Dendrochronology

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Drill for dendrochronology sampling and growth ring counting

Dendrochronology or **tree-ring dating** is the scientific method of dating based on the analysis of patterns of tree-rings. Dendrochronology can date the time at which tree rings were formed, in many types of wood, to the exact calendar year. This has three main areas of application: paleoecology, where it is used to determine certain aspects of past ecologies (most prominently climate); archaeology, where it is used to date old buildings, etc.; and radiocarbon dating, where it is used to calibrate radiocarbon ages (see below).

In some areas of the world, it is possible to date wood back a few thousand years, or even many thousands. In most areas, however, wood can only be dated back several hundred years, if at all. Currently, the maximum for fully anchored chronologies is a little over 11,000 years from present.[1]

Contents

History

Dendrochronology (word derived from Greek δένδρον, *dendron*, "tree limb"; χρόνος, *khronos*, "time"; and -λογία, *-logia*) was developed during the first half of the 20th century originally by the astronomer A. E. Douglass, the founder of the Laboratory of Tree-Ring Research at the University of Arizona. Douglass sought to better understand cycles of sunspot activity and reasoned that changes in solar activity would affect climate patterns on earth which would subsequently be recorded by tree-ring growth patterns (*i.e.*, sunspots → climate → tree rings).

Growth rings

Growth rings, also referred to as *tree rings* or *annual rings*, can be seen in a horizontal cross section cut through the trunk of a tree. Growth rings are the result of new growth in the vascular cambium, a lateral meristem, and are synonymous with secondary growth. Visible rings result from the change in growth speed through the seasons of the year, thus one ring usually marks the passage of one year in the life of the tree. The rings are more visible in temperate zones, where the seasons differ more markedly.


The growth rings of an unknown tree species, at Bristol Zoo, England.

The inner portion of a growth ring is formed early in the growing season, when growth is comparatively rapid (hence the wood is less dense) and is known as "early wood" or "spring wood" or "late-spring wood". The outer portion is the "late wood" (and has sometimes been termed "summer wood", often being produced in the summer, though sometimes in the autumn) and is denser. "Early wood" is used in preference to "spring wood", as the latter term may not correspond to that time of year in climates where early wood is formed in the early summer (e.g. Canada) or in autumn, as in some Mediterranean species.


Pinus taeda Cross section showing annual rings, Cheraw, South Carolina.

Many trees in temperate zones make one growth ring each year, with the newest adjacent to the bark. For the entire period of a tree's life, a year-by-year record or ring pattern is formed that reflects the climatic conditions in which the tree grew. Adequate moisture and a long growing season result in a wide ring. A drought year may result in a very narrow one. Alternating poor and favorable conditions, such as mid summer droughts, can result in several rings forming in a given year. Missing rings are rare in oak and elm trees—the only recorded instance of a missing ring in oak trees occurred in the year 1816, also known as the Year Without a Summer.[2] Trees from the same region will tend to develop the same patterns of ring widths for a given period. These patterns can be compared and matched ring for ring with trees growing in the same geographical zone and under similar climatic conditions. Following these tree-ring patterns from living trees back through time, chronologies can be built up, both for entire regions, and for sub-regions of the world. Thus wood from ancient structures can be matched to known chronologies (a technique called *cross-dating*) and the age of the wood determined precisely. Cross-dating was originally done by visual inspection, until computers were harnessed to do the statistical matching.

To eliminate individual variations in tree ring growth, dendrochronologists take the smoothed average of the tree ring widths of multiple tree samples to build up a ring history. This process is termed replication. A tree ring history whose beginning and end dates are not known is called a *floating chronology*. It can be anchored by cross-matching a section against another chronology (tree ring history) whose dates are known. Fully anchored chronologies which extend back more than 11,000 years exist for river oak trees from South Germany (from the Main and Rhine rivers) and pine from Northern Ireland.[3][4][5] Another fully anchored chronology which extends back 8500 years exists for the bristlecone pine in the Southwest US (White Mountains of California).[6] Furthermore, the mutual consistency of these two independent dendrochronological sequences has been confirmed by comparing their radiocarbon and dendrochronological ages.[7] In 2004 a new calibration curve *INTCAL04* was internationally ratified for calibrated dates back to 26,000 Before Present (BP) based on an agreed worldwide data set of trees and marine sediments.[8]

Sampling and dating

Timber core samples measure the width of annual growth rings. By taking samples from different sites and different strata within a particular region, researchers can build a comprehensive historical sequence that becomes a part of the scientific record; for example, ancient timbers found in buildings can be dated to give an indication of when the source tree was alive and growing, setting an upper limit on the age of the wood. Some genera of trees are more suitable than others for this type of analysis. Likewise, in areas where trees grew in marginal conditions such as aridity or semi-aridity, the techniques of dendrochronology are more consistent than in humid areas. These tools have been important in archaeological dating of timbers of the cliff dwellings of Native Americans in the arid Southwest.

A benefit of dendrochronology is that it makes available specimens of once-living material accurately dated to a specific year to be used as a calibration and check of radiocarbon dating, through the estimation of a date range formed through the interception of radiocarbon (B.P., or '**B**'efore '**P**'resent, where present equals 1950-01-01) and calendar years.[9] The bristlecone pine, being exceptionally long-lived and slow growing, has been used for this purpose, with still-living and dead specimens providing tree ring patterns going back thousands of years. In some regions dating sequences of more than 10,000 years are available.[10]

The dendrochronologist faces many obstacles, however, including some species of ant which inhabit trees and extend their galleries into the wood, thus destroying ring structure.

Similar seasonal patterns also occur in ice cores and in varves (layers of sediment deposition in a lake, river, or sea bed). The deposition pattern in the core will vary for a frozen-over lake versus an ice-free lake, and with the fineness of the sediment. Some columnar cactus also exhibit similar seasonal patterns in the isotopes of carbon and oxygen in their spines (acanthochronology). These are used for dating in a manner similar to dendrochronology, and such techniques are used in combination with dendrochronology, to plug gaps and to extend the range of the seasonal data available to archaeologists and paleoclimatologists.

While archaeologists can use the technique to date the piece of wood and when it was felled, it may be difficult to definitively determine the age of a building or structure that the wood is in. The wood could have been reused from an older structure, may have been felled and left for many years before use, or could have been used to replace a damaged piece of wood.

Applications

European chronologies derived from wooden structures found it difficult to bridge the gap in the 14th century when there was a building hiatus which coincided with the Black Death.[11] Other plagues which were less well recorded also appear in the record.

In areas where the climate is reasonably predictable, trees develop annual rings of different properties depending on weather, rain, temperature, soil pH, plant nutrition, CO2 concentration, etc. in different years. These variations may be used to infer past climate variations.

Given a sample of wood, the variation of the tree ring growths provides not only a match by year, it can also match location because the climate across a continent is not consistent. This makes it possible to determine the source of ships as well as smaller artifacts made from wood but which were transported long distances, such as panels for paintings.

Dendrochronology has become important to art historians in the dating of panel paintings, and can also provide information as to the source of the panel - many Early Netherlandish paintings have turned out to be painted on panels of "Baltic oak" shipped from the Vistula region via ports of the Hanseatic League. Since panels of seasoned wood were used, an uncertain number of years has to be allowed for seasoning. Panels were trimmed of the outer rings, and often each panel only uses a small part of the radius of the trunk, so dating studies usually result in a "terminus post quem" (earliest possible) date, and a tentative date for the actual arrival of a seasoned raw panel using assumptions as to these factors.

See also

- Baumkuchen, cake that resembles growth rings
- Dendroclimatology
- Dendroarchaeology
- Dendrology
- Paleoclimatology
- Post excavation
- Varve
- Timeline of dendrochronology timestamp events
- sclerochronology
- acanthochronology

References

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External links

- Bibliography of Dendrochronology (http://www.wsl.ch/dbdendro/index_EN)
- International Tree-Ring Data Bank (http://www.ncdc.noaa.gov/paleo/treering.html)
- Digital Collaboratory for Cultural Dendrochronology (http://vkc.library.uu.nl/vkc/dendrochronology/research/ProjectsWiki/Digital%20Collaboratory%20for%20Cultural%20Dendrochronology.aspx)
- Ultimate Tree-Ring Web Pages (http://web.utk.edu/~grissino/)
- Oxford Tree-Ring Laboratory (http://www.dendrochronology.net/county_lists_uk.asp#)

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