A plea for publication of data

The Ages of Bristlecone Pine

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For a number of years trees in excess of 4000 years of age have been reported and, quite naturally, there has been widespread interest in anything that could live to such an age (1). This interest is further heightened by the beauty of the subject--the bristlecone pines and their surroundings. These trees grow in the White Mountains of east-central California and have been artistically twisted and sculptured by their harsh environment (Figure 1).

Several factors have been suggested as contributing to the longevity of the bristlecone pines: slow growth due to soil conditions and relative aridity; sparse ground cover incapable of supporting a destructive fire; highly resinous and dense wood resistant to decay and insects; and needles that are retained for 20 to 30 years, providing a photosynthetic capacity for spanning many years of stressful conditions (2). Whatever the reasons for their success in survival, there can be little doubt that these trees are the oldest living things. The study of their wood is pertinent to climatology as well as chronology.

Figure 1

Background of Tree-Ring Dating

The techniques and theories of tree ring dating (dendrochronology) have their foundation in the work of A.E. Douglass in the early part of this century (3). Douglass and his successors, Glock, Shulman, *et al.,* were interested in climatic variations over long periods of time and turned to the examination of the variation in width of annual growth rings as a clue to climatic conditions for those annual periods. They were interested in groups of wide rings as evidence of seasons of plenteous rainfall and favorable growth conditions; groups of narrow rings suggested dry, stressful climatic Conditions. Of course, they identified the time of occurrence of these climatic variations by counting the number of successive tree rings, but *tree ring dating as it has developed consists of substantially more than simply counting the number of rings in a tree.* Before examining the current techniques of tree ring dating we should review the fundamental principles of tree growth and the formation of rings.

Tree growth is confined to a layer of cells beneath the bark and wrapping the woody part of the tree. As this layer of cells, the cambium, produces more cells the tree grows in diameter. A typical growth cycle begins in the spring with the cambium laying down large, well-developed cells. As growing conditions become less favorable in the summer--less moisture, etc.--the cells formed are smaller, more dense, and have a dark appearance. In the fall and winter, growth largely stops. The cycle of rapid growth (large, light cells) and slower growth (small, dark cells) gives rise to the appearance of successive "rings" for each growing season. Counting these rings in a cross section of wood then gives an indication of the number of seasons of growth.

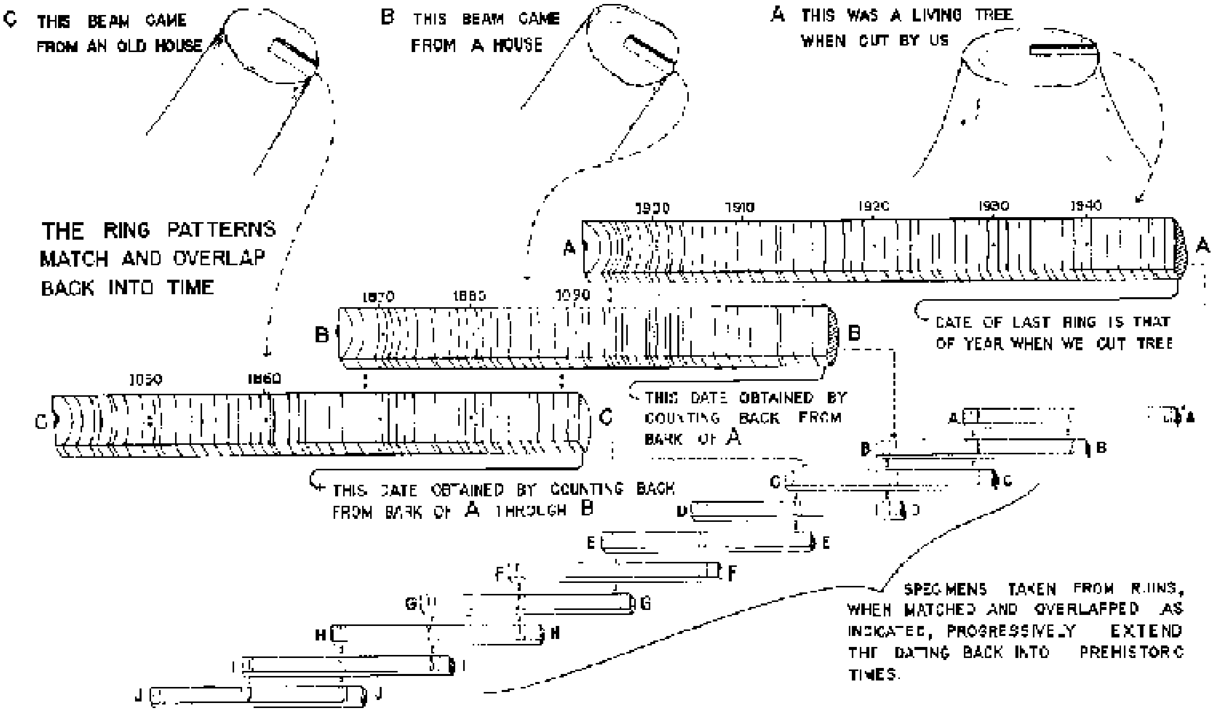

Figure II. From Stokes and Smiley. The method of constructing a chronology by successively overlapping distinctive ring patterns.

Two phenomena sometimes complicate the straight-forward situation described above. The first of these is "multiple ring" years. If, after summer has set in and small cells are being produced, sudden rains stimulate additional growth of large cells, a second ring of small cells will be produced when the growing season actually ends. It is relatively easy for a trained examiner to detect such occurrences because of the peculiar composition of the first or "false" rings of the season.

The second and more difficult complication is that of "missing" rings. In dry and climatically harsh years, no detectable growth may occur. In this case no ring is formed and the ring is missing for that season or year. Such missing rings are not usually discovered directly but they may be inferred from a variety of data, including the actual tree ring dating process which we will now discuss.

Two Basic Principles

The first principle of tree-ring dating can be simply stated:

one growth ring is equivalent to one year of growth.

This principle is commonly applied, even by schoolboys, to determine the age of a freshly cut tree. If the cut is clean enough, the rings are counted and the age of the tree is presumed to be equal to the number of rings. Despite the possibility of some missing rings or multiple rings the procedure is basically valid and generally accepted.

The second principle is also simple but was not verified by observation until 1904. At that time A. E. Douglass had been studying the annual variation in the thickness of tree rings as a clue to climatic patterns. It seemed logical to him that the *pattern of variation* in ring widths (thicknesses) seen in one specimen of wood should be the same as that seen in other specimens that grew at the same time under the same environmental conditions. He made the crucial observation while casually examining the stumps of a cut-over forest in northern Arizona. What he saw was "sets of compact patterns of ring variation duplicated from one tree stump to another with such clarity as lo be easily recognized without a ring count" (3). This was the foundation of the second basic principle of tree-ring dating:

two Specimens of wood with similar distinctive ring growth patterns grew at the same time and may be correlated ring for ring, year by year.

An illustration of the way this principle can be applied to build a tree-ring chronology is given below.

Suppose that a certain tree began growing in 1866 and another in 1890. In 1916 the *first* tree is cut down and fashioned into a large beam used as a structural element in a building. The other tree continues to grow until the present day at which time it also is cut down. Ideally, this second tree would be found to contain 83 annual rings (in 1973). If it has a distinctive growth pattern in its first 26 rings (counting from the center of the tree), this same distinctive growth pattern will probably be found in the beam from the first tree which was used for building in 1916. This would allow precise placement of the age of the wood used in the building with respect to the present, i.e., at least 57 years before present.

But more. Since the first tree was growing 24 years before the long-lived survivor, its additional rings extend the chronology pattern to 107 years. By correlating distinctive patterns in successively older specimens the chronology can be extended back into time as far as the specimen data permits. This process is illustrated in Figure II (4).

Once the distinctive ring patterns are identified for the master chronology, any specimen found to contain a significant portion of the pattern is precisely dated. Applications to archaeology and other fields are apparent and have been successful (4).

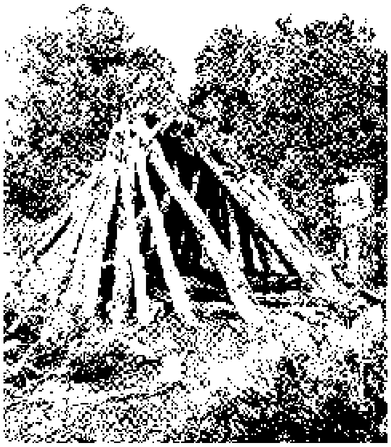

Photo by Clifford Gedekoh

Figure IIa. From Stokes and Smiley. A well preserved Navajo hogan in the American Southwest. Such structures provide ample material for accurate dating by tree-ring method.

Three Practical Difficulties

The fundamental prerequisite for cross matching is a distinctive pattern of ring widths. Unfortunately, such patterns are not as common as dendrochronologists might wish. In order for wood to exhibit a distinctive pattern it must have grown through a period when distinctive climatic variations occurred, *and* it must have been sensitive to this variation. Climatic variation is common but many trees grow in environments relatively insensitive to such variation. For example, trees growing on even terrain or lowlands where ample water supplies are always available (semipermanent water tables, etc.) will ordinarily not reflect year to year variations of climate. In other words, because they do not feel a significant variation in year to year stress they produce rings of the same size year after year. Their wood specimens are described as *complacent* (as opposed to distinctive) and are not suitable for cross matching. Distinctive patterns are most commonly found in specimens from stressful environments.

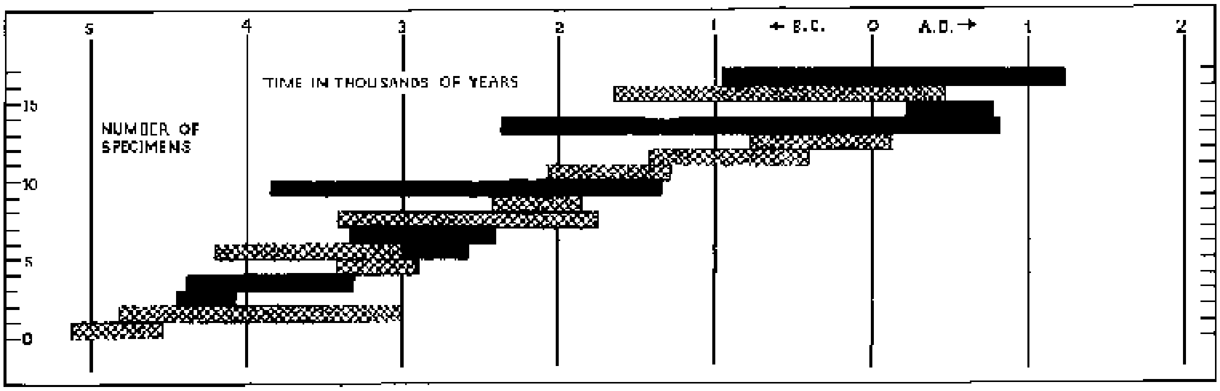

Figure III. Components of the bristlecone pine master chronology. Components with sensitivities less than .3 are indicated by solid bars. From Ferguson.

Climatic cycles with long periods (greater than 15 years) superimpose trends of increasing ring widths and decreasing ring widths on yearly variation. Also there is a general trend of decreasing ring width with age of the tree. These and other similar factors can largely be filtered out by the use of standard statistical methods. Difficulties of this type are presumed to be of minor significance.

A third and serious difficulty relates to the completeness of the data. The most distinctive features of a pattern and the most useful for cross matching are the minimum" rings. These are the occasional extremely thin rings formed during a very stressed season. Unfortunately these are the rings most easily missed in tabulating the data. The magnitude of this problem is more readily appreciated when it is recognized that specimens with 10 rings per millimeter are sometimes included in chronologies. Microscopes and semiautomated instrumentation partially relieve this problem, but despite these aids, missing rings are a real and probably permanent hazard in tree-ring dating. The location of a few missing rings in a large specimen may be inferred when attempting to cross match, but when as high as five percent of the rings are missing, cross matching is obviously questionable if not futile.

A Successful Application (4)

The middle of the nineteenth century was a period of territorial and political dispute in the American Southwest. The end of the Mexican War in 1848 was confirmed by the treaty of Guadalupe Hidalgo, which treaty explicitly acknowledged "all native claims." Amongst these legitimate claims were those of the Navajo Indian Tribe. Nevertheless, a number of years later all Navajos were forcibly removed from their lands and impounded on a distant reservation by the United States Army. In 1868 a treaty was executed between the United States and the Navajo Indians allowing them to return to their native lands.

The congress has authorized the Navajos to bring substantiated claims for their rightful territories lost at the time of establishment of reservations. Of focal concern are the lands actually occupied during the period 1848 - 1868; although earlier occupation would have some relevance also.

Two independent lines of evidence have been presented with regards to several sites of occupation. The first of these are cultural records which include oral reports of early recollections and some substantiating documentation. The second line of evidence is based on tree-ring dating. Absolute master chronologies based on long-lived trees in the regions of interest have served to specifically date the remains of hogans and other Navajo artifacts (Figure IIa). Of special interest is the fact that the cultural records corroborate the tree ring dates in establishing Navajo occupation during the period in question.

The Bristlecone Pine Chronology

The history of the development of the Bristlecone Pine chronology goes back to 1954 and the discovery by Edmund Schulman of several of these trees in excess of 4000 years of age. The chronology has now been extended by C. W. Ferguson to at least 7485 years (before present) with hopes of pushing it to perhaps 10,000 years (5).

A master chronology has been published for 7104 years. This chronology was compiled from two previously existent chronology units plus the data for 17 individual specimens. The layout and regions of cross matching of the specimens are indicated in Figure III. The number of specimens cross matching for any given period averages about four. No information has been published on how well the specimens cross-matched, nor is data provided allowing such a check. However, partial statistical analyses of the quality of the component specimens are available.

Bearing in mind the principles and difficulties inherent in tree-ring dating, it is worthwhile to examine several features of the Bristlecone Pine chronology:

Bristlecone Pine Data Quality

"In bristlecone pine, problems of cross dating are caused by so-called 'missing' rings associated with the extremely slow growth rate of this species on and sites. One specimen, for example, contains more than 1100 annual rings in 12.7 centimeters of radius . . . In some instances, five percent or more of the annual rings may be missing along a given radius that spans many centuries." In fact, up to 10 percent of the rings may be missing along a given radius (6). This creates a situation where it is difficult if not impossible to find significant cross matches. This is especially true because it is generally the very narrow diagnostic rings which are "missing." In other words, the very rings responsible for the distinctiveness of a pattern are the ones most likely to be missing.

In general, samples with a high proportion of missing rings will exhibit complacent ring patterns. It is not surprising, then, to find that nearly 50 percent of the bristlecone pine samples used as components in the 7104-year master chronology have mean sensitivities of less than .30 (5). Such low sensitivities are suggestive of complacent samples that would cross match about the same regardless of where they were placed in the chronology.

"Ball-park" Placement

A preliminary search for regions of cross-matching usually involves visual comparison of what are called "skeleton plots." These plots illustrate the most distinctive features of a pattern and are a useful tool in the hands of competent researchers. However, it is extremely difficult to use such a procedure when dealing with samples containing hundreds of rings in comparisons with a master chronology with thousands of rings. Therefore, in the case of the bristlecone pine chronology, the expedient of determining initial placement by a radiocarbon date has been employed. In the words of the researcher, "I often am unable to date specimens with one or two thousand rings against a 7500-year master chronology, even with the 'ball-park' placement provided by a radiocarbon date" (6). Two observations are in order here:

1. The construction of the bristlecone pine chronology is at least partially *dependent* on radiocarbon dating.

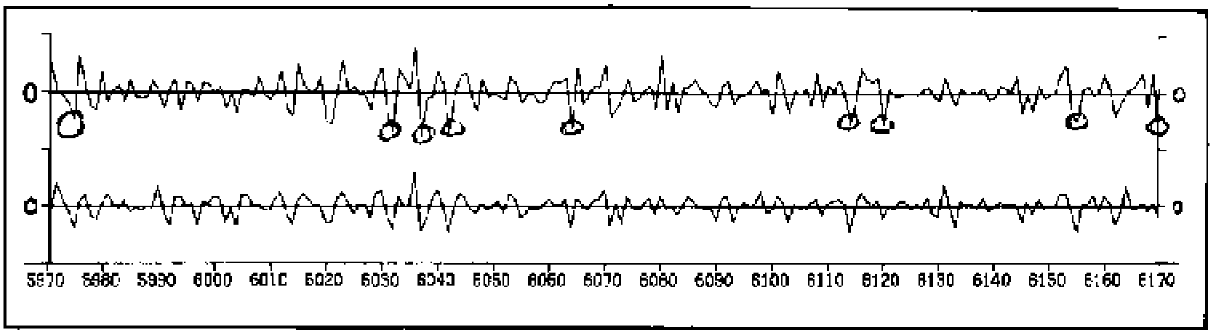

Figure IV. A segment of Pine Alpha (upper plot) compared to the master chronology (lower plot). "Missing" rings are circled - see the text. From Ferguson.

2. Complacent samples could be fit into the chronology reasonably well based on their radiocarbon dates and with "missing" rings supplied as needed. (Evidence pertinent to this possibility is presented in the next section.)

Some elaboration is needed on the first point since the author quoted above claims that the bristlecone pine chronology "constitutes the first *independent* time control of such length for radiocarbon analysis" (7) (emphasis supplied). The incongruity of such a claim lies in the fact that radiocarbon dating influences the dating of bristlecone pine specimens and then these specimens are used to calibrate radiocarbon dating (8).

The bristlecone pine chronology has generally been accepted as verifying the validity of radiocarbon dating for greater than 7000 years (9). Unless the chronology can be shown to be free of radiocarbon dating influence, such attempted verification is improper and invalid.

Pine Alpha "Missing" Rings

Pine Alpha was the first tree found to be over 5000 years old. It is also the only one of the bristlecone pines for which ring indices have been published. A comparison of Pine Alpha to the master chronology is given in Figure IV (5).

It is noteworthy that this specimen is one of the more sensitive components of the master chronology; having a mean sensitivity of .51. In the figure certain minimum ring years are circled. These rings have been ambiguously referred to as "missing" rings (10). Whether these rings have been "supplied" or "found" is not clear. If the latter is the case no further comment is necessary. If the former is the case it should be noted that removal of these rings would yield a complacent sample not suitable for cross matching.

Published Data

When major advances in science are made it is customary for sufficient data to be published to allow the scientific community to independently evaluate the conclusions reached. Considering the far-reaching implications of the bristlecone pine chronology to radiocarbon dating, archaeology, climatology, etc., one would expect generous documentation of the basic chronology. Actually, apart from the Pine Alpha data discussed above, no ring width data have been published for the components of the chronology. Only the final conclusion (the master chronology) has been published.

Briefly, there is information on which samples go where in the chronology, how sensitive the samples are, but *not* how well they fit, i.e., the correlation between one sample and another. *Since no ring width data is available it is not possible to independently check the published conclusions.* Requests to obtain such data have met with refusal:

"There were strong reasons why I published the chronology as a filtered series; thus, I would not be able to release the index values to you" (6).

There are stronger reasons why a careful and detailed investigation of the bristlecone pine chronology should be made.

Summary

1. Dendrochronology has been shown to be on solid scientific footing with successful applications in several fields of investigation.
2. The bristlecone pine chronology has been reviewed and reasons found to ask the following questions:

a. How can such a chronology be constructed with a high percentage of complacent specimens?

b. How can specimens with up to 10 percent of their rings missing be cross matched under any circumstances?

c. How can this chronology be used to "calibrate" radiocarbon dating when radiocarbon dating is used in construction of the chronology?

d. If a ring is "missing" how can it be found, especially when a high percentage of rings are missing?

e. Why is only the final chronology published, with refusal to release the data upon which it is based?

It is concluded that at this time there are no compelling reasons to accept the bristlecone pine chronology as valid.

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