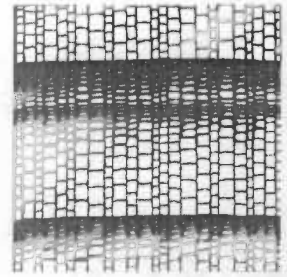
Time, Trees, and Prehistory



Tree-Ring Dating and the Development of North American Archaeology 1914–1950

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Most of the archaeological tree-ring research conducted in the Southwest between 1930 and 1941 was funded by three private institutions (Gila Pueblo Archaeological Foundation, Museum of Northern Arizona, and Laboratory of Anthropology) whose financial portfolios survived the market collapse more or less intact. Tree-ring dating in the American Midwest was funded for a time by the Tennessee Valley Authority, though even there private funding was obtained toward the end of the decade. Additional tree-ring projects were funded by federal agencies such as the National Park Service, and labor was occasionally supplied by the Federal Emergency Relief Administration, but these projects, in the Southwest at least, tended to be smaller in scale and narrower in scope than the monumental projects in the East (see Fagette 1996). The economic situation thus did not determine in any strict sense the nature and scope of archaeological tree-ring dating research, but it may be that students and young scholars sought dendrochronological training in order to differentiate themselves in the tight labor market of the time.

The third phase in the development of archaeological tree-ring dating, from 1942 to 1950, is marked by a near cessation of archaeological tree-ring research, primarily brought on by U.S. involvement in World War II. If the 1930s have been described as the "halcyon days" (Bannister and Robinson 1976:52) of archaeological tree-ring dating, the 1940s can only be described as a period of disintegration, emphatically ended by the publication of the first radiocarbon dates for North American archaeology (Libby 1955). After 1950, then, absolute dates became the luxury of archaeologists the world over. The complicated history of archaeological tree-ring dating since 1950 has yet to be written. Suffice it to say that, after a number of trials and tribulations, archaeological tree-ring dating has over the last five decades matured into a healthy and vibrant discipline.

Principles of Dendrochronology

Dendrochronology, the study of tree-time, is the highly specialized science of assigning common-era calendar dates to the growth rings of trees (Stokes and Smiley 1968). It currently enjoys a broad array of applications in climatology, forest ecology, geomorphology, art history, and archaeology across the globe (see Baillie 1995; Cook and Kairiukstis 1990; Dean, Meko, and Swetnam 1996; Hughes et al. 1980; Schweingruber 1988). Tree-ring dating is a straightforward procedure, at least in principle. In practice, it can be astonishingly difficult.

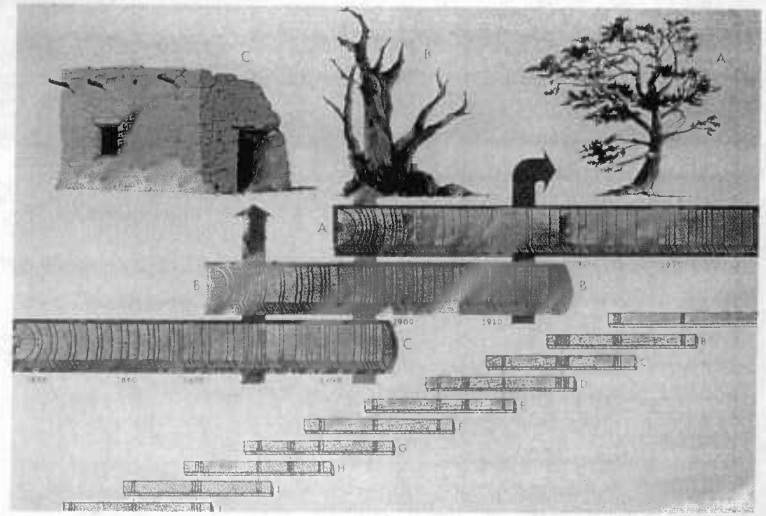

Figure 3. The principle of crossdating as presented by Stokes and Smiley (1968:6).

Tree-ring dating is not ring counting, despite what many recent textbooks and popular treatments of archaeology state. To determine accurate common-era calendar dates for tree rings, the dendrochronologist must have intimate knowledge of the vagaries of ring growth found in trees in a given region. To gain this knowledge, she or he must visually compare and match the patterns of ring growth in large numbers of specimens from a single species. This fundamental practice, which has since been elevated to a principle of tree-ring dating, is *crossdating* (Douglass 1941d).

Crossdating is classically defined as "the procedure of matching ring width variations . . . among trees that have grown in nearby areas, allowing the identification of the exact year in which each ring formed" (Figure 3; Fritts 1976:534). Note the emphasis on ring-width pattern matching, the absence of any suggestion of "ring counting," and the implication that accurate tree-ring dating begins with the analysis of specimens from living trees. As Douglass noted as early as 1911 (Douglass 1914), crossdating must be conclusively demonstrated in living trees of a given region before dendrochronological analysis may be used in any research situation, whether archaeological, ecological, or climatological.

More recently, Fritts and Swetnam (1989:121) have argued that crossdating is a procedure that "utilizes the presence and absence of

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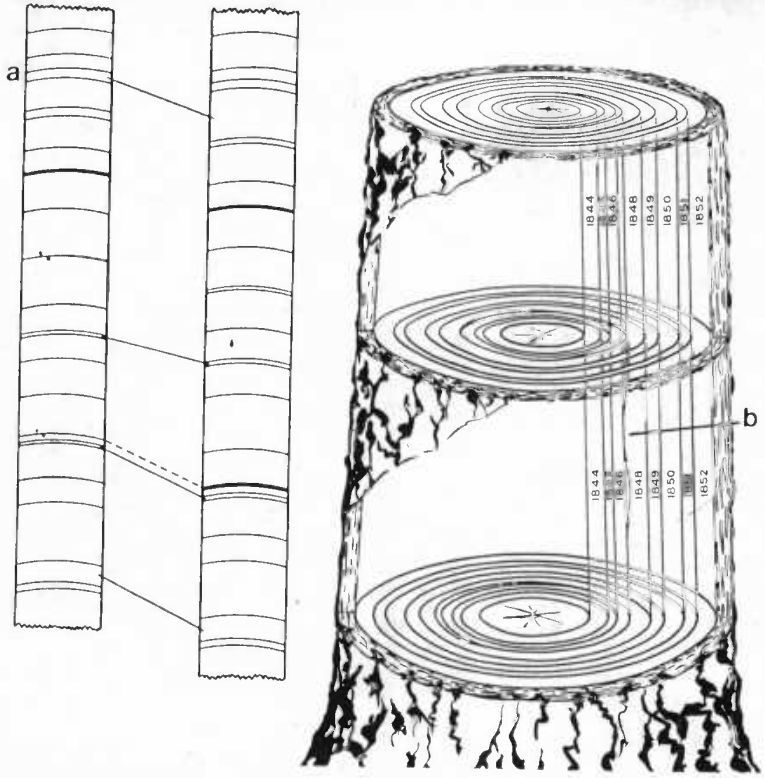

FIGURE 4. Problem rings: (a) missing ring; (b) locally absent ring (A.D. 1847) (Stokes and Smiley 1968:15).

[ring] synchrony from different cores and trees to identify the growth rings that may be misinterpreted." This definition alludes to the problematic nature of some tree rings, including missing rings and double rings. Implicit here also is a working assumption of dendrochronology—that datable tree-ring species produce only one growth ring per year. To make a long story short, in the absence of accurate crossdating by the dendrochronologist, tree-ring specimens and chronologies cannot be considered correctly dated, and any interpretations that are predicated on those specimens or chronologies must be considered invalid (Baillie 1995).

There are four conditions that must be fulfilled before tree-ring dating may be seriously considered in any given area (Stokes and Smiley 1968). The first requires that the examined tree species add only one

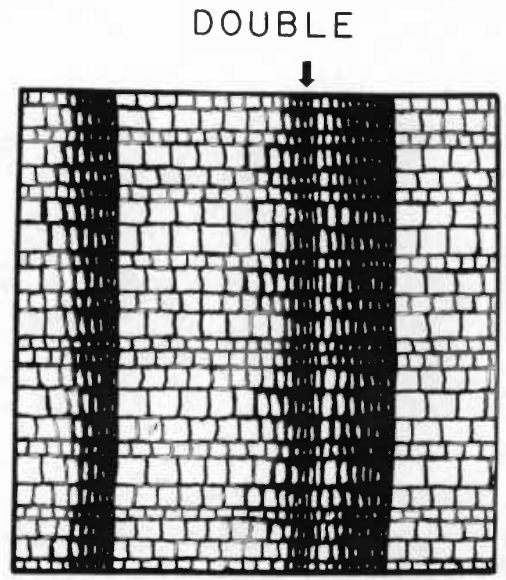

FIGURE 5. Double ring (Stokes and Smiley 1968:17).

growth ring per calendar year. In a particularly stressful year, however, such tree species may fail to produce a growth ring, in which case the dendrochronologist notes a *missing ring* (Figure 4). In stressful years, trees may also produce rings that are apparent only at certain points along the stem, in which case the dendrochronologist notes a *locally absent ring* (Figure 4). In either of these cases, if the problem rings are not identified, the rest of the sequence will be assigned dates that are too early by one or more years. If the ring for 1847 is locally absent or missing, for example, and has not been recognized as such, the ring grown in 1848 will be incorrectly assigned the date of 1847, the ring for 1912 will be dated 1911, and so on. Additional difficulties are presented by *double rings* (Figure 5), which are created when climatic conditions prompt a tree to begin shutting down growth, only to have growth resume when favorable conditions return. If not properly identified, a double ring will lead to crossdating that is off by one year, and subsequent rings will be dated one year too late. The potential for missing and double rings varies by tree species and location; it is therefore imperative that the dendrochronologist identify such problems by properly crossdating the specimens.

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The second condition that must be satisfied requires that tree growth be limited by the relative availability of one environmental factor. Extensive research in tree physiology has demonstrated that many factors affect tree growth, including environmental, genetic, and idiosyncratic variables, but for tree-ring dating to work, a single environmental, and preferably climatic, factor must be dominant. In semiarid areas of the American Southwest, for instance, tree growth varies in response to available moisture, whereas in Alaska trees respond primarily to temperature fluctuations. In the Southwest, trees that are stressed, *sensitive* in their ring series, and therefore useful for dendrochronology are typically found at forest borders and on rocky, steep, and south-facing slopes. Insensitive trees are typically found in well-watered areas with well-developed soils.

The third condition requires that the growth-limiting factor exhibit annualized variability that is recorded in the growth rings in trees. Circular reasoning belabors the point, but it remains nevertheless: Because dendrochronology requires ring-width pattern matching, there has to be a pattern in the ring widths to match. Trees that enjoy beneficial growth factors tend to produce annual rings that are relatively uniform in their width and, in a sense, have no pattern. (In a strict sense, they have a uniform pattern.) Such insensitive ring series are labeled *complacent*.

The fourth condition of dendrochronology requires that the *climate signal* recorded in the ring series be in an area geographically extensive enough that the same ring-width sequence can be identified in trees found in localities far removed from one another.

The principle of crossdating and the prerequisite conditions for tree-ring dating are invariable. Accurately dated tree-ring chronologies cannot be developed if any of the conditions are breached, and all specimens must be accurately crossdated before a reliable tree-ring chronology can be developed (Baillie 1995). Only then can the dendrochronologist attempt to date archaeological specimens. As we shall see, the former task is the more difficult of the two—it took Douglass 15 years to develop a tree-ring chronology for archaeological sites in the American Southwest.

The actual process of dating a tree-ring specimen in the Douglass method requires, first and foremost, creation of a smooth surface on which the rings are clearly visible. Once such a surface is prepared, the dendrochronologist creates a graphic representation of the ring-width variability known as a *skeleton plot*, in which long lines are written on

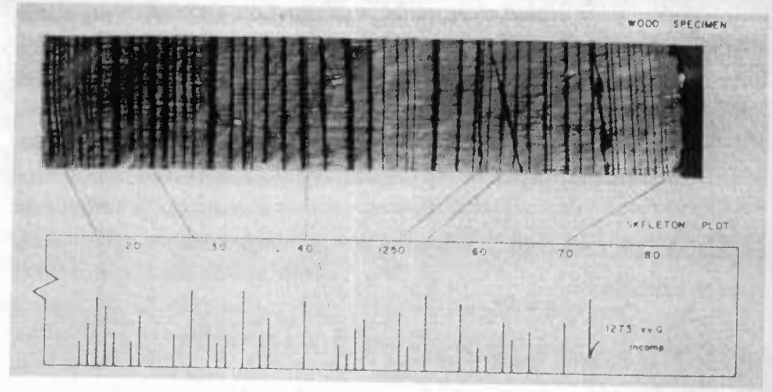

FIGURE 6. The skeleton plot, a schematic representation of ring-width variability developed by Douglass. Courtesy of the Laboratory of Tree-Ring Research.

graph paper to indicate relatively narrow rings, a "B" indicates a relatively large ring, and other unique attributes that may assist in the dating are noted (Figure 6; see Stokes and Smiley 1968). The skeleton plot is then compared to the master chronology. When the pattern indicated in the plot matches the pattern on the chronology, and all missing, double, or locally absent rings have been identified, an accurate and precise date can be assigned to all rings on the given specimen. Archaeologists are primarily interested in the date assigned to the outer ring, but the archaeologist's task with regard to tree-ring dating has just begun when the date is determined by the dendrochronologist. The interpretation of archaeological tree-ring dates is complicated by the vagaries of prehistoric behavior and archaeological sampling and preservation.

The first factor complicating the task of archaeological tree-ring dating is behavioral: the prehistoric inhabitants of the site of interest must have made use of species that satisfy the requirements mentioned above. If inhabitants of the prehistoric American Southwest had built their dwellings with cottonwood trees and cooked their food exclusively with cottonwood logs, we would not have tree-ring dates in that region, because that species violates one or more of the required conditions. A good example of such a situation can be found in the Phoenix and Tucson basins of Arizona, where preservation in the dry environment is often exquisite but few tree-ring dates are available because datable species were not locally available (for an exception, see Dean, Slaughter, and Bowden 1996).

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The second complicating factor for archaeological tree-ring dating is one of preservation. Datable wood and charcoal specimens must be preserved in the archaeological record for recovery by archaeologists. Thirteenth-century cliff dwellings in the American Southwest tend to be well dated because wood beams have been preserved in dry rockshelter environments. Conversely, tenth-century open-air sites and pit structures in the Southwest are relatively difficult to date because wood and charcoal samples are poorly preserved in even moderately wet environments (Ahlstrom 1997).

A third complicating factor in the dating of archaeological specimens has to with the professional biases of archaeologists themselves. As we have seen, the development of a tree-ring chronology is perhaps the quintessential cumulative and iterative procedure. Archaeologists since the late nineteenth century have devoted far more attention to glamorous and romantic sites than to poorly preserved or apparently mundane ones. In spite of archaeologists' aesthetic bias, tree-ring chronologies are more democratic and require that all time periods be equally well represented. This situation often demands that archaeologists make specific, targeted searches for appropriate tree-ring material in sites that they might not otherwise investigate. The specimens that allowed Douglass to announce that he had "bridged the gap" in his southwestern tree-ring chronology in 1929 came not from Mesa Verde or Chaco Canyon, or even a long-occupied Hopi village, but from a disturbed open-air site in east-central Arizona.

Even to consider the use of tree-ring analysis for archaeological dating, however, one must find specimens that meet the four conditions identified by Stokes and Smiley (1968) as well as determine (1) whether crossdating exists between archaeological specimens, (2) whether the climate signal that produces crossdating in living-tree specimens is the same as that in archaeological specimens, and (3) whether archaeological and living-tree specimens crossdate.

From a dendrochronological perspective, all properly crossdated tree-ring dates are equal. There is no statistical uncertainty associated with properly crossdated tree-ring dates; a corollary is that tree-ring specimens either date or do not. Responsible dendrochronologists do not succumb when archaeologists ask for a "likely date" (Baillie 1995). Once a tree-ring date is determined, however, its interpretation becomes the archaeologist's responsibility. From the archaeologist's standpoint, all tree-ring dates are not created equal, and a body of theory has been developed over the last seven decades for the proper interpretation of

TABLE 1. Symbols Used to Qualify Tree-Ring Dates by the Laboratory of Tree-Ring Research.

Symbols used with the inside date	
year	No pith ring is present.
p	Pith ring is present.
fp	The curvature of the inside ring indicates that it is far from pith.
+p	Pith ring is present, but because of the difficult nature of the ring series near the center of the specimen, an exact date cannot be assigned to it. The date is obtained by counting back from the earliest date ring.
Symbols used with the outside date	
B	Bark is present.
G	Beetle galleries are present on the surface of specimen.
L	A characteristic surface patination and smoothness, which develops on beams stripped of bark, is present.
c	The outermost ring is continuous around the full circumference of the specimen.
r	Less than a full section is present, but the outermost ring is continuous around the available circumference.
v	A subjective assessment that, although there is no direct evidence of the true outside of the specimen, the date is within a very few years of being a cutting date.
vv	There is no way of estimating how far the last ring is from the true outside.
+	One or more rings may be missing from the end of the ring series, whose presence or absence cannot be determined because the specimen does not extend far enough to provide an adequate check.
++	A ring count is necessary because beyond a certain point the specimen could not be dated.

Note: The symbols B, G, L, c, and r indicate cutting dates in order of decreasing confidence. The + and ++ symbols are mutually exclusive but may be used in combination with all other symbols.

archaeological tree-ring dates (Haury 1935a; Bannister 1962; Dean 1978a; Ahlstrom 1985; 1997; Nash 1997b). Most contributions to archaeological dating theory occurred after the period of interest in this book, but several key concepts should be noted here.

The Laboratory of Tree-Ring Research at the University of Arizona assigns codes (Table 1) to archaeological tree-ring dates to describe certain

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attributes of the specimens and indicate the qualities of the assigned tree-ring date. At the most general level, dendrochronologists distinguish between "cutting" and "noncutting" dates. Cutting dates are assigned to specimens that have evidence that the last ring present on the specimen was the last ring grown by the tree before it died. Noncutting dates represent the opposite situation—there is no evidence that the last ring present on the specimen was the last one grown by the tree before it died, and indeed there is no way of knowing exactly how many rings are missing from the outside of the specimen.

From an interpretive standpoint, cutting dates are of far greater utility to the archaeologist than noncutting dates (Dean 1978a; Nash 1997b). Cutting dates do not necessarily indicate the year of construction of a given site or date the occupation or abandonment of a site, but they indicate the year a tree died and therefore are far closer to the behavior of interest to the archaeologist. There are many more potentially mitigating circumstances that must be accounted for when archaeologists interpret noncutting dates, however. In the absence of additional data, noncutting dates can provide only a *terminus post quem*, a date after which a given event must have occurred. Despite recent efforts to alleviate the interpretive difficulties associated with noncutting dates (Nash 1997b), they remain the most recalcitrant of tree-ring dates.

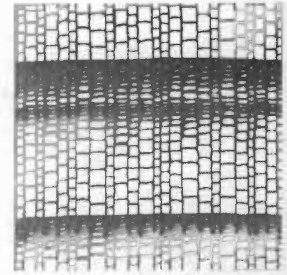
A final concept useful to archaeologists is that of *date clustering* (Ahlstrom 1985). If a number of tree-ring dates from a given site cluster in one or more, but usually less than three (Ahlstrom 1985), calendar years, one can infer that some construction event in prehistory has been well dated.

These principles, terms, and conditions of successful dendrochronology have been developed and refined throughout the course of the twentieth century, but the principle of crossdating remains basic to all applications of the technique. Archaeologists have made significant contributions to dendrochronological method and theory, and with a common vocabulary in hand, we may turn to a detailed treatment of the development of archaeological tree-ring dating.

CHAPTER 2

Lord of the Rings

A. E. Douglass and the Development of Archaeological Tree-Ring Dating, 1914–1929



Before the publication of the December 1929 issue of *National Geographic* (Douglass 1929), archaeologists working in the American Southwest had no idea how old the prehistoric ruins they studied actually were (Haury 1995; Zeuner 1951). Educated guesses suggested that ruins such as those of Pecos Pueblo might be 1,000 or 1,500 years old (Kidder 1927b, 1936) and that Basketmaker occupations in the San Juan region might be between 3,000 and 4,000 years old (see Baldwin 1938; Cornelius 1938; Kidder 1924; Renaud 1928; Roberts 1935, 1937). The goal of *some* southwestern archaeologists by the late 1920s was to establish a firm, if undated, chronology on which to place southwestern archaeological sites.

An astronomer by training, A. E. Douglass first became interested in the study of tree rings in 1901 while working at the Lowell Observatory in Flagstaff, Arizona (Bannister 1963; Douglass 1937; Glock 1933; Webb 1983). He realized that his research on sunspots would be greatly enhanced if he could find a terrestrial, long-term, proxy record of their activity, and he began looking for possible record sources. Since tree growth was known to be partially dependent on rates of photosynthesis and therefore sunlight intensity, Douglass began examining stumps of long-lived coniferous trees left by loggers in the Flagstaff area. It was during this period of exploratory analysis that he formulated the basic principles of dendrochronology, but archaeological applications for his research had not yet been considered.[1]

1. For detailed treatments of Douglass's research before 1914, see Douglass 1909, 1914, 1919, 1921, 1928 and Webb 1983.

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