*

ERC-22 and 23. The chronology runs from 19 BC to AD 60vv. Both were retrieved from the excavation *cantieri* and are said to be from the port and vaulted cellars of the S*cavi Novi*, where they had been excavated about a decade before we collected them. They and a large number of fir (*Abies*) and spruce (*Picea*) timbers were discovered stacked as lumber in a carpenter's workshop. Many showed signs of use and re-use, as well as burning on their exteriors from the Vesuvian eruption.[82]

(94) *Garigliano: River A (Pilings where the Appian Way bridges the Liris River)*

Provenience is the same (but a different set of bridge pilings) as Dominic Ruegg's slightly later group (see No. 83 above). The sample was measured by the late Bernd Becker. The chronology runs from 303 to 66vv BC.[83] The radiocarbon date for the end is 73±20 BC.

(95) *Šibenik (Croatia): Gusteransici Shipwreck*

One sample: SIG-1A. The ring-sequence runs from 251 BC to 169vv BC. No sapwood is present. The ship is thought by excavator Zlatko Gunjaća to be from the late second/early third century.

(96) *Arapis River (Greece): Logs Found During Dredging Operations*

Four samples: BCO-2, 3, 4, 5. The chronology runs from 357 BC to 188vv BC. The radiocarbon date for the end is 191 BC±45. These riverine oaks were collected by Becker, Kromer, and Maniatis in 1986 in their attempt to find pre-glacial material.

(97) *Florina, Lofos (Greece): Agiou Panteleimonos*

FLA-8AB and 9ABCDE. The ring-sequence runs from 297 to 193vv BC. Excavator Maria Akamati's estimated construction date is ca 200 BC. All samples were found in the destruction debris (perhaps fallen roof beams) from the field of M. Tazenkas. The samples were excavated on 27 July 1982. The building was destroyed between 120 and 84 BC.

[82] Kuniholm 2002, pp. 235–239.

[83] Here we have resisted the temptation to add the 513-year chronology from the Comacchio ship (Kuniholm et al. 1992, Berti 1992), which, although it would have given us a long extension from 22 BC (Bark present) to 534 BC, is composed of boxwood (*Buxus sempirvirens*). The boxwood does crossdate with the oak, however.

At this point we pause to catch our collective breaths. Ninety-seven chronologies and 2367 years are sufficient for the time being (see **Fig. 14**). Some very long chronologies in the first millennium — like the Bekdemir Mosque's in the second millennium — would reassure us that everything is properly in place. There is more early material from the very early AD period and the BC period yet to be placed, but that is outside the scope of the Marmaray story. The more or less steady progress of life along the Marmara shore, albeit with the interruptions noted by Magdalino, is a story in itself. But, as we observed at the very beginning, this long chain of dates could never have been developed without the help of the Marmaray material. Some tantalizing topics for the future remain.

First, for the dates themselves, with every new sample that we add to the chronologies presented here, the more solid the dates presented will become. The current state for the earliest material in this long chronology is thin and relies heavily upon historical sources for confirmation. We will not be able to claim absolutely pure dendrochronological dates for many of these early samples until we have filled the gaps that exist between modern Aegean forest oaks and the Marmaray *iskele*s many times over. Replication is the keynote. What we present here is a work in progress, which we hope will in time become an invaluable resource for archaeological, historical, economic, and architectural — not to mention climatological — research in Istanbul and across the Aegean region.

In the meantime, we envisage many exciting developments for the work presented here: it should be possible, for example, with the assistance of the excavators, geologists, and surveyors, to draw fairly accurate lines to delineate the Yenikapı shoreline from period to period. We may — for example — be able to come up with an estimate for the average lifetime of an *iskele*. Patterns of import for timber from period to period should become clearer. We may also have the opportunity to ask where many of the ships whose timbers were found at Yenikapı were built. Anywhere in the Roman/Byzantine world is possible. As soon as the samples are forthcoming, we will try to fit them into our chronological framework. The coordination of our results with the vast quantity of artifacts remains ahead of all of us. Our work with the Marmaray wood is only partially done.

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