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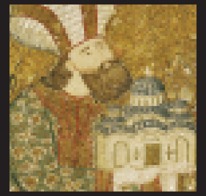

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The Oxford Handbook *of* BYZANTINE STUDIES

The Oxford Handbook of Byzantine Studies presents discussions by leading experts on all significant aspects of this diverse and fast-growing field. Byzantine Studies are concerned with the history and culture of what has come to be known as the Byzantine Empire, that is, the empire of East Rome based in the city of Constantinople, the present-day Istanbul. Situated on the Bosporus, on the site of the former ancient Greek colony of Byzantium, Greek in culture, Roman in administration and law, Christian in religion, Byzantium (as it has come to be known today) endured for more than a millennium, finally succumbing to the Ottoman Turks in 1453. Byzantium's borders fluctuated over the ages, at their most extensive in the sixth century stretching from Spain to Mesopotamia, later shrinking to little more than Constantinople and its immediate hinterland. Under the rule of emperors, patriarchs, and bureaucrats a distinctive society developed. The imperial court, headed by the emperor as God's vice-gerent on earth, became legendary for the magnificence of its ceremonial, dazzling visitors from East and West alike. Byzantium's impact on Europe, major in the Middle Ages, can still be felt today, especially in the Orthodox world of eastern Europe and Russia. Indeed, Byzantium's impact in the European Middle Ages is hard to over-estimate, as a bulwark against invaders, as a meeting-point for trade from Asia and the Mediterranean, as a guardian of the literary and artistic heritage from the ancient world, as a creator of its own artistic style.

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CHAPTER I.2.17

DENDROCHRONOLOGY

PETER IAN KUNIHOLM

Dendrochronology, or tree-ring dating, is deceptively simple. Some species of trees add their annual growth increments in two parts: 'spring wood' and then 'summer wood' cells, so that, when seen on the end-grain, they look like 'rings': hence the term. When trees in a given climatic region are similarly affected by yearly changes in the climate (as they are throughout most of the Byzantine world), their rings can be matched ('crossdated') with one another so that a given ring can be assigned to a specific calendar year. Sometimes a felling time within a year can be identified. Dendrochronology is the only form of archaeometric dating with this kind of annual or sub-annual resolution. The method works only with species having clear, annual growth rings, and, since the vast majority (99 per cent of monuments where any wood is preserved) of Byzantine and meta-Byzantine buildings were built with oak, this immediately makes tree-ring dating feasible for the Byzantinist. Species in which the annual ring-boundaries are non-existent or indistinct, for example, olive, willow, poplar, and most fruit or orchard trees (whose ring-growth may reflect merely the assiduity or the laziness of the gardener), cannot be crossdated. See Kuniholm 2001 for further discussion and bibliographic references, also Grissino-Mayer 1993 for a list of species which can be crossdated.

Crossdating is the fundamental principle upon which all dendrochronology is based. The researcher has to be assured that rings from two or more specimens were formed in the same year. Simple ring-counts are not sufficient. Neither is a single pattern of co-variation in ring-width (a 'signature'). In order to avoid the possibility of an accidental (but spurious) 'match' dendrochronologists try to compare samples which have at least 100 rings and multiple signatures rather than shorter-lived specimens which may not preserve enough signatures to guarantee the fit. These ring-patterns may be generated by a wide variety of causes (see Schweingruber 1988; Cook and Kairiukstis 1990; Eckstein 1972). The ring-patterns which are most usually crossdatable are the trees' mutual response to some climatic stimulus; in some regions principally rainfall or lack of it; in others principally temperature; in yet others some combination of the two. For the Byzantine world April–May–June rainfall dominates all other stimuli (Hughes and others 2002; Griggs and others 2007). This stimulus-and-response is therefore specific to a climatic region: that is, the south-western USA, the extreme northern timber-line (>~60°N), northern Europe, the eastern Mediterranean, etc. The climatic boundaries for crossdating have been best determined, in practice, by trial and error. Sometimes they fit the map, sometimes not, and then an explanation for the apparent anomaly must be sought. Wood cut from a forest site in Calabria in southern Italy, for example, crossdates with wood from Greece and Turkey, but it does not crossdate with wood from Spain, or over the Alps, or even Sicily. The first two non-fits are no surprise, but the non-fit with Mt Etna in Sicily, only 80 km away, is, and therefore requires explanation. Sicily appears to belong more to the North African climate system rather than to that of the central/eastern Mediterranean. Similarly, wood from the Black Sea coast of Turkey (the Pontos) does not crossdate with wood from central and western Europe, although forthcoming work in Romania and Bulgaria may help join the chronologies.

Caveats to the dendrochronological method include:

(i) the possibility of reused wood: for example, the Arizona mesas, where wood cut in pre-Columbian times is still in use today (for comments on dendrochronological interpretation see Bannister 1963);

(ii) changing habits of users of wood: for example, Renaissance painters in different centuries tended to let their panels dry out for two, to five, to eight, to ten years before painting on them (see Klein references); for architectural timbers, however, the Byzantine and Ottoman practice seems to have been for the carpenters to cut the wood and use it almost immediately;

(iii) heavily trimmed wood: for example, cut boards or musical instruments;

(iv) wood imported from some other climatic region: *Abies* (fir) at Herculaneum imported from the Alps, or *Quercus* (oak) supports for panel paintings in England and the Low Countries which were imported as cut boards from the Baltic (all Klein refs.; Kuniholm 2002; Kuniholm and others 2007);

(v) wood which is so badly degraded that its ring- and cell-structures are not preserved;

(vi) 'complacent' ring-sequences: that is, little or no significant change from year to year;

(vii) wood that has such erratic ring-sequences that they appear to fit in more than one place;

(viii) and no wood preserved at all, for example, the Baths of Caracalla or Diocletian in Rome with their hundreds of empty beam-holes.

Lest this long list of caveats seems discouraging, as an addendum to (ii) above, we note the following:

Monument	*Inscriptional date*	*Dendrochronological date*
Thessalonike, Moni Vlatadon, roof repair	1801	1800 winter
Ambelakia, Schwartz House	1787	1786 winter
Siatista, Nerandzopoulou House	1754	1753 winter
Thessalonike, Nea Panaghia	1727	1727
Thessalonike, Frourio Vardari	1597 spring	1597 spring
Thessalonike, White Tower	1535	1535

Clearly the woodcutters for these buildings must have been following Vitruvius' dictum (whether they had heard of Vitruvius or not) that one should always use one's wood fresh while it was still easy to cut.

The standard cautions that govern an archaeologist's activities in the field apply to dendrochronology as well. One of the reasons for the success of the dendrochronological method has been the history of regular interaction between the archaeologist in the field and the worker in the laboratory. Beware of singleton samples, wood from uncertain contexts, wood that shows signs of reuse, indications of repairs, the wrong kind of nails, traces of machine-sawing where one might expect only axe and adze-marks, etc. For other cautions see appendix III in Baillie 1982.

Techniques

Sampling

Full cross-sections provide the greatest amount of information. When cutting these is either impossible or forbidden (from a living tree or from an important architectural monument), the dendrochronologist is obliged to resort to coring. A Swedish increment corer is used to extract thin radial cores from standing trees, and a variety of commercially available drillbits is used to extract similar radial cores from intact architectural timbers. Klein and colleagues in the Hamburg laboratory have had good success with some 2,000 oil paintings painted on wooden panels by surfacing the end-grain with a razor blade and measuring directly from the panel (Eckstein and others 1983; Klein 1980, 1986, 1991, 1993, 1994). Byzantine icons are the obvious next step—the reserve collection in the Byzantine Museum in Athens has something like 25,000 pieces—but we have generally stayed away from such easily transportable icons of uncertain provenance until the master chronologies built

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from architectural timbers were solidly in place. On rare occasions a good, high-contrast photograph of the end-grain has allowed a piece of wood to be dated. The disadvantage of photographs is that microscopically small rings are almost impossible to discern unless the photographer had the forethought to do some sanding and polishing before taking the photograph. For both sections and cores it is important to include as much of the sapwood where it is extant and to avoid knots, cracks, and other blemishes which distort the patterns of ring-growth. On any sample, if the bark or the 'waney edge' (an Anglicism for the surface immediately beneath the bark) is present, the date when the tree was felled can be determined to the year. For oaks (which have estimatable even if region-specific amounts of sapwood—for the Aegean we use 26 +/− 9 years), if a significant amount of sapwood is preserved, the felling date can be estimated with varying degrees of precision to within several years. In other species, or in oaks with little or no sapwood and an unknown amount of missing heartwood rings, only a *terminus post quem* date is possible.

Analytical

The surface of the sample to be studied is prepared with fine sandpaper or a razor blade so that every ring can be measured and morphological oddities noted, usually under a binocular dissecting microscope. Then, whether a low-technology (skeleton-plotting or 'the Douglass method', see Stokes and Smiley 1968) or a more high-technology method is used, the latter including complete measurement of the ring-series and various kinds of statistical analyses (see the more recent handbooks listed below under Further Reading), the rings have to be matched to one another. Once wood or charcoal specimens have been crossdated, they are then set in order, beginning with an absolutely dated tree, and a chronology is built in step-wise fashion into the past as far back as the evidence will allow. For the best recent summary of the general methodology see Schweingruber 1988. Whether a low-technology or a high-technology method is used, the final result should be the same: a date that is accurate to the year and that can be replicated by other workers.

Building the Long Chronologies: Northern Europe

For Europe between the Pyrenees and the Baltic a long, continuous chronology for oak of some 8700 years is in place, thanks largely to quantities of Irish bog oaks and ten thousand oak stems from the Rhine, Main, and Danube Rivers (Pilcher and others 1984). Long lists of dated medieval buildings are provided by Hollstein 1980,

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and Schmidt and others 1990. Without this fundamental work none of the studies of panel paintings would have been possible. Yet, at the beginning, it was not clear to the European workers that this was all going to come together as neatly as it did (Baillie 1983).

The Byzantine World

The Byzantine dendro-world has not been as rich as Europe north of the Alps (few bogs, and the rivers have been picked clean). Secure oak and conifer chronologies built by the Cornell laboratory from some 200 buildings (as of March 2007) are as follows:

Oak		*Pine*	
Turkey	1044 to present	Turkey	1292–2000
Black Sea Coast	1089 to present	Turkey Juniper	1037–1988
Central and Western Greece	1162 to present	Greece	1243–2002
Thrace and Thessalonike	1169 to present	South Italy	1148–1980
'Yugoslavia' Late	1543–1850	Yugoslavia	1632–1981
'Yugoslavia' Early	1073–1351	Cyprus	1479–2004

Less-secure, and still tentative chronologies from some 46 sites are:

'Roman Gap' Oak, Late	381–2004
'Roman Gap' Oak, Early	−518–348 estimated

The 'Roman Gap' terminology deserves explanation. The late first millennium BCE and the early first millennium CE have given us more trouble than all the other nine millennia combined from which we have collected wood. Although we have over 100 oak chronologies or singleton pieces in hand, many of the data sets are short, many only 100–150 years long, and the collection sites range from Italy and Croatia to eastern Turkey. Seaside sites could have been supplied by ship from anywhere in the Roman world. As more material is collected and added to the above, the so-called 'Roman Gap' problem should sort itself out. For example, several really long data sets would confirm the overlapping placements of the shorter ones. In the summer of 2006 some 600 oak samples were collected from the Yenikapı excavations in Istanbul and are being measured. It is entirely possible that this approximately 33-year gap between 348 and 381 will have been filled by the time anybody reads this prose. At http://arts.cornell.edu/dendro we will post a list by May 2007 for any reader who needs a Byzantine or meta-Byzantine date. To save the reader additional time and effort, we will also post a list of the 400-odd buildings which we have already visited and which have *not* yielded any datable wood.

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Reference Sources

Two journals devoted exclusively to dendrochronological subjects are the *Tree-Ring Bulletin* (1934–) and *Dendrochronologia* (1983–). Over 1,500 archived tree-ring data sets are in the International Tree Ring Data Bank in Boulder, Colorado (http://www.ngdc.noaa.gov/paleo/ftp-treering.html), and a polyglot cross-referenced guide to dendrochronological terminology in seven languages is to be found in Kaennel and Schweingruber 1995.

Additional Applications

Applied dendrochronological topics now include the study of changes in both the immediate and distant environment, the history and effects of pollution, stream erosion and infill, forest fires, earthquakes, glacial movement, volcanoes, tsunamis, seasonal river flooding, insect life-cycles, human intervention in the forest, and changes in wood utilization and exploitation, and so on. Schweingruber 1988 provides an extraordinary illustrated listing, with bibliography, of many of these fields and sub-fields into which dendrochronological research has evolved. With the wealth of documentation available in Byzantine sources, this kind of study might seem of marginal interest, but now and then the trees tell us something about which the chronicles are silent. See Stahle and others 1998, where the authors note that the collapse of the Jamestown colony occurred during the coldest winter in the last 1000 years.

Case Studies in Dendrochronology

In contrast to some of the other archaeometric techniques where the laboratory scientists interact very little with the archaeologists, dendrochronology from its very beginning has been typified by close collaboration between laboratory and field workers. In practice the dendrochronologist has visited the site, discussed its problems and interpretation with the excavator, and only then has taken the sample. An ideal sample will be of value to both parties, that is, datable and from a significant archaeological context. Instances where dendrochronology has been applied with noteworthy results to the interpretation of archaeological sites and archaeological or art-historical artefacts include the following, selected from two of the three principal regions where tree-ring dating has been done extensively.

Europe

New work of relevance to Byzantinists as models of what might be achieved in the Byzantine world includes studies of the medieval and prehistoric Netherlands (Jansma 1995), the early medieval and Viking settlements at Haithabu (Eckstein 1969, 1972; Eckstein and others 1983). It also includes the analysis of a long series of medieval buildings in the Rhineland (Hollstein 1980), a thorough study of private houses in the Mosel Region (Schmidt and others 1990), and the identification of the imported Polish oak which served as supports for Netherlandish panel paintings (Baillie and others 1985; Eckstein and others 1986) as well as for wainscoting in English country houses.

Aegean and the Near East

Dendrochronological analysis of approximately two hundred medieval buildings in Greece and Turkey has been carried out since 1973 (Kuniholm and Striker 1987; Kuniholm 1994). One striking example of how the method can require a change to old ways of thinking is the Church of the Holy Apostles in Thessalonike where a puzzling, long-misunderstood monogram (*Niphon Ktitor*) which suggested a date of 1310–14 is contradicted by the dendrochronological date of 1329 which happens to be the year when Niphon returned from exile (Kuniholm and Striker 1990).

'Dendroprovenancing' as mentioned earlier for exported Polish oak in northern Europe is possible in the Aegean as well, with Alpine fir and spruce found in a Renaissance palace in Dubrovnik on the Dalmatian Coast, Black Sea oak found in medieval monuments in Istanbul and Thessalonike, and Alpine fir and spruce found in the destroyed Roman towns of Pompeii and Herculaneum (Kuniholm 2002; Kuniholm and others 2007).

Case Studies in Environmental and Climatic Reconstruction (North America Omitted)

Europe

For the medieval warm period see Hughes and Diaz 1994; and for southern Europe see Urbinati and Carrer 1997. For environmental reconstruction for earlier periods see the bibliography in Kuniholm 2001.

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Aegean and the Near East

For an early résumé see Kuniholm 1990 for a singular drought event in the Little Ice Age. Then see Hughes and others 2002, and now Griggs and others 2007. This subject has barely begun to be investigated to its full potential. The difference between the Byzantine world and everywhere else is that the Byzantinist is in the fortunate position of being able to play the references in the chronicles against the tree-rings.

Radiocarbon Calibration and Wiggle-Matching

Radiocarbon does not have the precision that Byzantinists need. A date to within a half-century or so, although acceptable to a prehistorian, does not serve the medievalist well at all. However, when no dendro-datable wood is preserved, then one is forced to rely on this method. Where possible, 'wiggle-matching' of seriated samples should be used. As anyone who has used radiocarbon knows, the calibration curve itself is not a straight line. It wiggles as it goes back in time as more or less radiocarbon is created in a given year. If one were to take a 100-year piece of wood and cut it into decade-long pieces and radiocarbon date each one (keeping the pieces in order, of course), it would produce a similarly wiggly line. The researcher can then match the wiggles of the calibration curve against the wiggles produced by the newly dated set of samples and arrive at a much closer fit than if a single sample were being dated. See the Oxford Labs web-site and the OxCal program for practical examples.

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Further Reading

Other basic explanations of the dendrochronological method and useful illustrative material are to be found in Douglass 1935, Glock 1937, Stokes and Smiley 1968, Ferguson 1970, Eckstein and others 1984, Cook and Kairiukstis 1990, Baillie 1995, Dean 1997. For a polyglot explanation of terms see Kaennel and Schweingruber 1995. One reason for the successful development of dendrochronology is the extent to which workers have shared information, even raw unpublished data. A series of international meetings with titles that do not necessarily appear in electronic key-word searches has brought the tree-ring community together at irregular intervals, and the published proceedings form a sequence that charts the progress of the field. In chronological order they are Fletcher (ed.) 1978, Eckstein and others 1983, Ward (ed.) 1987, Bartholin and others 1992, Hughes and Diaz 1994, Dean and others 1996, Stravinskiene and Juknys 1998. All contain nuggets of information that might be put to advantage by the Byzantinist.