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Dendrochronological Investigations in the Aegean and Neighboring Regions, 1983-1986

Peter Ian Kuniholm

Cornell University, Ithaca, New York

Cecil L. Striker

University of Pennsylvania, Philadelphia

Abstract

In the four years of dendrochronological investigation covered by this report [1983-1986] we have increased the number of sites studied and samples collected by about 70%, extending the scope of prospecting beyond Greece and Turkey to Yugoslavia and Italy, and including prehistoric, ancient and medieval sites as well as natural forest and riverine wood. The number of samples which can be crossdated has now almost doubled, and a revised absolute oak master chronology for the region now extends from the present to A.C. 1073. The upgrading of computer facilities and the addition of new long sequences has required a forward correction by 35 years of the absolute oak chronology for all sets heretofore dated before 1546. We now have a sufficient number of samples with bark or terminal growth ring for preliminary statistics on the distribution of Aegean oak sapwood, ultimately essential for felling year estimation and archaeological interpretation. The total number of dated oak samples is also large enough for a first synopsis of sample abundance in the region studied. Both of these results differ from those obtained by others for Northern Europe and the British Isles.

Introduction

Since our last report in this journal (Kuniholm and Striker 1983), the authors have carried out four more annual campaigns of dendrochronological prospecting in Greece, Turkey, Yugoslavia, and Italy.[1] These yielded 211 samples from 13 forests, six from two natural riverine sites, 640 from 48 standing buildings dating mostly from the medieval period to the present, and 281 from 26 archaeological sites, including charcoal. This brings the total number of samples collected since the beginning of this project in 1973 to more than 2,770 including 545 from 63 forests, six from two natural riverine sites, 1,776 from 139 standing buildings, and 452 from 50 archaeological sites.

Prior reconnaissance of sites to be sampled, together with increased understanding of the nature and requirements of dendrochronology on the part of cooperating archaeologists working in the region, significantly reduced the number of buildings and sites inspected in this period which proved to be unsuitable for dendrochronological study. Nevertheless, our work in the Peloponnese, in the Province of Bursa, and in southern Yugoslavia required primary exploration for our purpose, yielding, as in the past, approximately one site among three visited appropriate for sampling.

Our dendro-archaeological approach continued to keep in balance three objectives: to extend the absolute regional tree-ring chronology backward in time, to investigate buildings and sites where tree-ring dating might solve problems of chronology, and to enlarge the understanding of regional tree-ring response to climatic variation, including the determination of the geographical limits of synchronous response. Since any given sample has potential information useful for one or all of these objectives, and since this can be determined only by laboratory analysis, we continued our practice of collecting all samples from buildings or sites which from field inspection appeared to have at least 50 growth rings.

Climatic Response of Forest Trees in the Aegean Region

Since 1983 the zone within which we have been able to crossdate trees from living forests has remained the *[Page 386]*same on the east and south. To the west and north, however, the limits of this climatic zone have been pushed west across the Adriatic to Monte Pollino in Calabria, Italy, and north to the Ötztal, just west of Innsbruck, Austria.

In 1984, F. H. Schweingruber kindly provided us with his unpublished curve of *Pinus leucodermis* from Monte Pollino (1441-1980), and immediately we realized that we had not only an excellent fit with *Pinus leucodermis* at Grevena, Greece (1255-1981), with 540 years of overlap, but also a good fit with *Pinus nigra* at Çatacik Forest, east of Eskisehir, Turkey (1293-1981), also with 540 years of overlap. Our report of these findings at a conference in 1984 prompted F. Serre-Bachet (1985) to measure cores collected a decade earlier by her from Monte Pollino (1148-1974), and she, too, found good crossdating. A year earlier V. Siebenlist-Kerner (1984) had published chronologies of larch (*Larix*). stone pine (*Pinus cembra*) and spruce (*Picea abies*) from the Ötztal, and these, too, fitted the curves from S. Italy, Greece, Turkey, and even Cyprus. It seems that the higher the altitude (1500 to 2000m), the better the fit. Curiously, a chronology from Mt. Etna in Sicily, also kindly provided by Dr. Schweingruber, does not crossdate at all with Monte Pollino which is only 255km to the NNE, much less with more distant forest sites in Greece and Turkey.

The continuation of prospecting for wood from natural forest, riverine and bog sites is essential to several broad aspects of our investigation. First, the aforementioned connections to the north and west suggest that if we are able to connect our Aegean chronologies with existing long absolute northern European chronologies by way of intermediate natural as well as man- made sites in Yugoslavia and Italy, it may be possible to bridge lacunae in the Aegean floating chronologies by way of the northern European chronologies.

Second, the creation of numerous and widely-distributed long oak and conifer chronologies from natural sites, where the provenance of the wood is known, alongside chronologies from man-made sites, where it is not, will allow us ultimately to define microclimatic regions within our large area of investigation. The process of defining the characteristics and limits of these regional chronologies is empirical, statistical and descriptive, and is accordingly complex and slow (Schweingruber 1985). But as the data base increases and our understanding of microclimatic variation becomes more refined, it will in time be possible to address such questions as the source of wood used in a particular building or the lumber trade in a particular period. The recent proof of continuous export of Baltic oak to England and the Netherlands from the 14th to 17th centuries (Eckstein, Wazny, Bauch and Klein 1986) demonstrates the exceptional value of such inquiry.

The Master Chronologies

From the 23 buildings newly investigated or re-sampled in Greece in this period (Fig. 1 and Table 2), a large number of samples crossdate with our existing North Greek Master Chronology, most exceptions being either not of oak or possibly too early. Noteworthy among these sets are felling year dates, given by the presence of bark, of 1759 for an undocumented major remodeling of the service buildings of the Monastery of Rossanou at Meteora; and in Thessaloniki, the undocumented date of 1597 for construction of the Octagonal Tower or Frourio Vardari, the date of 1535 for the much disputed original construction of the White Tower, and the date of 1800 for the remodeling and re-roofing of the katholikon of the Monastery of Vlatadon, attested to by an inscription of 1801. Other crossdated sets in which the last preserved ring is not the terminal growth ring will require further interpretation for estimating felling years and their significance for the structural history of the buildings from which they come.

The increasing ease in crossdating samples which fall within the time limits of the North Greek Oak Master Chronology has also been helpful in our ability to add to the relatively few samples from the early 16th century by selection for sampling of several buildings presumed to date from this period (e.g. the churches at Meteora).

The common response of trees to climatic variation over long distances in the region, reported earlier by us, made it likely that we would find further correspondences in samples from geographically widely separated buildings and sites. As we approached the limits of progressively earlier buildings appropriate for sampling in Greece, especially from the first millennium A.C., it was logical that we extend the geographical scope of our sampling to southern Yugoslavia and western Turkey, returning in the latter case to several buildings from which we had taken samples a decade before. We include the results of our earlier sampling in this report (Fig. 2 and Table 2).

By far the largest building to be investigated was St. Sophia in Istanbul where the samples obtained might be expected to yield a continuous sequence, beginning with the period of its original construction in the early 6th century, continuing with subsequent modifications in the building, and ultimately connecting with our absolute North Greek Oak Master chronology. The results obtained thus far from the analysis of 171 samples taken from the building have fallen somewhat short of this ex-*[Page 387]*pectation (Kuniholm and Striker 1985). Nevertheless, we have been able to crossdate one set with the North Greek chronology from the porch of the Türbe of Mustafa I, and in time it may be possible to connect sequences already combined from other contexts throughout the building with our absolute chronology.

Samples from two buildings near Çanakkale also crossdated securely with the North Greek Oak Master chronology, yielding in both cases the exact felling and presumed construction years from samples with bark preserved. From the Castle of Kilit Bahir the terminal growth ring of 1463 is identical with its construction date given by inscription. A tower known as Cezayirli Hasan Pasha Köskü near ancient Troy, heretofore undated, yielded a felling year of 1783.

A set of 17 samples from the Church of the Dormition of the Virgin at the Monastery of Gracanica near Pristina in southern Yugoslavia not only crossdates closely with the North Greek Oak Master curve but also provides the earliest extension of the curve backward in time to 1073.

The significance of this is that a master oak chronology, which we had initially proven to be valid for Northern Greece, and which we could demonstrate from samples taken from forest trees extended over a much wider region, can now on the basis of samples from older buildings be shown to include some sites in southern Yugoslavia and northwestern Turkey.

It is also of interest to compare the summary of results given here at the end of Table 2 with those reported earlier by us. While the absolute number of crossdated samples and sites have both increased by about 70%, the proportions of crossdated sites of about one-half and of samples of about one- third have both remained constant, an increasingly strong indication of the future prospects for crossdating similar material.

To reflect these findings appropriately, we have created a new Aegean Oak Master Chronology subsuming all crossdated sequences from this expanded region, while preserving at the same time the North Greek Oak Master Chronology as a subset of this larger chronology (Fig. 3). This is a first step toward defining sub-regions for the purpose described above.

Correction of the North Greek Oak Master Chronology

Since the publication of our North Greek Oak Master chronology as of September 1982 (Kuniholm and Striker 1983: 416, Fig. 3) we have been concerned with resolving two of its problems. The first was verification of the early 16th-century bridge where overlap in the years 1523-1546 was short and the number of samples limited. The second was that dendrochronological dates obtained by us for some buildings from the 13th to 15th centuries were too early, falling, when sapwood was taken into account, as much as three decades before their accepted dates.[2]

Two factors were helpful in resolving these problems. In spring 1986, the dendrochronology laboratory at Cornell University completed a two-year major upgrading of computer facilities, involving the full conversion from computer punchcards to interactive microcomputers, and reducing to a fraction the time formerly needed to run crossdating tests. This made possible for the first time the highly efficient re-running of a series of statistical checks and controls of our absolute oak chronology. This capacity could then be combined with newly-acquired sets of samples collected in the 1984 and 1985 campaigns specifically to correct the 16th-century deficiency, including several with long tree-ring series.

The process of control and verification is continuous and still underway, but it has already yielded a significant correction affecting the two aforementioned problems, bringing with it benefits and some additional problems as follows. The thin bridge at 1523-1546 may now be shown to have been an incorrect placement. It is replaced by new sequences spanning the early 16th century and requiring the advancement by 35 years of all earlier components of the absolute oak chronology. This brings the majority of pre- 16th-century sites into closer agreement with accepted dates established by inscription or historical record.

There are exceptions, however, in particular the Church of the Holy Apostles in Thessaloniki where a revised dendrochronological date of 1329 as the *terminus non ante quem* for construction cannot for the present be reconciled with the accepted date of 1310-1314 established by inscription and known historical circumstances. And this problem also affects the dates of the closely-related churches of Hg. Aikaterini in Thessaloniki and the Olympiotissa at Elasson. Since we cannot predict how long it will take to reconcile these and related discrepancies, the revised dates for these and other problematical buildings are given in parentheses in Table 2 to indicate their provisional nature.

Felling Year Estimation from Sapwood

The exceptional value of dendrochronology as a dating tool is its capacity to establish dates exact to the year for the growth of tree-ring sequences. Since lumber for rough construction is almost always used green because of its *[Page 388]*ease of working (in contrast to wood seasoned even as little as one year). We may presume the felling year of a tree and the year in which it is to be used for construction to be the same. This presumption is verified by others in regions where wood from dated buildings has been dendrochronologically studied for this purpose (Hollstein 1980: 35-36) and is corroborated by our evidence from the Aegean.

However, the exact felling year of a tree can be established only if the bark or terminal growth ring is preserved; and this occurs infrequently, even in rough construction, being confined to such members as joists or sawed-off stumps of temporary scaffolding putlogs. We have them in no more than about 10% of the buildings or phases we have studied. Normally timbers are squared by the carpenter for use, removing an unknown number of rings.

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Table 1. Mean number of sapwood rings in 21 sets of Aegean oak samples.

No. of rings	Site	No. of samples
34±4	Çanakkale, C. Hasan Pasa köskü	4
33±8	Arnaia, Chalkidiki, forest	10
33±7	Meteora, Rossanou Monastery	8
32±12	Aiani, Hg. Demetrios	11
32±7	Palamas, Hg. Athanasios	11
31±6	Pythion Castle	5
30±11	Devecikonagi, forest	25
27±11	Istanbul, Belgrade Forest	70
27±9	Karabük, Zonguldak, forest	10
27±8	Thessaloniki, Vlatadon Monastery	19
27±5	Siatista, Nerandzopoulou House	6
26±8	Yenice, Zonguldak, forest	11
26±3	Çanakkale, Kilit Bahir Castle	14
23±6	Rendina, Monastery	8
23±5	Didymoteichon, Ç. S. Mehmet	23
21±6	Thessaloniki, Nea Panaghia	18
20±6	Ambelakia, Schwarz House	10
20±3	Livadia, Paterma Forest	13
18±4	Teriachio Forest, Ioannina	13
18±3	Thessaloniki, Frourio Vardari	21
13±1	Istanbul. St. Sophia	4

The obvious usefulness in determining how many rings were lost in the process of squaring, thereby allowing an estimate of the felling year of the timber, has stimulated inquiry about the number of sapwood rings in mature oaks (Baillie 1982: 54-60 and Eckstein 1984: 21-27). If this number conformed to normal distribution, even if only one sapwood ring were preserved in an oak sample, it would be possible to estimate the probable statistical range in which the felling year occurred and, within the same limits, the construction date when it was used. The estimate would also be useful in establishing a more proximate *terminus post quem* for felling years of oak samples in which only heartwood is preserved.

Research to date on this issue has revealed not only significant regional variation in the mean numbers and distributions of sapwood rings, but differences in trees growing at different altitudes in the same region, and even differences from samples taken at different heights from the same tree (Hughes, Milsom and Leggett 1981). Thus, it is essential both that caution be exercised in applying these estimates and that the regional data bases for them be increased and refined.

We are now able to offer a preliminary analysis of numbers of sapwood rings in Aegean oak based on 152 samples from 7 forests and 162 samples from 14 crossdated sets from buildings in which bark or terminal growth rings are preserved, a total of 314 samples from 21 sets (Table 1).[3] Our results for the Aegean material are consistent with the high level of variability found elsewhere; and we have found no correlation between sapwood rings and such factors as geographical location, altitude (known for forest sites), date, or sample abundance.

Thus with regard to geographical location, the difference in teh mean number of sapwood rings betweeen teh most western forest, Teriachio (18 ± 4), and that of Yenice (26 ± 8) almost 1200 km to the east, is only 8; but between Teriachio and Arnaia (33 ± 6), only 250 km to the east, it is 15. Similarly, with regard to altitude, the mean number of 27 sapwood rings is the same for both Istanbul, Belgrade Forest, at an altitude of 70-80m, and for Karabük, at an altitude of 900m. Corresponding absence of correlation is found among the samples from buildings, with th additional problem that, in most cases, the source of wood is unknown.

Thus, while the number of sapwood rings in Aegean oak analyzed by us so far appears to conform to normal distribution (Fig. 4) with its mean at 25.6 rings ±9 for one standard deviation, this should not obscure the significant differences from set to set, not to mention from sample to sample. Accordingly, the use of this value for estimating construction years of buildings must always be with cautious awareness of its statistical nature and of the fact that the actual original number of sapwood rings in a randomly selected unknown sample with incomplete sapwood could differ significantly from it.

Sample Abundance

In order to examine more easily the distribution of our samples and to determine whether they cluster in phases, we have shown our nine-century long absolute oak master chronology in graphic form as averages for each decade over this time span (Fig. 5). We assume that beginning with the 13th century the samples are sufficient in number to represent more than simply our selection of sites or the accident of preservation; and these fall into four distinct phases with maxima at 1263, 1435, 1692 and 1898+, and minima at 1342, 1537 and 1830-32. Since these samples are almost all from wood members in otherwise masonry buildings the sample population is fairly homogeneous, lending itself to speculation about the reason for its cyclical nature.

If these are anthropogenic rather than natural, as has been suggested for transalpine Europe and the British Isles (Baillie 1983: 42-44), we must first inquire whether these cycles are primarily a reflection of timber availability or are rather a measure of the broader phenomenon of building activity; and then the extent to which they relate to regional historical or economic phases. A difficulty in de-*[Page 391]*riving information such as this is that abundance curves such as ours are composites of data including last preserved rings and sample lengths, with the latter values arbitrarily determined in many cases by the way logs were split for use as building timbers. Strictly speaking, a more accurate measure of building activity would be a curve limited to last preserved rings. In this the maxima and descending values would be identical, but the minima and ascending values different.

Notwithstanding its tentative nature and the complex variables of which it is made, the Aegean sample abundance curve appears currently to bear relationship neither *[Page 392]*to historical events in the region nor to the periods of prosperity and decline presumed to be associated with them. Indeed, if anything, the relationship seems to be inverse. The first maximum, 1263, falls at the end of a period of presumed decline defined by the Fourth Crusade and Latin Occupation and descends to the minimum at

1342 during a period of presumed Palaeologue recovery. The next maximum at 1435 comes toward the end of a final period of Palaeologue decline; and, while the increase in sample abundance might reflect increasing Ottoman activity in the region, one would expect this to continue rather than diminish to the next minimum at 1537. Likewise, we should expect a period of depletion beginning with the Ottoman decline about 1600 rather than the increase in abundance continuing to the next maximum at 1692.

A comparison between Aegean oak sample abundance and a similar class of samples from central Europe flanking the Rhine River (Fig. 6)[4] raises the further questions of whether these geographically widely separated chronologies show synchronous phases of sample abundance and depletion, and, if so, what the significance is of such correspondence. The Aegean maximum at 1435 and the minima at 1342 and 1830 fall relatively close to central European counterparts respectively at 1430, 1350 and 1810; while the Aegean maxima of 1263 and 1692 as well as the minimum of 1537 appear to be non-synchronous with the central European curve with corresponding maxima at 1190 and 1725 and a minimum at 1660. Despite the tentative and inconclusive nature of this comparison and the limited and constantly changing data on which it is based, this aspect of European and Near Eastern dendrochronology will repay continued revision and refinement in analysis. As the only index of material cultural activity which can be independently and exactly measured, region by region and for centuries at a time, it offers a unique possibility for inter- regional comparison.

Prehistoric and Ancient Material

The information on Prehistoric and Ancient sites presented in Table 3 summarizes the geographical and chronological distribution and quality of the evidence. At 21 of the sites there are tree-ring sequences ranging in length from one century to eight, as at Gordion and Trento-Fiavé. While crossdates with long overlaps have been found between some of these floating chronologies, other possible fits with shorter overlaps must await a third overlapping chronology to confirm the correctness of the placement.

In the 30 centuries through which this material is distributed, spanning the period A.D. 200 to 2800 B.C., 25 centuries are represented by measured tree-ring sequences, in some cases as few as two or three, but in others by as many as 30 to 40. In only five centuries between the 21st and 26th B.C. are sequences completely lacking. Then there is a long gap of some 800 years before the Chalcolithic and an even longer gap until the Neolithic.

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Footnotes

1. Two important recent additions to the general literature on dendro- chronology are Schweingruber 1983 and Eckstein 1984.

2. For a discussion of the statistical basis of and causes for possible error in crossdating see Wigley, Jones and Briffa (1987).

3. The statistical information and analysis of sapwood was compiled by Carol B. Griggs.

4. From E. Hollstein (1980: 11) reporting the state as of 1974.

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