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Tree rings and time: recent historical studies in England

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By studying the annual growth rings of long-lived trees, and those preserved in ancient timbers that have survived in waterlogged or very dry conditions, it is possible to date past events in calendar years and to investigate climatic and other environmental changes. Dendrochronology has many applications, including the dating of buildings and ships and the calibration of the radiocarbon timescale that is so widely used in archaeology. Here the technique is outlined and some recent applications of it in England are described.

Tree-ring dating (dendrochronology) is now an established technique used to date both cultural activities, such as land clearance and the construction of buildings and ships, and natural events such as earthquakes, forest fires and volcanic eruptions. For example, tree rings have dated the massive eruption on the Greek island of Santorini that is thought to have contributed to the collapse of the Minoan civilization on Crete;[1] they have helped to re-date Saxon and medieval pottery,[2] and they have been used to date changes in climate, river flows and lake levels in several parts of the world.[3]

Tree rings provide annual dates in calendar years and also represent a diary of environmental change. Thus, the widths of the rings and their other physical attributes (e.g. maximum wood density) have provided the basis for extensive palaeoclimatic reconstructions, notably in northwest Europe and the southwestern USA. This is of interest to archaeologists and also to those concerned with issues such as global warming.

Now that a large body of tree-ring information has been amassed, closer study of the database is beginning to yield historical information about trade, the sources of timber, the nature and history of woodland management, and the frequency of natural disasters. It is also able to provide accurate dating frameworks for other, less precise, dating methods that have previously relied largely on typological differences, such as pottery dating and the evolution of carpentry techniques.

How tree rings are studied

Tree-ring dating was developed in the southwestern USA in the early decades of the twentieth century. In this arid region, tree growth responds clearly to changes in the amount of rainfall from year to year; a series of ring widths has been likened to a fingerprint that uniquely represents the time period through which the tree grew. Every individual tree shows its own life history in its rings, but trees of the same species, growing over a relatively wide area, share similar weather, which is reflected in the ring-width pattern.

If one examines many trees of the same species growing at the same time in the same locality, it is possible to match the individual tree's patterns and filter out the individual variation, to produce a regional chronology that records a pattern of growth typical of that area. By finding progressively older sources of wood, such as building timbers or buried stumps, it is possible to match the outermost rings of this growth from older times to the innermost rings of living, or recently felled, trees and to extend the pattern back in time (Fig. 1). This is basically an exercise in visual pattern matching, at which the human eye excels, but computer-based mathematical matching confirms the dendrochronologist's visual matching and provides the repeatable, objective levels of similarity needed for wider acceptability.

Of course, not every specimen of timber can be successfully dated. If the tree has suffered from natural disease or damage, or from the effects of human management, these influences may be superimposed on the basic weather-related pattern of rings to such a degree that matching to the established chronologies becomes impossible. It is always preferable to have several contemporaneous timbers from a new site, rather than depend on dating a single specimen. There is also the danger that a single piece of wood could have been re-used from another earlier artefact, or in repairing a surviving building. It must be remembered that in dendrochronology one is dating only the time of growth of the original tree.

We know from extensive research that in Europe, until relatively recently, trees were usually used within a year or so of their felling. Therefore, dating the felling of the tree closely dates the use of the wood. However, for this to be achieved it is essential that one has a tree-ring record that preserves the outermost rings of the tree. Where the bark is still present on the timber, this is not a problem and, even when it is not, by knowing how the anatomy of the ring relates to the growth period it may be possible to deduce the season of the year in which felling took place.

Often one finds traces of the outer layers of what was the living part of the tree (the

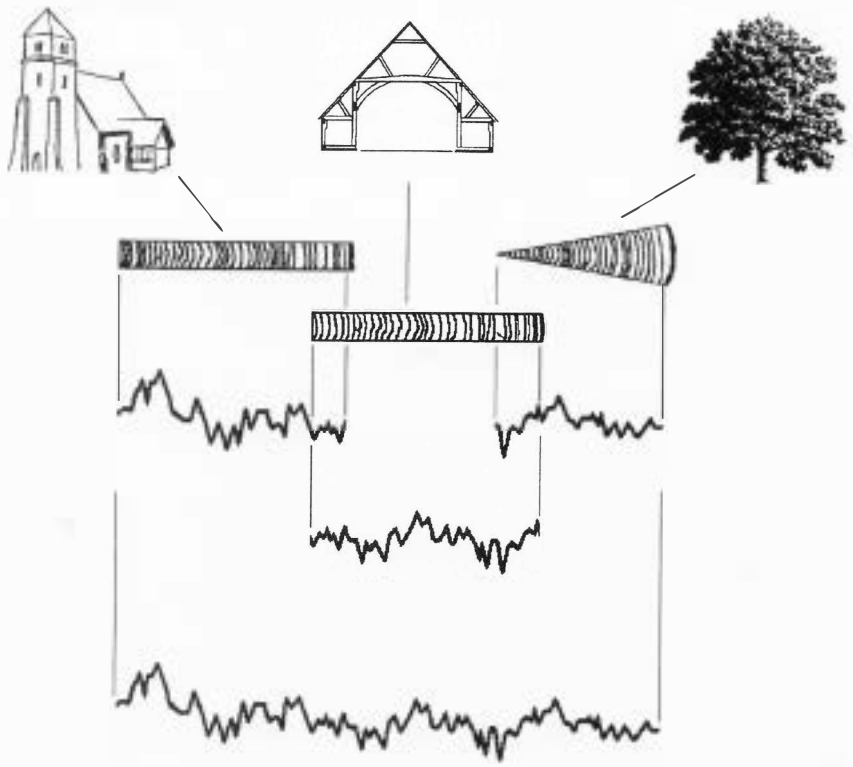

Figure 1 *Tree-ring chronologies are constructed by overlapping successively older ring-width series from a variety of sources. In practice many series may be used for any part of the final chronology.*

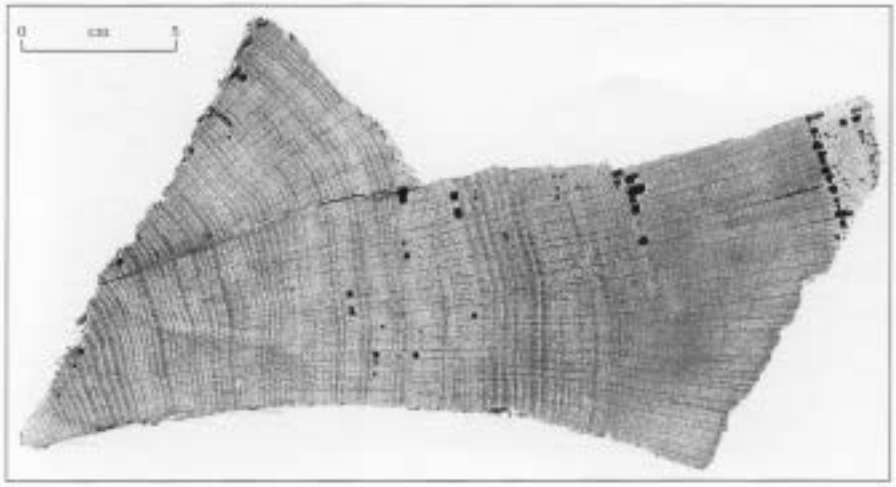

Figure 2 *A cross-section of oak showing the variable widths of the growth rings. The lighter rings in the outer (right-hand) 2 cm are sapwood rings. The black holes (2–3 mm in diameter) are the result of destruction by deathwatch beetle, usually more common in the sapwood, but here found also in the inner heartwood.*

sapwood), and then one can make fairly good estimates of how many rings have been lost during processes such as the conversion of the wood into planks or other usable objects, or the decay of these less resilient sapwood layers (Fig. 2). Therefore, although tree rings can be dated to the very year of their formation, tree-ring dates are frequently expressed as a probable range, based on an estimate of sapwood loss. When only the inner rings (the heartwood) remain, one can date only the outermost surviving ring and conclude that the tree must have been felled after a certain date (allowing for the minimum likely number of sapwood rings).

Dendrochronology in England

In Britain, where the climate is more complex and variable than in arid regions such as the American Southwest, it was thought for a long time that trees would not so readily yield their secrets. Only 30 years ago, dendrochronologists from continental Europe declared that the climate–growth relationships in Britain were too complex and that any progress towards building dating chronologies would take a "massive onslaught from many regional centres of study".[4] However, this has now been achieved for oak (*Quercus* spp.), which, compared with other species, is durable and also well represented in the historical record. The early development of dendrochronology in England was confused by studies of wood from imported timbers, particularly in art-historical studies of pictures that had been painted directly onto oak boards that later proved to have been imported via the Baltic.[5]

By the mid-1980s only about a third of new sites in southern England containing oak timbers could be dated,[6] whereas now the figure is probably about two thirds. This increasing success rate reflects the accumulation of ring-width data from more and more regions, representing growth on a wider range of soil types, slope aspects and woodland communities. Some regions remain dendrochronologically more difficult than others, although much progress is currently being made. Oaks in the relatively dry regions of East Anglia and Southeast England, where trees have been managed for many centuries, often achieve sufficient size for use as constructional timbers in under 50 or 60 years, and such short series of ring widths are generally less easy to date.

Some surprising results

Even in a well researched field such as English traditional domestic (vernacular) architecture, tree-ring dates are proving invaluable in refining typological dating and studying topics such as the spread of building techniques, the importation of wood and changes in the use of woodland resources. An interesting recent example of how tree-ring dates have forced a reappraisal of accepted knowledge is that of the dating of Priory Barn (Little Wymondley, Hertfordshire; Figs 3, 4).[7]

Priory Barn is known to have survived on the site of an Augustinian priory and, on the basis of the history of the priory and the use of some archaic joints in the timbers, it was believed to be a fourteenth-century construction. Radiocarbon dates produced in the 1960s suggested a late thirteenth, late fifteenth or early seventeenth century date.[8] However, it was clear from empty mortice holes unrelated to the present structure that some roof timbers had been re-used.

The site was perfect for dendrochronological study. The barn had an abundance of accessible oak timbers that retained sapwood, often complete out to the bark surface, with many rings in each timber.

Figure 3 *External view of Priory Barn, Little Wymondley, Hertfordshire.*

Figure 4 *Internal view of Priory Barn, Little Wymondley, Hertfordshire, showing the author taking samples for dendrochronological study.*

Figure 5 *View of the east facade of the farmhouse at Home Farm, Newdigate, Surrey, built of timbers felled in the period 1574–1603.*

Small cores, 15mm in diameter, were extracted from a range of timbers throughout the building. After measuring all the tree rings and matching the samples to each other, comparison with previously dated material from many other sites enabled the time of felling of the majority of timbers to be dated to the winter of AD 1540–41. Some of the re-used timbers dated to the period AD 1373–95. It became clear therefore that, contrary to previous belief, the barn largely postdated the dissolution of the monasteries and incorporated the probable remains of an earlier barn on the site.

Once this had been established, the historians went back to the records and found that the new post-dissolution owner of the site was Surveyor of the King's Works to Henry VIII, noted for his work on several important timber-frame buildings. With a very well replicated site chronology established, it then became possible to date some relatively short sequences from timbers used as battens to hold the external weatherboarding in place. Whereas in recent barns the feather-edged weatherboarding usually goes over the main structural timbers, completely covering the external walls, here it occurred in panels between the main posts. The dating proved this to be original to the barn and showed it to be a rare example of the earliest form of such weatherboarding – a transitional phase between the older infill panels, often of wattle and daub or vertical boards set in grooves, and the fully external long boards seen widely today.

Another example of a dendrochronological date that proved a structure to be different in age to the accepted typological date comes from Little Braxted in Essex, where a detached kitchen (see pp. 14–16 of this issue), later converted to a dovecote, was dated by Hewett[9] on the basis of the carpentry to the closing decades of the fifteenth century, but was later dated by dendrochronology to AD 1398–1410.

The fine resolution of dates that is possible with dendrochronology is unmatched by other scientific dating techniques and it has proved invaluable in separating events that are closely contemporaneous . Thus, building sequences and repairs to building complexes can often be identified. For example, the various buildings making up manorial residences in Brittany have been distinguished,[10] as have refits from original timbers in ships.[11] In the latter case, dendrochronology was probably the only independent way of proving that timbers suspected of having been added to strengthen the Tudor warship Mary Rose were indeed of more recent origin than the launch of the ship. The dating survey revealed other previously unknown parts of the ship that had been refitted, and recently a rib has been dated that shows that extensive refits were being undertaken in the few years before she sank in 1545.[12]

In an investigation of a complex of buildings at Home Farm, Newdigate, Surrey,[13] it proved possible to distinguish two phases of building, separated by only a few years, in different parts of the complex. The east facade and doorway of the farmhouse (Fig. 5) were built using trees felled

Figure 6 *View of the east end of the south barn at Home Farm, Newdigate, Surrey. Dendrochronology revealed that this was built of timbers felled in the winter of AD 1608–9.*

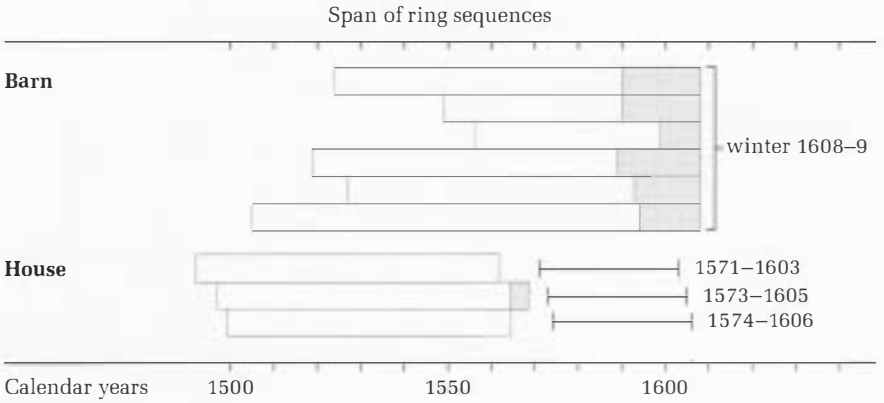

Figure 7 *Bar diagram representing the relative positions of overlap of the dated timbers from two phases of building at Home Farm, Newdigate, Surrey, demonstrating how these two phases can be distinguished on the basis of their tree-ring series. The shaded portions represent the sapwood rings and the horizontal lines (lower right) indicate the most likely range of felling dates.*

in the period 1574–1603, whereas the east end of the south barn (Fig. 6) was built of trees that retained their complete sapwood and were found to have been felled in the winter of 1608–9 (Fig. 7). This end of the barn was much older than had previously been expected on the basis of carpentry style and it yielded useful information about how the site evolved as a working farm.

Determining where trees grew

There is often a question as to the geographical origin of timbers. Historical records show that building timbers were valuable and that they were often transported around the country as well as being imported.[14] With ships' timbers there is often even less certainty about the source. Recent work on this subject[15] suggests that, although there have been some spectacular successes in pinpointing the origin of timbers, generally the source areas can be expressed only at the scale of regions several hundreds of kilometres wide.

In the future it seems likely that other attributes of tree-rings, such as the chemical constituents of the wood, will be investigated more widely in order to make progress in determining the source areas[16] and also in environmental reconstruction.

Notes

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16. For example, the study by S. Durand, P. Shelley, R. Antweiler, H. Taylor, "Trees, chemistry, and prehistory in the American Southwest", *Journal of Archaeological Science*, **26**, 185–203, 1999.