Dendrochronology

by Peter Ian Kuniholm

This article was one of several companion reports that appeared together in the *American Journal of Archaeology* under the title "Science in Archaeology: A Review" (*AJA* 99:1995). These reports were designed to bring Classical archaeologists up to speed on the latest developments in the various disciplines of archaeometry.

Abstract

Over 6000 years of tree-ring chronologies covering much of the period back to about 7500 B.C. have been developed over the past 20 years for the Aegean, the Balkans, and the Near East. The goal is to have an unbroken chronology from the present to the Neolithic against which archaeologists, art historians, and anthropologists may date finds of wood or charcoal with a theoretically possible precision of one year.

Method

Tree-ring sequences from trees that grow in a seasonal climate, i.e., with one growth increment per year, with the size of that growth dependent upon some climatic stimulus such as cold in the Polar regions, drought in the Aegean, and various combinations of the two stimuli in regions in between, can be compared so that these increments, more popularly known as "rings," can be dated to the calendar year in which they were formed. Crossdating, or matching patterns of ring-growth from one tree to another and assigning rings to specific years, is possible only among trees growing in the same general climatic region. Crossdating can sometimes be achieved in spite of human interference to ring-growth such as thinning of stands, resin-gathering, fire damage, and other traumas such as severe weather effects, pollution, lightning damage, etc., not to mention shaping of the wood at the time of construction and decay afterward. Both visual and statistical techniques are employed to guarantee the accuracy of the matches. In addition to simple ring-width analysis, X-ray densitometric methods are used to reconstruct past environmental conditions.[1] Wood or charcoal samples taken from standing buildings or excavated from archaeological sites can be crossdated with each other and with wood from living trees to extend the tree-ring chronology beyond the date of the oldest ring of the oldest living tree in the region. Dendrochronology is the only archaeometric technique where determination of absolute dates accurate to the year is either theoretically or practically possible. For a thorough treatment of recent progress in dendrochronological and dendroclimatological work world-wide see F. H. Schweingruber, *Tree Rings: Basics and Applications of Dendrochronology* (Dordrecht and Boston 1988).

Dendrochronology in the American Southwest and in Europe

Tree-ring studies have been a staple of anthropological investigation in the American Southwest[2] since the early decades of this century and in Europe since World War II. The bristlecone pine chronology of the American Southwest now exceeds 8500 years with the possibility that up to 3000 floating years will be added in the reasonably near future. The European oak and pine chronology, a composite of work done in Germany and Northern Ireland, is now over 11,000 years long.[3] Of particular interest to many *AJA* readers is the recent development of a 1000-year oak chronology in Poland which has demonstrated that panel paintings in Western collections, signed by artists such as Rubens, Rembrandt, etc., were clearly painted on oak boards imported from Gdansk in the Eastern Baltic.[4]

Significant work, but outside the scope of this report, is going on elsewhere: some archaeological, some

climatological, and some palaeoclimatological. Notable progress has been made in recent years in South America with the development of long chronologies from *Fitzroya cupressoides* in the vicinity of the Patagonian glaciers, in China with attempts to link the tree-ring record with the Chinese archival records, in Russia with the study of tree-growth at the northern timber-line, and in Spain with the study of medieval monuments.

Dendrochronology in the Aegean

The work of the present author has been focused on the Aegean for the last 20 years. We have about 6000 years of chronologies spread out over the last 9500 years in a region bounded by the Turkish-Georgian frontier in the east, the mountains of North Lebanon in the south, including all of Turkey, Cyprus, Greece, parts of Bulgaria and (the former) Yugoslavia, and extending to the instep of the Italian boot at Mt. Pollino in Calabria. Whether we can push northwards into the Crimea, northeastwards into the Caucasus, and southwards into North Syria and other near eastern countries remains to be seen. Mesopotamia and Iran are for the moment inaccessible but may some day yield useful information. We expect cedar and juniper found in Egypt but imported from the Lebanon to crossdate with Anatolian chronologies.

Absolute chronologies for several genera of trees extend back for a millennium. Our oak sequence ends in A.D.927. An 8th/9th century gap in the oak chronology may be filled this summer by timbers from Amorium.[5](See also ADP '95 for an update on the first millennium A.D.) A post-Justinianic gap exists just after the primary timbers from St. Sophia in Istanbul were cut. Another gap exists around the time of Constantine. Indeed, the millennium from roughly A.D. 500 to 500 B.C. is the most problematic of the last 4200 years, although the B.C. half may have been sorted out by the recent construction of a 513-year ring-sequence from boxwood timbers in the Comacchio (Ferrara) shipwreck.[6] The sequence, with which a number of other ring-chronologies crossdate, is dated to the last decades B.C. by three and a half tons of lead ingots stamped with the name AGRIPPA. A 1761-year continuous ring-sequence from around 498 B.C. to around 2259 B.C. is the longest we have. Early Bronze Age sequences are still under construction. For the prehistoric period the most notable advance in the last year has been the development of almost 700 years of chronologies for the Neolithic site of Çatal Höyük. (For a highly detailed account of Çatal Höyük and the current excavations taking place, please see the web page compiled by the current excavator, Dr. Ian Hodder, and his team at Cambridge.)

Practical Matters

For the dendrochronological method to succeed, long ring-sequences are needed. We have had junipers with as many as 918 annual rings. Çatal Höyük charcoal fragments no larger than a half-golfball have as many as 250 rings preserved. Crossdating material like this is relatively easy. Trying to date samples with fewer than 100 rings, on the other hand, is generally a waste of our time. Quantities are important. A set of 100 samples is vastly preferable to a set of 10, and single samples are to be avoided except in desperation. One cannot tell from internal evidence whether a single sample has been re-used from an earlier construction, cut particularly for the purpose to which it was finally put, or is some later repair. Species are important. Oak, pine, juniper, fir, boxwood, yew, spruce, and occasionally chestnut have been crossdated. Olive is hopeless, as are willow, poplar, and fruit trees. Large rings in these genera may mean merely that the gardener in the orchards in which they grew was unusually industrious that year. Cypress is usually undatable because the latewood cannot easily be distinguished from an individual annual ring. Finally, the condition of the sample is important. If the bark is present, the precise felling year may sometimes be determined. If some sapwood rings are present, only an estimate of the felling date may be made. If only heartwood is present, the date of the last preserved ring is, at best, a *terminus post quem* date.[7]

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