

DENDROCHRONOLOGY: timber as a timepiece and so much more

Dr Nicola Davies explains the science of
analysing tree-ring data

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The centre of a polished slice of a petrified tree from the late Triassic period (approximately 230 million years ago) found in Arizona. The remains of insects can be detected in an enlarged image

The term dendrochronology refers to the practice of determining a tree's age from its rings. The science of dendrochronology hinges on the growth rings that trees produce annually during their growth seasons. The width of a tree ring is dependent on a number of factors, including the available moisture from precipitation and variations in temperature endured by the flora. This scientific field of study concerns itself with the interpretation and dating of historic, scientific, cultural and climatic occurrences and trends. Dendrochronology demonstrates the inherent utility and flexibility of trees and timber.

Dr Henri Grissino-Mayer, Professor of Geography at the University of Tennessee-Knoxville, says, "Like any other science, dendrochronology has overarching principles. Many of these principles are borrowed from other sciences. For instance, the principle of uniformitarianism states that the present is the key to the past so with this principle we can reconstruct climate, for example, with tree-ring data."

Birds of a feather flock together, so do oak and elm ... apparently

The similarity between the growth rings of trees in the same general location, as well as those facing the same climatic conditions, allows dendrochronologists to analyse tree-rings and construct extensive chronologies going back thousands of years. One particular chronology of central Europe goes back some 10,000 years. The Central European study analysed oak (*Quercus robur*) trees almost exclusively and was completed by the Hohenheim Laboratory.

There is much more to dendrochronology than counting rings in trees. "We don't just count tree rings!" states Grissino-Mayer, "Statistical orientation is necessary. My training as a biogeographer, biologist and a statistician come together. We ensure that the tree rings we analyse are precisely dated to the exact date without any plus or minus to the year. This is the principle of crossdating. We will not use tree-ring data unless we are 99.99% confident that the tree rings are precisely dated."

The amateur falls victim to the false premise that he can identify

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A dendrochronological drill bit designed to make core samples for accurate laboratory analysis. Frequently used to date timbers in ancient wooden structures such as timbered houses, barns and ships

when a particular ring was formed. Tree-ring growth may not always be annual. Therefore, the field of dendrochronology dictates that a particular tree-ring be assigned a specific calendar year. For this to be successfully carried out a number of principles must be satisfied.

The first fundamental principle is that the growth rings of the tree species must be well-defined, i.e. there must be sufficient contrast between the wood formed early in the growth season and the wood formed in the latter part of the growth season. This usually accounts for the lighter and darker rings. Second, the rings must have concentric uniformity toward the centre or the pith. Third, there must be variations in the annual rings – the principle of sensitivity. In other words, the tree should be able to demonstrate its sensitivity, or response to environmental variables, by the presence of a range of ring widths. Since dendrochronology is dependent on tree-ring patterns, a tree with the same ring widths throughout would provide no distinct pattern that could be used in crossdating or matching with that of another tree.

It's alive!

Despite the difficulty in absorbing and employing the rigid methodology of dendrochronology, dead trees give up their secrets without much resistance – timber obtained from archaeological finds, victims of large construction projects, tree stumps and fallen logs. The more intrepid among you may have turned your thoughts to vivisection – how are tree rings obtained from living trees? There's a tool for that – the increment borer.

The increment borer allows scientists to remove a narrow cylindrical sample



The Editor's own crude attempt to date a mature pine tree which he has chopped up for firewood! It appears to be about 70 years old but an expert could date it more accurately as each apparent annual ring needs to be interpreted properly

Andrew Ellicott Douglass

The modern development of dendrochronology as a science can be credited to the astronomer Andrew Ellicott Douglass, who founded the University of Arizona Tree-ring Research Laboratory in 1937. This laboratory has worldwide recognition as a foremost authority on dendrochronological techniques and their application in the fields of environmental and social science.



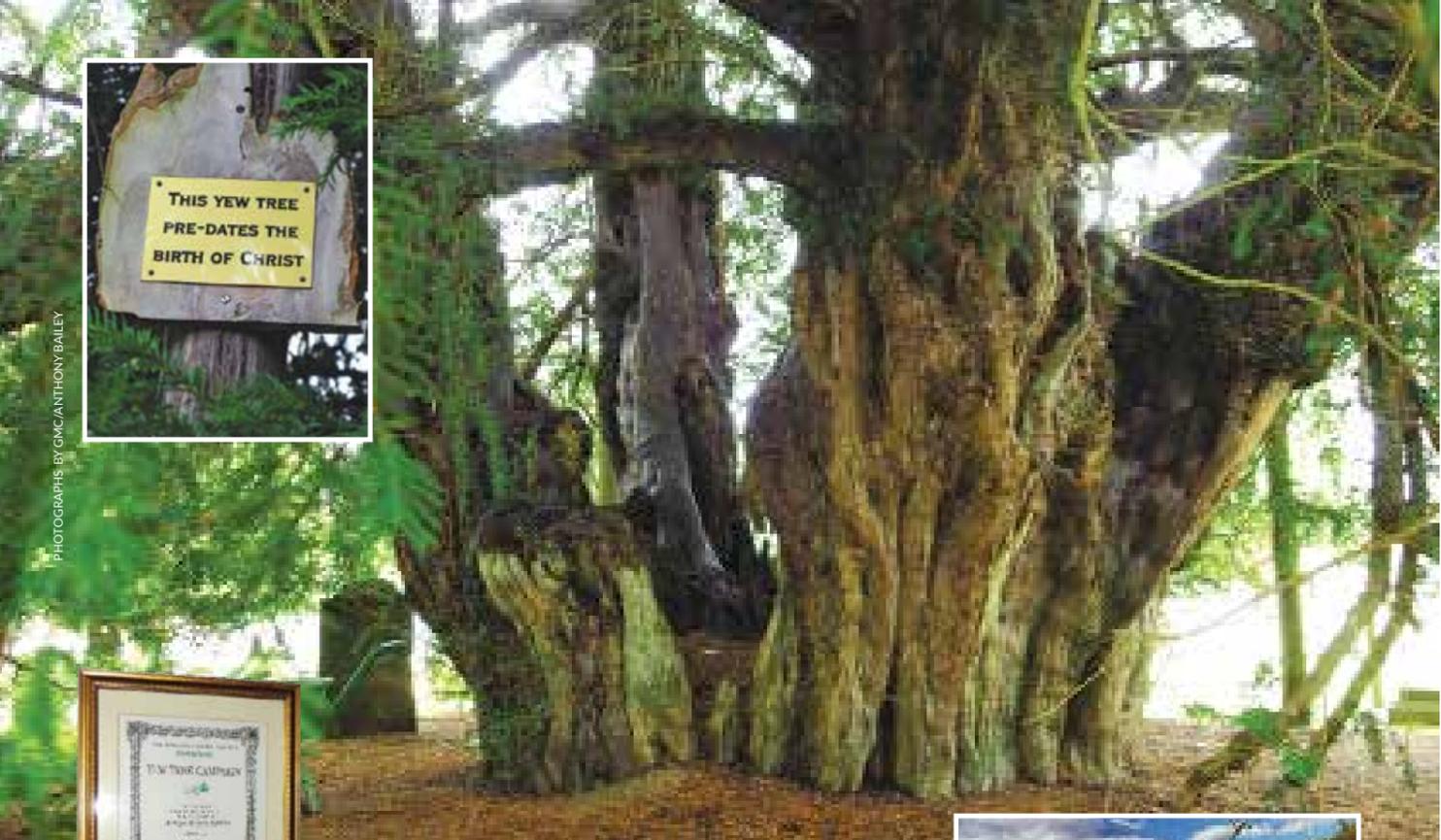
An accelerator mass spectrometer at Lawrence Livermore National Laboratory used for carbon dating. Dendrochronological samples can be used as reference markers to help improve the accuracy of carbon dating

of a tree trunk. The tool is composed of a hollow metallic cylinder, measuring about 4–5mm, though sometimes even up to 160mm. The cylinder's tip is threaded to form an auger or cutting tip. A detachable metal handle is attached perpendicularly to the cylinder to facilitate the torque needed to drill into the tree trunk.

After extruding the wood, the tree-ring containing sample is taken to a laboratory for analysis. The sample has to be sanded smooth to more accurately reveal the tree rings. ►

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Main image: A massive split yew tree (*Taxus baccata*) growing in the churchyard of St Mary's, Buxted, East Sussex. Almost impossible to accurately date a tree in this condition without a central trunk intact

Inset and above: A campaign was mounted to determine and agree the age of this massive yew, which by expert common consent is indeed more than 2000 years old

These rings are then measured using a microscope and the data stored in a computer. The data is then compared with other chronologies from recognised chronology datasets, using computer software that matches ring patterns of the sample to a master pattern.

Dendrochronology in the UK

Many assumed that dendrochronology would have been hampered in Britain because of the complex climate experienced there. Science, however, has silenced the doubters and Grissino-Mayer confirms, "The UK is at the forefront of dendrochronology. Tree-ring dating is used in its historic and prehistoric structures and musical instruments. These data can be used to reconstruct climate and date historic structures. The UK has had some of the top dendrochronology programmes for a long time now."

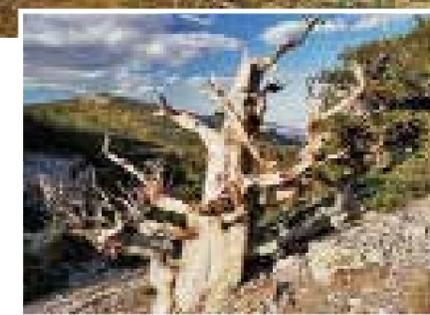
For accurate dendrochronological analyses to be carried out, an existing master tree-ring pattern has to be available for a particular geographical region and for the specific tree species. This places limitations on how far into the past tree-ring dating

can be applied. Currently, accurate dendrochronological studies are only facilitated because of tree species like the bristlecone pine (*Pinus aristata*) and oak, whose ages span centuries and sometimes millennia, providing a somewhat continuous pattern against which other trees may be matched.

In the UK, oak is one of the most documented species because of its widespread use in building timber-framed structures in the past. However, oak wasn't the only species used in construction; elm (*Ulmus procera*) and Western red cedar (*Thuja plicata*) were also utilised. If the only master chronology available for a region is for the oak species, its use in the crossdating and analysis of other species will certainly be unreliable.

The limits of time

Despite proving itself an accurate dating method, dendrochronology does have some limitations. One of the foremost limitations is that, in some parts of the world, the tree species that are available don't demonstrate clear-cut seasonal patterns. Grissino-Mayer explains, "Tree-ring dating doesn't work so well in the tropics. In these



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Whereas tree ring dating in the UK is most commonly done with oak timbers, in the US the rather raggedy looking bristlecone pine is the dendrochronologist's tree of choice

areas, trees don't shut down growth to form an annual ring and without that we cannot count the tree rings."

Additionally, where there is an availability of suitable tree species, the wood needs to be adequately preserved so that the tree-rings will be easily identifiable; each specimen should have a minimum of 30 rings. In some cases, trees that are cut at a young age don't have enough rings to facilitate accurate cross-matching.

Another requirement and potential hindrance to the application of dendrochronology in historical studies is that there has to be a fairly extensive use of timber within the time period and geographical region under consideration. Tree-ring analysis of the timber used in construction is a major way in which time stamps can be identified and applied.

Other limitations are linked to the



Above left: A portrait of Mary Queen of Scots, determined to date from the 16th century by dendrochronology by an unknown artist. Previously it was thought to be an 18th-century copy

Above right: Little Moreton Hall, Cheshire is mid 16th century, like the portrait to the left. Dendrochronology can be used in buildings like this to determine whether much older timbers have been incorporated in the structure



St Brothen's Church, Llanfrothen, Wales is a Grade 1 listed structure which has had various changes made to it. Tree ring dating has determined that the trees used to make the rood screen dated between 1496-1506

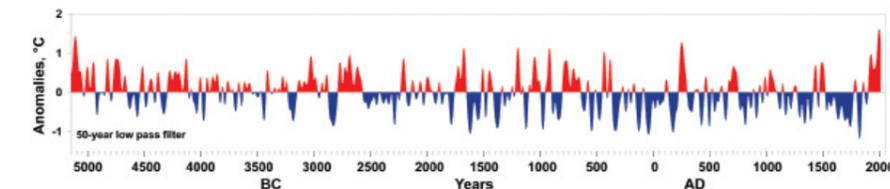
inherent structure of a tree developing from sapwood to heartwood. It is well-known that sapwood – the outer lighter-coloured section of a tree trunk – is much softer than the inner and darker-coloured heartwood. As such, sapwood is more prone to decay precipitated by moisture and insects. This may result in the absence, or removal, of sapwood from timber surfaces used in the construction of timber structures. The removal of the sapwood along with the outer tree-ring often makes it impossible to pinpoint the particular year that tree was felled.

Despite the anomalies and



On a lighter note - Baumkuchen is a traditional German layer cake made from flour, eggs, butter, sugar and vanilla, the name translates as 'tree cake' on account of the rings in the cake - yummy!

limitations, it is safe to say that dendrochronology has allowed us to leverage trees and timber into powerful timepieces. It is true that the field of tree-dating has its fair share of critics. However, there is extensive and well-documented research spanning decades to support the principles involved in dendrochronology. The enthusiast can access dendrochronology archives and databases for themselves. For example, the Vernacular Architecture Group maintains a dendrochronological database of tree-ring dates for more than 3,000 buildings in the UK.



This chart underlines some of the difficulties of dating timber from tree rings due to the sometimes extreme changes in temperature that can affect each ring

Dendrochronology websites

- National Centers for Environmental Information (NOAA)
www.ncdc.noaa.gov/data-access/paleoclimatology-data/datasets/tree-ring
- Nottingham Tree Ring Laboratory
www.tree-ringdating.co.uk
- Oxford Tree Ring Laboratory
www.dendrochronology.net
- University of Arizona Laboratory of Tree Ring Research
ltrr.arizona.edu
- Vernacular Architecture Group
www.vag.org.uk

Taking up dendrochronology

Grissino-Mayer provides the following tips to aspiring dendrochronologists, "You have to be a tree person! You need to take biology courses and study botany. Maths is also important for this field as you will be working with very specific software. Hence, it is a combination of maths and sciences. You need to read a lot on your own. Visiting a tree-ring laboratory can be beneficial. For example, you could interact with foresters, biogeographers, dendroecologists and dendroclimatologists who regularly use tree-ring data."

As a woodworking enthusiast, you can start your first project in this field by attempting to date a tree or even the timber used in your home. If you don't have access to the wooden slabs or cross-sections that you need, you might have to obtain an increment borer. This tool will also come in handy when coring live trees. Be sure to seal the hole you create to protect the tree from disease. All the information you need is readily available, and the results of your investigation might surprise you.

Dr Nicola Davies

Dr Nicola Davies is a psychologist and Freelance writer with hundreds of articles published in 10 countries. Her research skills make her amenable to a variety of subjects, all with a human interest angle. You can follow her on Twitter (@healthpsychuk) or sign up to her free blog: <http://healthpsychologyconsultancy.wordpress.com/>

