THE INTERPRETATION, PRESENTATION AND USE OF TREE-RING DATES

by Daniel Miles

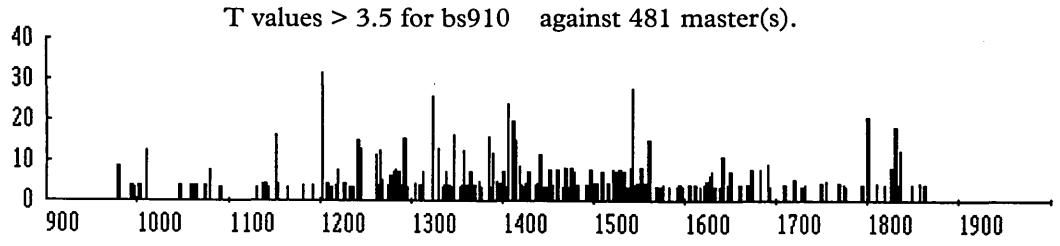
The science of dendrochronology has over the past decade advanced significantly, as the paper by Sarah Pearson in this volume clearly shows. However, there has not been an equal increase in the understanding of the general reader or user of tree-ring dating as to how to assess a date for validity of match, dating precision, and how this might be interpreted in dating a building or artefact. This paper outlines the process of dating, and attempts to highlight some of the problems associated with using tree-ring dates, setting forth a number of suggestions as to how these may be overcome. Examples of how precise felling dates may be reconciled with documentary dates have been summarised, to allow a more informed approach to the interpretation of felling dates; and the dendrochronological evidence for timber stockpiling is presented. Finally, the process of estimating missing sapwood rings is reviewed, and with the data generated over the past decade, new sapwood estimates are proposed which substantially reduce those previously used for the British Isles as a whole.

THE DATING PROCESS

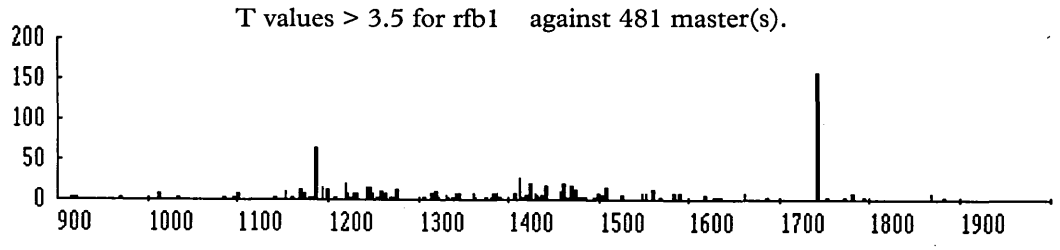
Tree-ring dates for standing buildings in Britain have been reported for the past 20 years, with half of these dates being produced within the last five years. What, however, is being dated when the bark edge is present, is the *felling* or *dying* of the tree itself. All too often the end user has taken such precise felling dates and used them as *building* or *construction* dates. This is not always valid, and there may be significant variation between the two dates. A further problem is that often the tree-ring sample will not have its outer sapwood complete to the bark edge, thus precluding the determination of a precise felling date. In such circumstances dendrochronologists have used various methods of estimating the most likely felling date or date ranges, but these are frequently incorrectly quoted as precise felling dates, even by eminent building historians or archaeologists. Even dates given as *termini post quem* or *earliest possible felling dates* have been corrupted and used as precise felling or building dates.

The principle behind tree-ring dating is a simple one: the seasonal variations in climate-induced growth as reflected in the varying width of a series of measured annual rings is compared with other, previously dated ring sequences to allow precise dates to be ascribed to each ring. When an undated sample or site sequence is compared against a dated sequence, known as a reference chronology, an indication of how *good* the match is must be determined. Although it is almost impossible to define a visual match, computer comparisons can be accurately quantified. Whilst it may not be the best statistical indicator, Student's (a pseudonym for W. S. Gosset) *t*-value has been widely used amongst British dendrochronologists.[1] The cross-correlation algorithms most commonly used and published are derived from Baillie and Pilcher's CROS programme,[2] although a faster version [3] giving slightly different *t*-values is sometimes used for indicative purposes.

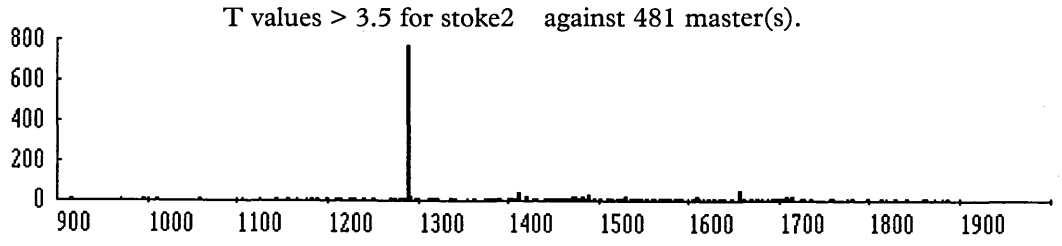
From statistical theory, *t*-values over 3.5 should be considered to be significant, although in reality it is common to find demonstrably spurious *t*-values of 4 and 5 because more than one matching position is indicated. For this reason, dendrochronologists prefer to see some *t*-value ranges of 5, 6, and higher, and for these to be well replicated from different, independent chronologies with local and regional chronologies well represented. Users of dates also need to assess their validity critically. They should not have great faith in a date supported by a handful of *t*-values of 3's with one or two 4's, nor should they be entirely satisfied with a single high match of 5 to 6. Examples of spurious *t*-values in excess of 7 have been noted, so it is essential that matches with reference chronologies be well replicated, and that this is confirmed with visual matches between the two graphs. A further useful check is by using a histogram, which can visually display all *t*-value matches as vertical bars of cumulative values over, say, 3.5 for each year for a wide period of perhaps a millennium. The three examples in Figure 1 show (a) a hopeless 'match' with no potential, (b) a good 'match' with at least two contenders – this ambiguity may occasionally be resolved by looking at the graphs, the *t*-value matches, and the geographical proximity of the reference chronologies (assuming the timbers being dated are local) and other dated samples to the sample being dated. The last example (c) shows an excellent clean 'match' which will no doubt be confirmed by visual comparisons with the graphs of the individual reference chronologies. It should be stressed that even if *all* available chronologies in a particular laboratory's database for the British Isles are included in the histogram, the results may not be strictly



Example of poor quality match, sample totally undatable



Example of good match, but visual checks with graphs required to exclude c.12thC match



Example of excellent match, which will undoubtedly be confirmed with visual checks

Figure 1
Cumulative t-value histograms of sample compared with database of reference chronologies.

representative in that some of the chronologies may not be independent of each other, thus skewing the results.

It is general practice to cross-match samples from within the same phase to each other first, combining them into a site master, before comparing with the reference chronologies. This has the advantage of averaging out the 'noise' of individual trees and is much more likely to obtain higher *t*-values and stronger visual matches. Sometimes, especially in urban situations, timbers may have come from different sources and fail to match each other, thus making the compilation of a site-master difficult.[4] In this situation samples must then be compared individually with the reference chronologies.

In reality, the probability of a particular date being valid is itself a statistical measure depending on the *t*-values. Consideration must also be given to the length of the sequence being dated as well as those of the reference chronologies. A sample with 30 or 40 years growth is likely to match with high *t*-values at

varying positions, whereas a sample with 100 consecutive rings is much more likely to match significantly at only one unique position. Samples with ring counts as low as 50 may *occasionally* be dated, but only if the matches are very strong, clear and well replicated, with no other significant matching positions (Figure 1). Here, it is essential for intra-site matching when dealing with such short sequences. Consideration should also be given to evaluating the reference chronology against which the samples have been matched: those with well-replicated components which are geographically near to the sampling site are given more weight than an individual site or sample from the opposite end of the country.

ASCRIBING FELLING DATES

Once a sequence has been satisfactorily dated with high supporting *t*-values and good confirming visual graph matches, a felling date is then ascribed for each dated sample. Figure 2 illustrates three possible situations: those samples with bark edge surviving can be ascribed *precise felling dates*, whereas samples with neither sapwood nor heartwood/sapwood transitions can only offer *termini post quem* or *earliest possible felling dates.* * Both of these cases can be treated in a straightforward manner, and clearly present no problems. Samples with heartwood/sapwood transition (abbreviated h/s, h/s boundary, or HST) or with incomplete sapwood give dendrochronologists, archaeologists and building historians serious problems in determining the correct *estimated felling date ranges.* In this paper, an imaginary sample with complete sapwood ending in 1631/2 will be used in presenting dates and date ranges. Often, especially in archaeological reports, dates will be either *AD*1632 or 1173*BC*, but this has been omitted here for clarity.

Samples with Complete Sapwood – Precise Felling Dates

As noted above, if the timber sample has its outer sapwood intact to the bark or underside of bark, then a precise date can be ascribed for the felling of the tree. By identifying the completeness of the last ring under the bark, the dendrochronologist can determine if the tree was felled in early, mid, or late spring, early or late summer/autumn, or in the winter of a particular year (Figure 2). However, the designation of such precise seasons can be problematical and should be treated with discretion. The annual ring width is measured from the ring boundary which signifies the period of winter when the tree lies dormant.

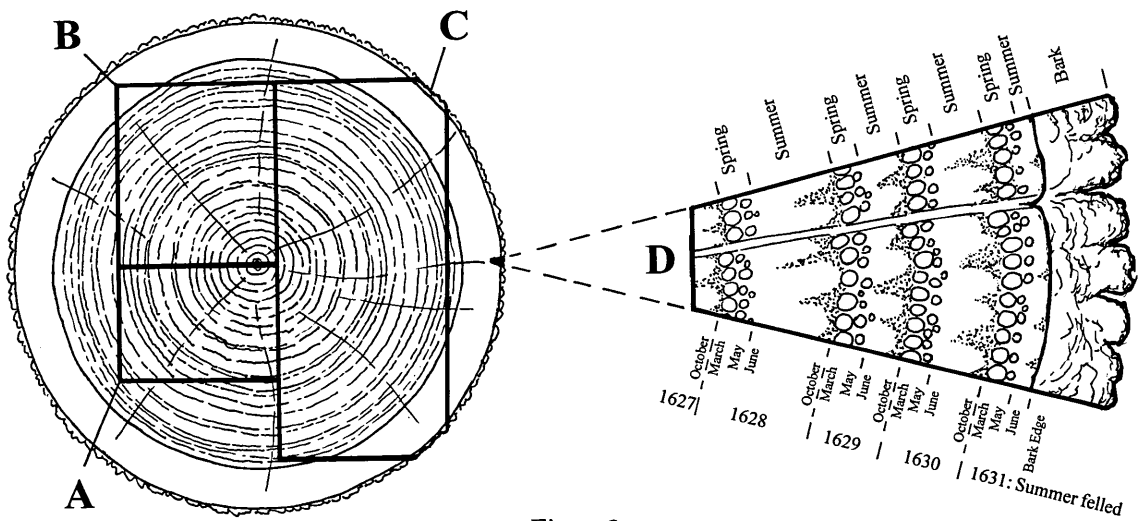


Figure 2
Conversion of tree showing (A) sample with no sapwood or heartwood/sapwood boundary, (B) sample which has some sapwood but not complete to bark edge, (C) sample with bark edge, (D) enlarged area of outer rings of sapwood showing growing seasons and summer felling.

* For several decades dendrochronologists have applied the term *terminus post quem* (abbreviated *tpq*) to the date for a timber without any sapwood or heartwood/sapwood boundary, for which all that can be said is that it was felled *after* the given date; the terminology is borrowed from that used by archaeologists for the dating of stratified layers. However, the term is considered by some to be ambiguous and has been misunderstood to mean the *latest* possible date for the timber. In this paper, the English phrase *felled after* or *earliest possible felling date* is used, and it is recommended that this should be adopted generally.

Therefore, when that last ring at the bark edge is complete, indicating winter felled, then the last measured ring is the same as the felling date. For example, a last measured ring of 1631 with winter felling would have been cut sometime between about October 1631 and February 1632. This is often shown in published results as *1631/2C* or *1631/2B,* in which the 'C' denotes Complete sapwood, and 'B' denotes Bark edge.

Often, the felling date for a timber with complete sapwood is not the same year as the last measured ring date. Partial rings are not normally measured as they might affect any composite master in which they might be included, but should be recorded so that a sample with a last measured ring of 1631, with complete sapwood having spring vessels, would have been felled in between approximately March and May of 1632. If just a few spring vessels are partially formed, then it should be said to be felled in *very early spring.* If one row of spring vessels is complete under the bark, then this would be said to be felled in the *spring* or *early spring.* If several rows of spring vessels are present, not unlike the complete spring growth in the previous years' growth rings, then this would be considered to be felled in the *late spring.* Some samples will sometimes have a series of spring bands which are only one row of spring vessels, or even one row of vessels spaced apart. The tree is a living biological thing and often does not correspond to set rules, so one must be circumspect in trying to focus too much on this aspect. Where these have been distinguished, they are all often published as *1631¼C* or *1632B.*

Similarly, summer/autumn growth indicates felling between the months of June and September, and is presented as *1631½C* or *summer 1632B.* Summer growth cannot be apportioned to particular months as one does not know if an incomplete summer growth ring is in fact a narrow ring of little but almost complete summer growth, or a wide ring only partially formed. The very best that can be managed (and then not always) is to distinguish between *early summer* and *late summer/autumn.* It is very difficult to know whether a sample has complete sapwood felled in the late summer/ autumn or the winter, and most European laboratories will categorise these as winter just to be on the safe side. It must be stressed that months can only be used as an approximate guide, as the complex relationship between climate, situation and changes in wood growth are subject to considerable variation, both between trees and from year to year. Therefore it is important *not* to ascribe a calendar month to the felling, but to be content with the *season* of the year in which the tree was felled.

Samples with no Sapwood or Heartwood/Sapwood boundaries – Earliest Possible Dates

Probably the least useful, easiest to determine, and most frequently mis-quoted dates are those from timbers without any evidence of sapwood at all. Generally, the conversion of oak trees into beams, planks and other various wooden objects removes all of the less-durable sapwood, as well as an indeterminate number of heartwood rings. Thus, one generally cannot have any idea of how many heartwood plus sapwood rings are missing in order to derive even the broadest felling date range. As some slow-growing oaks can exceed 400 years growth in little more than 400mm radial section, it follows that the removal of even 100mm of outer material can throw the result out by a century. In these instances, an *earliest possible felling date,* often referred to as a *terminus post quem (tpq),* can be given, meaning a date before which the tree could not have been felled. This is determined by adding to the last measured ring date the *minimum* number of sapwood rings of the appropriate sapwood estimate, thereby arriving at the earliest possible felling date assuming that the last surviving ring was at the heartwood/sapwood boundary, and that the number of sapwood rings was the lowest number within the 95% confidence range. Thus a last measured ring date of 1537 with no heartwood/sapwood boundary would have ten years added to it to give an *earliest possible felling date* of 1547, or *felled after* 1547. This means that it is very unlikely to have been felled before 1547, impossible to have been felled before 1537, and could just as easily have been felled in 1632. *Earliest possible felling dates* are often presented as *1547+, post 1547, felled after 1547,* or *1547 tpq.*

The only way possible to qualify this further is through a large number of *earliest possible felling dates* from a range of coeval timbers within a building phase. If the samples were from different trees (same trees could skew the results through the middle section only being used) and gave *earliest possible felling dates* all within 25 years of each other, then it is likely that the samples have all had a small number of heartwood rings removed with the sapwood. If this is the case, then it might be possible to suggest an *approximate felling date range,* making an educated guess of how much material had been removed. At Winchester College, the analysis of 25 panels found to be imported from eastern Europe showed that these derived from

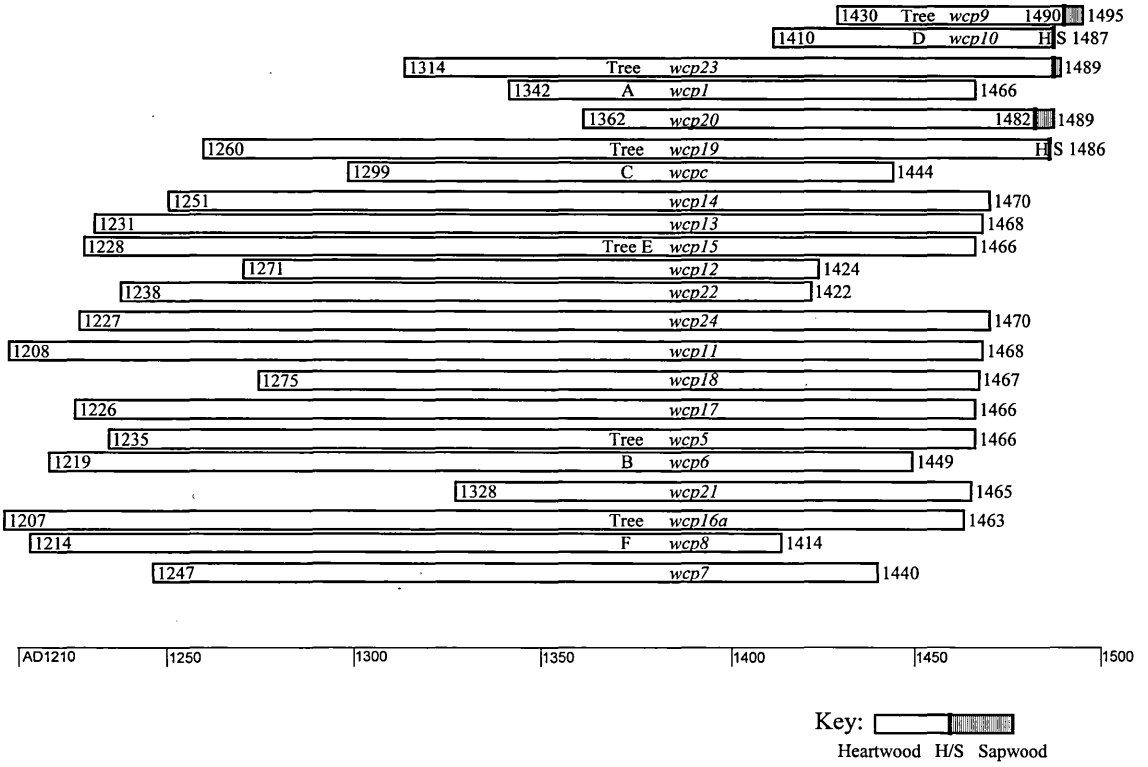


Figure 3
Bar chart of samples from Winchester College illustrating relationship of last measured ring dates from a contemporary group of samples.

13 trees.[5] Most had no evidence of sapwood, but five panels had either a few rings of sapwood or heartwood/sapwood boundary. Using only the samples without sapwood, it would be a reasonable guess that the heartwood/sapwood boundary was no more than 25 years after the last measured ring.[6] A similar study is probably possible in the timbers in the roof of Lincoln Cathedral.[7] Figure 3 shows that with a large data set such as Winchester College some conclusions can be made, but only in broad terms.

Samples with Incomplete Sapwood – Estimated Felling Date Ranges

When some or all of the sapwood is missing, but a rounded waney edge survives generally indicating a heartwood/sapwood transition, then the process becomes very much more complicated. In the case of British oaks, a sapwood estimate of 10-55 rings has been commonly used for the past ten years,[8] although estimates of 15-50[9] and other more local estimates have more recently been used. Clearly, if some or all of the sapwood is missing from a timber through conversion or decay, then it is impossible to determine precisely how many rings have been lost to the bark edge. Attempts have been made to determine a most likely date within this range,[10] but these have seen varying degrees of success. Simply put, if a sample has a heartwood/sapwood boundary date of 1600, but with no sapwood surviving, then a 95% confidence estimate of 10-55 sapwood rings would give a felling date range of 1610-1655. If a sample has the same heartwood/sapwood boundary date of 1600, but a last measured ring of 1629 with incomplete sapwood, then the 29 rings of sapwood would allow the same estimated felling date range to be reduced from a 45 year range to 25 years, i.e. 1630-1655.

Sapwood is rarely consistent, either from different timbers within a site or even from within a single tree. Very occasionally, the heartwood/sapwood transition date will be within a year or two of each other, as can be seen in a group of six samples found at the Council House, Shrewsbury Castle, but more often the number of sapwood rings will vary considerably. For instance, one core sample was found to have had 13 more rings of sapwood on one side of a medullary ray than the other, plus a sapwood inclusion, all within 10mm (Figure 4). There are also rare exceptions, such as finding no sapwood at all, or substantial sapwood inclusions. One modern example, also

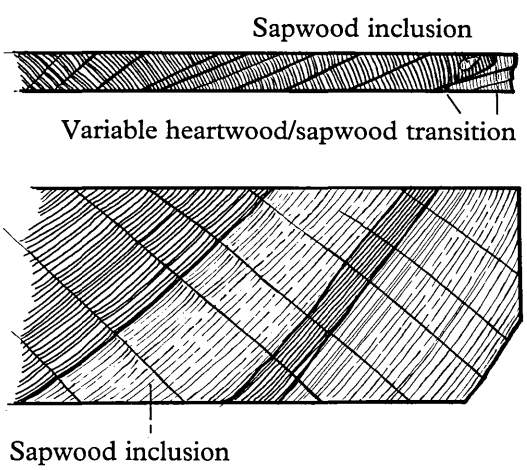


Figure 4
Examples of variable heartwood/sapwood boundaries and sapwood inclusions.

illustrated in Figure 4, had a heartwood/sapwood transition 100 years back from the bark edge. This was followed by a band of 35 years of sapwood, then by 20 years of heartwood, then by a final band of 45 years of sapwood. Had only the earlier heartwood/sapwood transition survived, then the estimated felling date range would be some two or three generations earlier than reality. This was also found in a late sixteenth-century building at 14 Callaughton, Shropshire where two of the principal rafters exhibited a band of decayed sapwood followed by a solid band of truncated heartwood. This had the effect of producing two estimated felling date ranges which were much earlier than the actual precise felling date produced by another timber with complete sapwood. This illustrates the necessity for taking as many samples as practicable, perhaps providing an alternative interpretation for single individual felling date ranges which are substantially earlier than other samples within a group.

ESTIMATION OF MISSING SAPWOOD

One method of sapwood estimation used at Sheffield University is that of Hillam, Morgan and Tyers.[11] This gives a minimum and maximum number of sapwood rings of between 10 and 55 years within 95% confidence limits. Mention has been made of a slight trend for fewer sapwood rings in younger oak trees under 100 years old, as well as a relationship between fewer sapwood rings and wider mean ring widths as previously suggested by Fletcher. However, these were not quantified and only a general sapwood range of 10-55 years was proposed to be used for the whole of the British Isles, for both mature and immature oak trees. The main drawback in using this broad estimate is that it is now clear that most trees from the south of the country and the midlands have fewer sapwood rings, so that the 55 year outer limit will often extend the felling date range far beyond that found in practice with English building timbers. Irish timber has a substantially higher number of sapwood rings on average than those from England, and it is the combining of these two groups of data which leads to this wider range. However, much more data has now been produced within the last decade, allowing us to see the limitations of applying a 10-55 year range throughout the British Isles. It would now seem to be more appropriate to use data from English trees only in England, rather than apply one estimate to satisfy the whole of the British Isles.

Nottingham University have used an estimate of between 15 and 50 sapwood rings,[12] although they have recently revised this for most of their work with a more localised estimate of between 15 to 40 years. In Kent, the study of a large number of buildings has produced sufficient data to allow a tighter and more realistic sapwood estimate of between 15 and 35 rings.[13]

Work with English Heritage in dating Oxfordshire buildings has produced a preliminary sapwood estimate of between 10 and 30 rings,[14] and an interim estimate of between 11 and 45 years has been compiled for Shropshire.[15] All of these sapwood estimates are within the 95% confidence limits; in other words one sample in twenty may fall just outside these limits.

All this shows that the estimates of sapwood are many and varied through Britain and abroad, but that there is a general trend for numbers of sapwood rings to decrease from north to south and from west to east across Europe. In Ireland, a 95% confidence level of 14-50 rings is used,[16] in Poland 9-36,[17] and in Finland 8-22 rings.[18]

Figure 5 shows three histograms of sapwood ring counts. These have been compiled from published dates from primarily standing buildings up to and including *VA* 27, including complete sapwood counts from only *dated* samples. Altogether, just over 900 sapwood ring counts have been used, 295 of these from the midland counties of Cheshire, Staffordshire, West Midlands, Northamptonshire, Cambridgeshire, and everything to the north, 219 from Shropshire, Hereford and Worcester, and Wales, and 406 from all other southern counties up to and including Gloucestershire, Warwickshire, Bedfordshire, Suffolk and Norfolk. Whilst

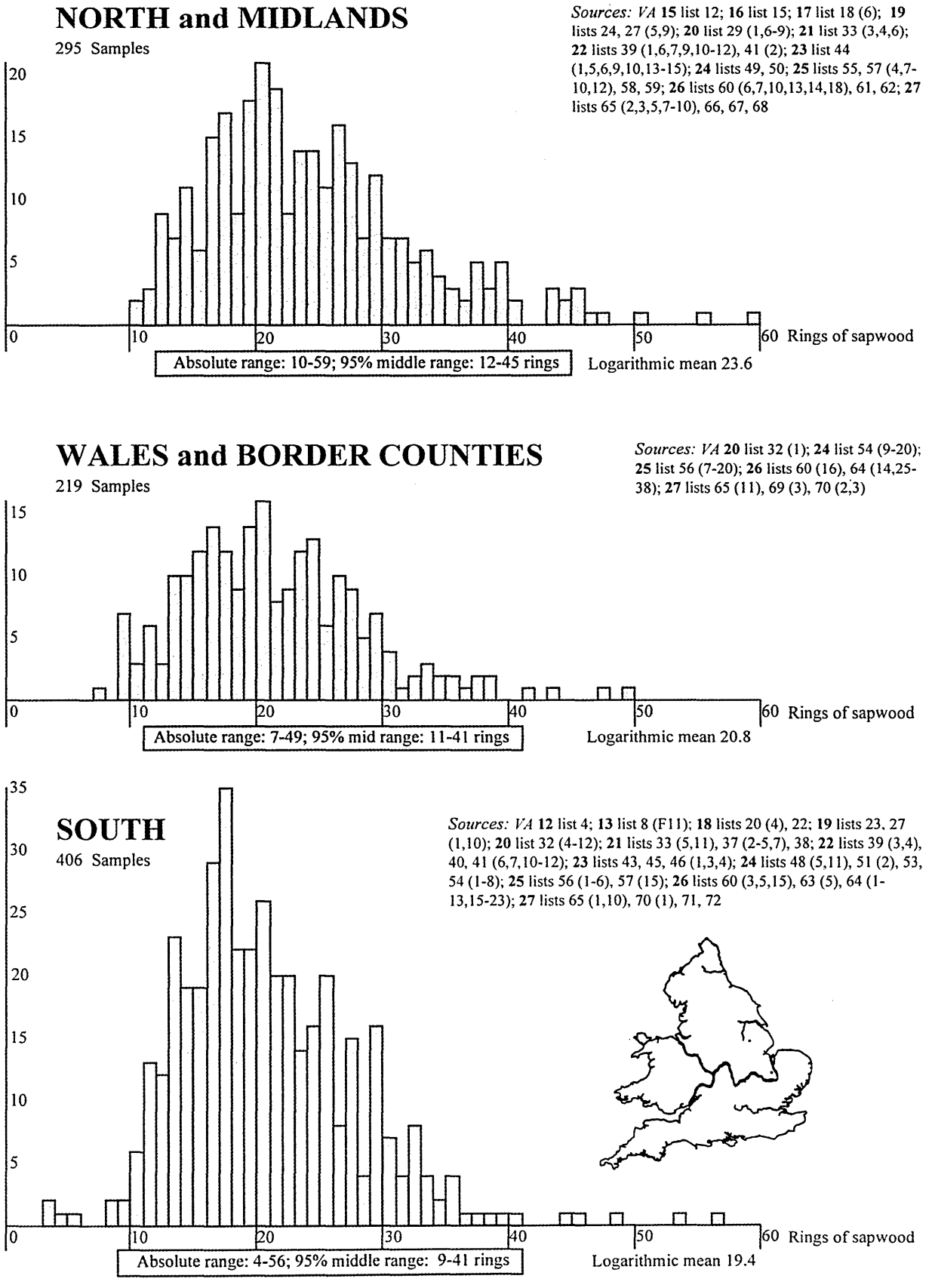


Figure 5

Sapwood distribution graphs for (a) Northern England and Midlands, (b) Wales and border counties, c) southern England.

these histograms are rudimentary, and do not include any sapwood counts from undated, unpublished archaeological timber or living trees, they are nevertheless representative of historic medieval and post medieval building timbers for which we are particularly anxious to apply estimated felling date ranges. All show substantially fewer sapwood rings than the 'national' estimate of 10-55 rings, but from north and south there is only a slight reduction of about five rings on average. They also all have skewed distributions averaging fewer rings than the arithmetical centre of the range.

Taking these data sets at face value, and not applying any refinement in averaging the overall trends, one can nevertheless see that a substantially reduced sapwood range might be applied to building timbers in these respective geographic areas. For the north, we have an absolute range of 10-59 rings, and by using the same methods as Hillam, Morgan and Tyers as well as Hughes, Milsom and Leggett, a 95% middle range would be between 12 and 45 years. Similarly, the timbers from Wales and the Welsh/English border counties have an absolute range of 7-49 rings, with a 95% middle range between about 11-41 years, whereas those from the south of the country have an absolute range of 4-56 rings, and a 95% middle range of 9-41 years. This is a subject worthy of a paper on its own, and it is hoped that present research by Sheffield University in Devon will result in a revised sapwood estimate which will be more appropriate for the south-west as well as other parts of the country. Somerset and Hampshire are also being subjected to intensive studies, and it is hoped that these too should produce more realistic sapwood ranges. The results of five years work in Shropshire are also now being collated. Nevertheless, the reader and user of dendrochronology should be aware of this general trend, and that the longer sapwood ranges given in the absence of more local determinations might be reconsidered. However, in light of the closeness in ranges between different parts of England, one should be somewhat cautious in using felling date ranges derived from small number of samples from individual counties without any further attributions such as mean ring width, etc., being taken into account.

Whilst determining which sapwood estimate is most appropriate for a particular site can be somewhat problematical, efforts to refine these further for particular samples can be even more contentious. Obviously, the lower limits of any given sapwood range can be reduced by any surviving sapwood. Otherwise, it is sometimes possible for the dendrochronologist to use his/her experience to further qualify the felling date range. A trend often noted is for slow-grown trees with narrow mean ring widths to have more sapwood rings than those from fast-grown trees with wider rings. For instance, timbers from the same site with complete sapwood may exhibit relatively narrow mean ring widths, whereas high numbers of sapwood rings may lead to an estimated felling date range qualified as "between 1610 and 1655, with the most likely felling date being in the later part of range". Conversely, sites in the south of the country often have fast-grown immature trees with wide mean ring widths. These might be qualified as "between 1610 and 1655, with the most likely felling date being in the earlier part of the range".

In the past, one method of presenting felling date ranges has been for the selection of a most likely date within an estimated felling range. This might be the middle of the range or a skewed date, presented as "1610 – (1635) – 1655" or "1635 – 25 +20". However, this manner of presenting dates can be misleading and is frequently misquoted. Whilst the date of 1635 might have the highest number of recurring sapwood rings within a date set, there is also an almost equally high probability of the date being 1634 or 1636. While there is a 95% chance of the actual felling date falling within the overall estimated felling date range, there is probably less than a 7 or 8% chance of the actual felling date being the same as the estimated "most likely" date, as Figure 5 clearly illustrates. As we can see, there is little difference in probability in other immediately adjacent date positions, especially once the graphs have been averaged.

The real danger is that these estimated most-likely dates are often misquoted and mis-interpreted as real precise felling dates. Users of dendrochronological results have been notorious for discarding the carefully laid down qualifications and caveats which accompany these estimated most likely dates. Most users are not satisfied with a felling date range, and are only too quick to use only the most likely estimated date, representing it as a precise date. Inevitably these misquoted dates are repeated in an ever-increasing wider range of publications, the majority of which seldom refer to the original report and rarely to the dendrochronologist or laboratory. Given these problems, it is suggested that these estimated most likely felling dates should not be used, nor should mid-range dates with + and – ranges, and that a *non-specific* qualification of which end within a felling date range a date might lie should be as far as the dendrochronologist should go in presenting felling dates. However, this is not very helpful when trying to present a series of dates and date ranges within a table or histogram. One example of how this might be overcome can be found in the recent paper "Nottinghamshire Houses dated by Dendrochronology"[19] where precise dates are denoted by a dot, whilst felling date ranges are delineated by a bar with a dot

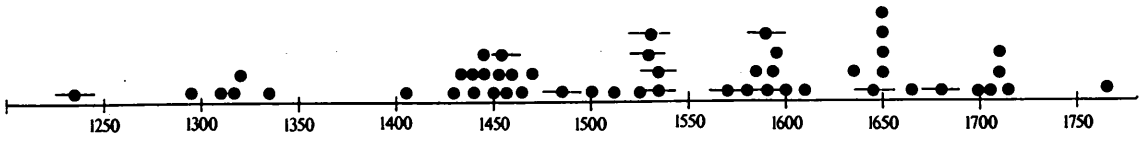


Figure 6
Method of presenting precise dates and estimated felling date ranges.
Courtesy of R. R. Laxton, C. D. Litton and R. E. Howard, 1995, 'Nottinghamshire Houses dated by Dendrochronology', Trans Thoroton Soc Nottinghamshire, 99, 53.

superimposed at the position of the most likely date (Figure 6). Because the scale of the histogram is small, and no calendar dates are ascribed for individual points, the likelihood of quoting non-specific dates as precise ones is minimal.

It is hoped that further research such as that already underway both in this laboratory as well as at Sheffield University might determine new statistically valid methods of determining sapwood by taking into account other factors such as mean ring width of the sample as a whole as well as the immediate preceding rings, age of tree, and general growth trend. All of these factors have some influence in calculating the number of sapwood rings.

Other methods have been used to reduce felling date ranges when a group of samples is analysed from a single phase or site. The method used at Nottingham is to take the average of all the heartwood/sapwood boundary dates, and from this last average heartwood/sapwood boundary determine a felling date range.[20] This is used when one phase of construction is likely, e.g. in a vernacular building and after the inspection of timbers *in situ* (Figure 7). Another method used is to present all the felling date ranges, and to then use the area of common overlap as a reduced felling date range.[21] Whilst this method appears to give a much narrower felling date range, it cannot be statistically justified. Both methods are based on the assumption that all of the trees dated were broadly contemporary, and as this is sometimes not the case, caution should be exercised in using either. Certainly, the best option is to present (in the first instance) individual felling date ranges for each sample within a group of timbers. Unfortunately, this is not very helpful for the user of dendrochronology in summarily presenting dates for a single phase of construction comprised of a number of differing felling date ranges. However, the method of averaging all of the heartwood/sapwood boundary dates before applying an appropriate felling date range is probably the easiest to qualify, and will give the highest chance of being correct, but only so long as the absolute variation in range of the heartwood/sapwood boundary dates is not greater than the appropriate 95% confidence level. Obviously the resulting estimated felling date range would be adjusted to account for the latest present sapwood rings. Nevertheless, some degree of compromise is required to provide 'users' with an easy-to-handle date range.

PRESENTATION OF TREE-RING DATES

All too often the meaning of a *terminus post quem,* or *earliest possible felling date,* has clearly been mis-understood, and incorrectly presented as a precise felling date. A recent example of this was watched by 3.7 million people on a recent BBC2 *Horizon* television programme in which a timber was recovered from a ship found off the coast of Alderney thought by the marine archaeologist to have been associated with the Spanish Armada battle of 1588. The timber had a last measured ring date of 1565, with no evidence of sapwood, therefore an *earliest possible felling date* of 1575 was given. Unfortunately, this was presented on television as a *felling* date of 1575, and used as evidence to suggest that the ship took part in the Armada. In reality, however, the felling date could just as well have been *after* 1588. During filming, it was stressed that the date was from a single timber; whatever the result was, it should be treated with extreme caution. Regrettably, this was edited out of the final programme.[22]

Another example of dendrochronology being misrepresented in the public arena is the debate over the authenticity of Rubens' *Samson and Delilah.* The original painting was supposed to have been painted in 1609. When questions were raised recently as to whether it was painted by Rubens himself, or by a minor hand some years later, the National Gallery commissioned a dendrochronological analysis by the University of Hamburg of the oak panels upon which the painting was applied. The panels had no sapwood or heartwood/sapwood boundary, but had a last measured ring date of 1588, thus

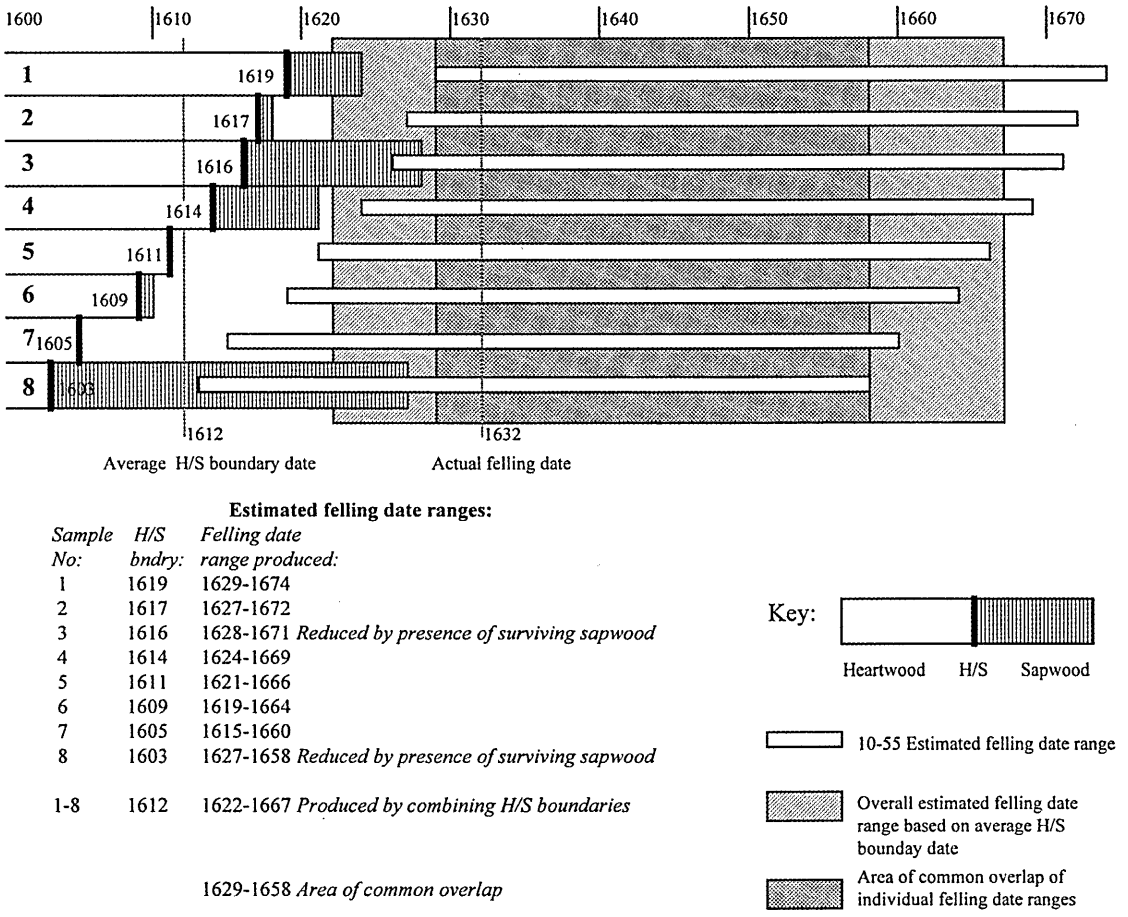


Figure 7
Methods of combining a number of individual estimated felling date ranges to produce a single felling date range determined from an average heartwood/sapwood boundary date, and to define area of common overlap.

giving an *earliest possible felling date* of 1597. This was interpreted by some as supporting the claim that the painting could just as easily have been painted in 1609. What was not stressed was that the painting could have been painted in 1620 or 1630, because it is not really known how much of the outer heartwood had been removed from the tree in conversion. Thus the dating neither proves or disproves a particular date after 1597. However, had the last measured ring been 1605, giving an *earliest possible felling date* of 1614, then one could say that it was *extremely unlikely* to have been painted by Rubens in 1609. Alternatively, had the last measured ring date been 1612, then one could quite safely state that it was *impossible* to have been painted by Rubens in 1609. Again this illustrates some of the difficulties in dealing with samples without any sapwood.[23]

In presenting tree-ring dates, it is important to make it clear whether the timbers dated have complete sapwood, partial sapwood, or no sapwood at all. Ideally, the date/date ranges for each timber should be given, but obviously this is not practical except in a detailed report. Where a number of timbers have been dated from a phase, it is obviously those timbers which have given *precise* dates which are most relevant, and of those, the *latest* precise date is most likely to be nearest the actual construction date. Where only a number of felling date ranges are available for a phase, there is no ideal way of presenting a combined estimate; probably the best option is to give a felling date range based on the average heartwood/sapwood boundary, the lower end of the range adjusted for surviving sapwood. Where complete sapwood is not available and felling date ranges or felled after dates are offered, then a reference must always be given as to which appropriate sapwood estimate is used.

The most important thing to remember whenever presenting a tree-ring date is that it is the *felling* of the tree which is being dated, not

the *construction* of the building. This should always be made clear in any summary. Either a date can be presented as: "Building X has been constructed of trees felled in 1632", or "Building X was constructed either during or shortly after 1632". One cannot say on dendrochronological evidence alone that a building was *built* in a precise year. English Heritage is presently drawing up proposed dendrochronology guidelines.[24] Whilst different conventions may be required for presenting condensed results such as the *Vernacular Architecture* tree-ring date lists, these would be appropriate for most applications. The proposed conventions for the publication and quoting tree-ring dates are reproduced here in abbreviated form with minor amendments:

Date span AD 1491-1632 (Lab, date)	*Date of the first and last ring of the ring sequence (laboratory, date result produced).* ***Should not be confused with felling dates.***
Felled spring AD 1632B (Lab, date)	*Bark edge present; last ring incomplete – felled late spring (¼B) or summer/autumn (½B) of AD 1632 (laboratory, date result produced)*
Felled AD 1631/1632B (Lab, date)	*Bark edge present; last ring complete or season of felling indeterminable – felled winter/early spring of AD 1631/1632 (laboratory, date result produced)*
Felled AD 1631/1632B? (Lab, date)	*Bark edge probably present – probably felled in AD 1631/1632; definitely not before (laboratory, date result produced)*
Felled AD 1630-1655 (Lab, date; reference for sapwood estimate)	*29 sapwood rings but no bark edge; sapwood estimate applied – there is a 95% chance of the timber being felled in any of the years within this range (laboratory, date result produced; details of sapwood estimate). Should* ***not*** *be quoted as "AD 1635 (-25 +20)" or "about AD 1635".*
Felled AD 1610-?1655 (Lab, date; reference for sapwood estimate)	*Heartwood/sapwood boundary probably present; sapwood estimate applied – the timber was felled after AD 1610 and possibly before AD 1655 (laboratory, date result produced; details of sapwood estimate)*
Felled after AD 1547+ (Lab, date; reference for sapwood estimate)	*No sapwood; unknown amount of heartwood may be missing – timber felled some unquantifiable time after AD 1547 (laboratory, date result produced; details of sapwood estimate)*

The recommendation must be that whenever tree-ring dates are being interpreted, quoted, or referenced, it is important to *always refer back to the Laboratory and dendrochronologist concerned* with a draft of how the dates are to be used. This practice would have prevented many misquoted dates from being printed. If the site is a particularly large and complex one, and the tree-ring dates are a fundamental part of the publication, then consideration should be given to joint authorship with the laboratory concerned.

RECONCILING FELLING DATES WITH BUILDING DATES

In the past, buildings with extensive building accounts or other documentary information have generally been neglected for dendrochronology. Apart from the work of Gavin Simpson of Nottingham University on Lincoln[25] and Ely Cathedrals,[26] and Coralie Mills on Exeter Cathedral,[27] little serious study has been undertaken. It has by some been considered to be a waste of resources to date buildings for which the building dates were

already known. This is regrettable, for much can be learned by relating the felling dates of timbers and the building accounts. Identification of the period intervening between the felling of the trees and the building date from documents should allow a greatly enhanced interpretation of tree-ring dates for other buildings.

Recent work has produced a number of tree-ring dates for which documentary dates are available. Stokesay Castle, for instance, has produced various felling dates of spring 1284, spring and summer 1285, spring 1287, summer 1288, summer 1289, and winter and spring 1290 from various parts of the Great Hall, North Tower and Solar cross-wing. Too few timbers had complete sapwood surviving to allow any trends in the phasing of the various elements of the complex to be detected, but instead suggest that all was under construction at one time. A licence to crenellate was obtained in 1291 from Edward I, suggesting that much of the building work was under way.[28]

At Lodge Farm, Odiham, precise felling dates were obtained for both the hall and the cross-wing. Detailed accounts for the rebuilding of the Lodge survive in the Exchequer Accounts for Edward III. Clearly the Lodge had been rebuilt in two phases; firstly the cross-wing with two precise felling dates from the winter of 1368/9, with the hall being rebuilt a few years afterward, with two precise dates of spring 1374 and spring 1375.[29] Whilst the Exchequer rolls covering the period 1373-1377 do not differentiate the work on the Lodge from that being carried out on Odiham Castle, the rolls covering the period 1366-1370 itemise clearly the work on the Lodge cross-wing.[30] Analysis of the building operations suggests a construction period of about five or six months, with the rates being paid suggesting work being executed during the summer months. Given that the two precise dates obtained indicate felling between October 1368 and March 1369, and that the Exchequer accounts cover the period up to Michaelmas (30 September) 1370, building could have taken place during the summer months of 1369 or 1370.

At Court Farm, Overton, we are fortunate in having both the house and the barn mentioned in the Winchester Bishopric Accounts.[31] The barn produced a felling date of late summer 1496 for one of the arcade posts, and a date of late spring 1496 for a joist found in the adjacent house, presumably a leftover timber from the barn.[32] The Accounts which cover the period Michaelmas 1496 to Michaelmas 1497 refer to the carriage of timber to build the Great Barn, as well as the costs of masons and labourers and the purchase of tiles, pegs/nails, and lime. In the Accounts for the following year, Michaelmas 1497 - 1498, reference is made to the cutting down of 120 oaks for 'the new barn being built'. Therefore the Accounts suggest that the timber had been obtained over two different years, and it was in the year that the principal timbers such as the arcade posts (one of which dated to the summer of 1496) were obtained. It was not until after September 1497 that the rest of the timber was obtained, transported, trimmed and sawn, and framed.

The house is of two coeval ranges, a partially-floored three-bay service/hall/parlour cross-wing, and a four-bayed floored range, possibly a court house. Two felling dates of summer 1504 and late spring 1505 were obtained for joists, and three struts and three collars over both ranges were all felled in the late spring of 1505.[33] The Pipe Roll covering the period Michaelmas 1504-1505 is missing, but the Roll for the year commencing 29 September 1505 shows payments being made for felling and trimming 30 oaks at Ecchinswell, six miles away, and for constructing six saw pits to saw the timber. References are also made to 39 tons of timber being trimmed and dressed at Willesley, and as no reference is made to this latter timber being felled during the period of the Accounts, it is possible that the timbers which have been dated to late spring 1505 were obtained from this source. During the period between Michaelmas 1505 and Michaelmas 1506, the Accounts state that the old hall was pulled down, with some timber and tiles salvaged, and that brick foundation walls were constructed. Here, we have seven timbers, six of which have been felled in spring of 1505, with references suggesting they were converted during the period of September 1505 and September 1506. The framing was then carried out during the early months of 1507, with the building being tiled and doors and window shutters hung before the end of September 1507.[34]

Overton again features in another documentary reference for a house at 73-77, Winchester Street, found in the rent collectors' accounts from Corpus Christi College, Oxford.[35] Seven precise felling dates were obtained for this building: a tiebeam felled in the spring of 1542, an axial beam from a tree felled during the summer of 1543, two studs, a window jamb, and a principal post from trees felled in the winter of 1543/4, and another stud from a tree felled in the spring 1544.[36] In a rent account compiled on or shortly after Michaelmas 1545, covering the period 29 September 1544 – 28 September 1545, the

house is referred to as being newly built, *de novo edificat.*[37] Although we do not have building accounts *per se,* we do know that one of the timbers was still part of a living tree in the spring of 1544, and that the property was habitable and occupied by the end of September 1545, a period of fifteen months having elapsed between the two.

Another example of documentary references tying up with felling dates can be found at the Abbots House, Butcher Row, Shrewsbury. This an elaborate three-storied, jettied and carved townhouse on a corner site. Here, precise felling dates of summer 1457 for a principal post, and late spring 1458 for a corner post and a stud,[38] fits well with a recorded ceremony in about April 1459 which in the borough bailiffs' accounts reads:

> *Et in den' solut' carpentar' abbatis de Lylleshill pro regardo ill' dat' in sufficacione domus sue in le Fyschstrete* .. xx*d*
> *Et in vino dat' dicto abbati eodem tempore pro honestate ville* ..... xiij*d*
>
> And in pence paid to the carpenter of the abbot of Lilleshall for his reward, given at the *sufficacio* of his house in Fish Street.....20d
> And in wine given to the said abbot at the same time for the good reputation of the town 14d

The meaning of *sufficacione* is not clear, but the verb *sufficio* means 'to lay the foundation for'.[39] This suggests that from spring 1458 to the ceremony in April 1459 the frame was being constructed off-site, and that the ceremony related to the construction of the stone foundation, but prior to the erection of the prefabricated frame on site.

These examples of comparing building accounts with felling dates are useful in that we can see that usually one if not two years intervenes between the felling of the latest trees, and the dates recorded in the accounts. That these buildings are all minor domestic or agricultural buildings also bears more relevance to the study of vernacular architecture when compared to major ecclesiastical or Royal buildings where different methods of obtaining and storing timbers may have occurred. But even without the building accounts, the dendrochronology sometimes can give a good indication of the timing of the framing as well as the erection of a building.

At Charlton Court Barn, Steyning, West Sussex, ten timbers produced precise felling dates. Nine of these were from principal posts, tiebeams, braces and purlins, and all were from trees felled during the winter of 1404/5. The tenth timber, a king post, was felled during the winter one year later, in 1405/6.[40] With such a large group of trees cut at the same time, the evidence strongly suggests they were felled for a particular project, and that they were converted almost immediately. So why the late date for the king post? An explanation might be that the building was framed between spring of 1405 and winter of 1405/6, but that when it was being erected the king post was either found to be defective, or was missing altogether, so that a replacement had to be cut at short notice.

Other, non-documentary, comparisons can be found in inscribed dates or date stones. Whilst these are often found to commemorate purchases, marriages, or other non-constructional events, it is nevertheless useful to look at those which clearly relate to felling dates obtained through dendrochronology. Alkington Hall, Whitchurch, Shropshire, produced a felling date of autumn 1591, and has a date plaque of 1592. At the Old Manor, Chawton, Hampshire a date stone of 1593 compares favourably with a felling date of winter 1592-3.[41] Meeson Hall, Shropshire, produced two felling dates of spring 1635 and spring 1637, and a carved overmantle contains an inscribed date of 1639. The slightly longer interval here may relate either to the fact that the trees dated may have been earlier than other, undated timbers, or that the internal fittings were completed later than the main structural shell.[42] Golding Hall, again in Shropshire, has a dendro date of summer 1666 for a principal rafter, and a date stone of 1668; again the comments above would apply.[43] Overall, the inscribed dates would suggest that the building dates are usually within a year or two of the latest felling date.

STOCKPILING OF TIMBER

Dendrochronological work over the past decade has shown that stockpiling, or use of previously felled timber, is not uncommon, and this is generally detected through multiple felling dates not far apart within a single phase. Generally, the term 'stockpiling' suggests timbers reserved for several years or more by large and wealthy institutions such as colleges or religious foundations, but in this paper the term is used for any instance where timbers have been stored either as leftovers from a previous building, or from timbers obtained from different sources. In the 350 building sites/ phases which this laboratory has so far published

in *VA,* up to and including *VA* **28,**[44] 279 phases had complete sapwood giving precise dates. Of these, 188 phases had two or more precise felling dates of which 87, or 46%, gave varying dates suggesting stockpiling. These dates have ranged between one and thirteen years apart, and in one phase as many as six different dates were detected, but certainly short-term stockpiling is the most common. Only primary-use timbers are included in the above statistics. The histogram below indicates the spread of dates in relation to different samples:

	Year apart range of complete sapwood dates over instances													
No. of phases with	1	2	3	4	5	6	7	8	9	10	11	12	13	years
2 different dates:	32	16	4	4*	3			1	1				1	
3 different dates:		8	4	3	1			1	2			2		
4 different dates:				1		1								
5 different dates:					1									
6 different dates:						1								

*One sample, with incomplete sapwood, was felled at least 4 years after another sample in the same truss with complete sapwood.

Thus, many sites do have timbers which have been stockpiled to a greater or lesser degree. Nevertheless, this figure of 46% appears to be remarkably stable, for in analysing the data for this exercise the precise felling dates were divided into three groups; dates published up to and including *VA* **25,** those from *VA* **26** and **27,** and those from this present issue. The calculations for each set of data were carried out independently, and each time a figure within 1/2 of 1% of 46% was obtained. However, considering that dendro sampling might provide felling dates for, at best, one or two percent of the trees used in a typical building, the 46% of phases with more than one precise date being felled in different years would probably be more like 60% or 75% in reality.

This figure illustrates how important it is to date precisely as many samples as possible from a single phase to allow a better interpretation of the construction date of the building. Half a dozen samples from varying elements of a building with precise sapwood dates all ending within the same year will strongly suggest a *construction* period within a year of the latest felling date. On the other hand, if only one precise date is available, then the person interpreting the results may suggest a construction period several years earlier than may in fact be the case. Of the 46% of the phases for which there is evidence for multiple felling dates, approximately one third of these were spread over two years, while another third were distributed between two and three years apart. This still leaves a significant proportion of examples of samples being felled over a period of four years or more. By applying this evidence to the sites where only one precise felling date was obtained, it would suggest that about 30% of these *may* be at least four years adrift of the actual latest felling date. It is really a matter of chance whether the single precise date was obtained from a timber felled just before the time of construction, or from old timber which had been stockpiled. Most dendrochronologists would present such dates as "felled and used in 1632 or shortly afterwards" to be safe.

This evidence is not discernible in the heartwood/sapwood boundary dates, which in themselves can vary by as much as 30 years or more in a single sample. The only (almost) certain way of determining whether a precise felling date obtained is representative for a phase of building is through replication, and using various types of structural members. However, it is not always possible for the dendrochronologist to obtain more than one precise date, short of demolishing the structure. A building may be of such high status that the entire sapwood will have been trimmed off during conversion and working of the timbers, or subsequently during repair works. The building may have suffered the depredations of time, decay and beetle attack destroying the soft sapwood, or only a handful of timbers from a phase may survive or be accessible for sampling, etc. Nevertheless, the dendrochronologist should never be satisfied with one sample with complete sapwood where there are others capable of being sampled. Unfortunately, dendrochronology is subject to budget constrictions as is any other science, and this too is a limiting factor.

Timbers with varying dates can be found in a building phase for a variety of reasons. Trees might have died within the woodland, or have lain for some time as windfalls. Some trees may have been deliberately 'ring-barked' and allowed to die standing, with felling taking place some years afterward.[45] Continuous sequences

of buildings or phases may result in smaller members such as studs, joists or rafters being left over and used in a later phase. A good example of this can be found at Court Farm, Overton, where the barn produced a single felling date of 1496, whilst in the house four timbers produced felling dates ranging from 1504 to 1505, with the sole exception of one joist dating from 1496, strongly suggesting this timber was left over from the barn.[46] Alternatively, timbers might have been obtained from different sources, and thus would have been felled at different times and under different circumstances. This is particularly common in town buildings where timber would have been available from intermediate sources such as timber merchants; this diverse sourcing would account for the poor intra-site matching often found in urban situations. It is also highly probable that carpenters and timber framers kept stocks of timbers left over from previous projects for use in future work.

An interesting contemporary reference strongly supporting the above explanation of differing felling dates, is found in an account by John Lancaster, agent for Corpus Christi College. During his tenure in Overton during the period 1519 to *circa* 1550, he was responsible for the building of several houses, and in an account from 1542 he states he had 17 pieces of timber remaining on his hands from earlier work.[47] No doubt many other similar accounts and inventories exist which show that timber was a valuable asset and would have been retained for future work.

Only rarely has deliberate stockpiling been detected. Although Shapwick House in Somerset produced only a single precise felling date,[48] some of the principal rafters and collars showed incontrovertible evidence of having been cut to size, but then left to season for at least 5 years before their joints were cut. This was apparent because the collars had severely distorted, but the tenons were perfectly true, proving that the timber was dry by the time the timbers had their joints cut (Figure 8). It is unfortunate that this roof had been recently *defrassed* (the action of chopping off sapwood

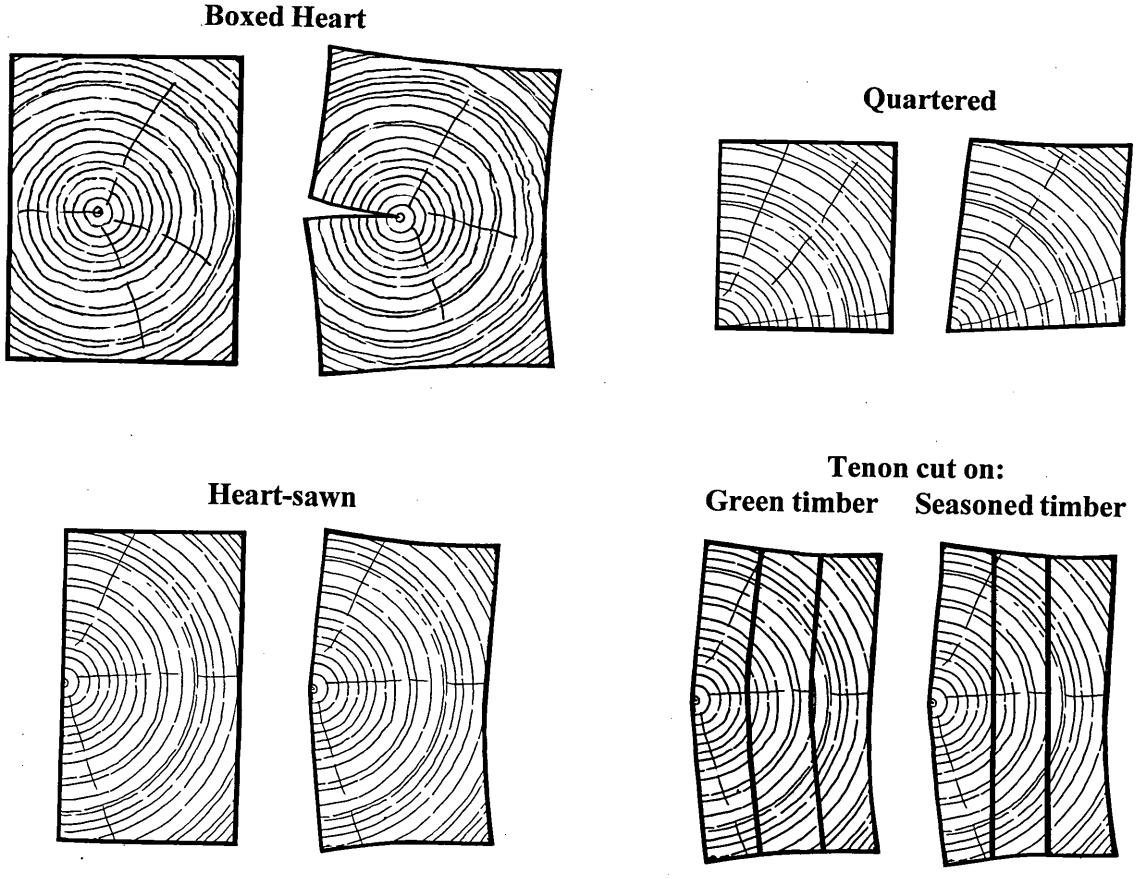


Figure 8
Methods of conversion and the deformation effects of subsequent shrinkage.

liable to beetle attack) so that the archaeological evidence of stockpiling could not be compared with dendrochronological evidence.

CONCLUSIONS

Whilst tree-ring dating is simple in theory, the interpretation of dates without complete sapwood is anything but straightforward and had led to much confusion and mis-quotation of dates in the past. Where timbers dated have only a partial sapwood or heartwood/sapwood boundary, then only an estimated felling date range can be given. It is recommended that when quoting estimated felling date ranges for samples with incomplete sapwood, only the outer limits of an appropriate 95% felling date range should be quoted, qualified only by surviving sapwood and, where there is sufficient evidence based on similar samples from the phase, or locality, an indication of which end of the range is most likely. The quoting of estimated most likely single dates, no matter how carefully qualified the statistics, should be discouraged. Where no indication of sapwood remains, then only a *felled after* date, or *earliest possible felling date,* can be given.

When the 10-55 year sapwood range was produced ten years ago, it was the best that could be produced based on the data available at the time. Histograms of over 900 sapwood ring counts now suggest that this range for the British Isles is too wide for England and Wales and that the upper end of this range could be significantly reduced. Three 95% felling date ranges have been calculated from this data, and ranges of 12-45 sapwood rings for the North and Midlands, 11-41 for Wales and the Border Counties, and 9-41 for the south of the country have been proposed. More detailed revisions of sapwood estimates are presently being carried out, both by this laboratory as well as by Sheffield University, using the wealth of both published and unpublished data sets now widely available, and taking into account other factors in addition to simple numbers of sapwood rings. From this research it is hoped to be able to produce sapwood estimates which are even more substantially reduced.

Evidence obtained by this laboratory suggests that instances of multiple felling dates within a phase of building are far more common than was previously thought, and that care should be taken to obtain as many complete sapwood samples from a particular phase of building as possible to identify correctly the latest actual felling dates and allow a better interpretation of probable construction dates. Ideally, research budgets should be broad enough to allow the sampling of at least eight to ten timbers with complete sapwood *if available.* Caution is needed when using single felling dates when interpreting building dates, as the likelihood of them being one or more years out is high.

Clearly it is vital that sufficient and accurate recording, interpretation of the structure, and phasing of the timbers is carried out at or before the time of sampling, and that this is made available to the dendrochronologist to locate precisely individual timbers. If the building has been incorrectly interpreted, the wrong timbers could be sampled, giving earlier dates for re-used timbers, or later dates for repairs or alterations. If only one or two samples are taken from a site, then this is a very real risk. Unfortunately, in many cases, only a few samples are available to the dendrochronologist, and the interpretation must take this into account. Ideally, detailed recording should be undertaken whenever a building is being dated, as the additional information apart from the date, such as jointing details, framing and truss design, and decorative elements such as moulding profiles, chamfer stops, and window designs, would be of immense value to future studies.

Examples of comparing precise felling dates with building accounts as well as date stones show that construction usually commenced within twelve months of the latest date of felling, rarely extending to more than two years. Again it is imperative that sufficient precise felling dates are obtained to identify correctly the latest date of felling, otherwise it is best to be circumspect when proposing construction dates.

Finally, when presenting tree-ring dates in any sort of document, report, or publication, the user should *always* consult the laboratory and the dendrochronologist who produced the date with a draft. This would ensure that what the user might consider to be a minor expendable phrase such as "not felled before" is not omitted. It must be remembered that it is the date of the *felling* of the tree which the dendrochronologist is giving, not the date of *construction* of a particular building or object. This latter interpretation is the role of the building historian or archaeologist, and should be based on a comparative analysis of documented building dates with precise tree-ring dates.

REFERENCES

[1] J. L. Walker, 1985, 'The Statistics of Dendrochronology: Some Observations and Comments', Unpubl paper.

[2] M. G. L. Baillie and J. R. Pilcher, 1973, 'A simple crossdating program for tree-ring research', *Tree Ring Bulletin,* **33,** 7-14.

[3] M. A. R. Munro, 1984, 'An improved algorithm for crossdating tree-ring series', *Tree Ring Bulletin,* **33,** 17-27.

[4] I. Tyers, personal communication.

[5] D. H. Miles, 'Analysis of Timberwork' in E. Lewis 'A Sixteenth Century Painted Ceiling from Winchester College', *Proceedings Hampshire Field Club Archaeol Soc* **51,** 1955, 142-6.

[6] M. G. L. Baillie, 1982, *Tree-Ring Dating and Archaeology,* London.

[7] R. Laxton, personal communication.

[8] J. Hillam, R. A. Morgan and I. Tyers, 'Sapwood Estimates and the Dating of Short Ring Sequences' in R. G. W. Ward, ed. *Application of Tree-Ring Studies,* BAR Int. Ser. **333,** 1987, 165-85.

[9] M. K. Hughes, S. J. Milsom and P. A. Leggett, 1981, 'Sapwood estimates in the Interpretation of Tree-Ring Dates', *J. Archaeol Science,* **8,** 381-390.

[10] R. R. Laxton and C. D. Litton, *An East Midlands Master Tree-Ring Chronology, and its use for dating vernacular buildings,* Nottingham 1988.

[11] J. Hillam et al, *op. cit.* n. 8 above.

[12] M. K. Hughes, et al, *op. cit.* n. 9 above.

[13] S. Pearson, *The Medieval Houses of Kent: An Historical Analysis,* RCHME 1994.

[14] D. Haddon-Reece, D. H. Miles and J. T. Munby, 'List 38 – Tree-Ring Dates from the Ancient Monuments Laboratory, HBMC', *VA* **21,** 1990, 46-50.

[15] D. H. Miles and D. Haddon-Reece, 'List 54 – Tree-Ring Dates', *VA* **24,** 1993, 54-60.

[16] M. G. L. Baillie, 1995, *A Slice Through Time – dendrochronology and precision dating,* London, 23.

[17] J. Hillam 'Guidelines for Dendrochronology' forthcoming EH publication.

[18] J. Hillam et al, *op. cit.* n. 8 above.

[19] R. R. Laxton, C. D. Litton and R. E. Howard, 1995, 'Nottinghamshire Houses dated by Dendrochronology', *Trans Thoroton Soc Nottinghamshire,* **99,** 45-54.

[20] R. R. Laxton et al, *op. cit.* n. 10 above.

[21] C. Groves, personal communication.

[22] J. Hillam, personal communication.

[23] C. Mills, personal communication.

[24] J. Hillam forthcoming, *op. cit.* n. 17 above.

[25] N. D. Foot, C. D. Litton and W. G. Simpson, 1986, 'The high roofs of the east end of Lincoln Cathedral', in *Medieval Art and Architecture at Lincoln Cathedral* (B.A.A. Conf. Trans., **8**), 47-74.

[26] W. G. Simpson and C. D. Litton, 1996, 'Dendrochronology in Cathedrals', in *The Archaeology of Cathedrals* ed. T. Tatton-Brown and J. Munby (Oxford University Committee for Archaeology Monograph **42**), 183-209.

[27] C. M. Mills, 1988, 'Dendrochronology of Exeter and its application', unpubl. PhD thesis, Sheffield University.

[28] D. H. Miles (forthcoming) AML interim tree-ring report on Stokesay Castle.

[29] *VA* **25,** 1994, 28-36.

[30] D. H. Miles 'The Building Accounts and the Existing Building' in E. Roberts 'Edward III's Lodge at Odiham, Hampshire, *Med. Archael.* **39,** 1995, 91-106.

[31] E. Roberts, 1996, *op. cit.* n. 30 above.

[32] *VA* **25,** 1994, 28-36.

[33] *VA* **25,** 1994, 28-36.

[34] E. Roberts, 1996, *op. cit.* n. 30 above.

[35] E. Roberts, personal communication.

[36] See List 85, below.

[37] E. Roberts and D. Miles (this volume) '73-77 Winchester Street, Overton, Hants.'.

[38] *VA* **25,** 1994, 28-36 (Here the reference was interpreted as a *completion* ceremony).

[39] G. Baugh, personal communication.

[40] D. H. Miles, 'The Tree-Ring Dating of Charlton Court barn, Steyning, West Sussex', Unpubl Ancient Monuments Laboratory Report 37/94.

[41] D. H. Miles and D. Haddon-Reece, 1996, 'List 72 – Tree-Ring Dates' *VA* **27,** 98-100.

[42] D. H. Miles and D. Haddon-Reece, 1996, 'List 72 – Tree-Ring Dates, *VA* **27,** 102-106.

[43] D. H. Miles and D. Haddon-Reece, 1996, 'List 56 – Tree-Ring Dates, *VA* **25,** 31-33.

[44] *VA* **18,** 1987, 54-5; **19,** 1988, 43-4; **20,** 1989, 46-9; **21,** 1990, 46-50; **23,** 1992, 48-51; **24,** 1993, 54-60; **25,** 1994, 28-36; **26,** 1995, 60-74; **27,** 1996, 93-113; **28,** 1997, 159-181.

[45] D. Haddon-Reece, personal communication.

[46] D. H. Miles and D. Haddon-Reece, 1994, 'List 56 – Tree-Ring Dates' *VA* **25,** 28-30, plus E. Roberts, 1995, 'Overton Court Farm and the Late-Medieval Farmhouses of Demesne Lesses in Hampshire', *Proceedings of the Hampshire Field Club and Archaeological Society* **51.**

[47] E. Roberts, personal communication.

[48] D. H. Miles and D. Haddon-Reece, 1996, 'List 71 – Tree-Ring Dates' *VA* **27,** 93-97.

ACKNOWLEDGEMENTS

The author is grateful to D. Haddon-Reece for much of the inspiration for the above, and for comments and calculations on the sapwood statistics. Helpful comments and information on various aspects were received from Cathy Groves and Jennifer Hillam of Sheffield University, Bob Laxton of Nottingham University, Coralie Mills of AOC Scotland, Sarah Pearson and Nat Alcock of the VAG, Alex Bayliss of English Heritage, and Nigel Fradgley of the RCHME. For the documentary material the contributions of Madge Moran, George Baugh, Bill Champion, and particularly Edward Roberts were especially valuable.