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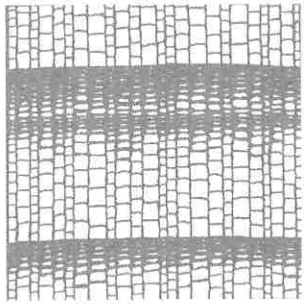
Time, Trees, and Prehistory



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

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For Carmen

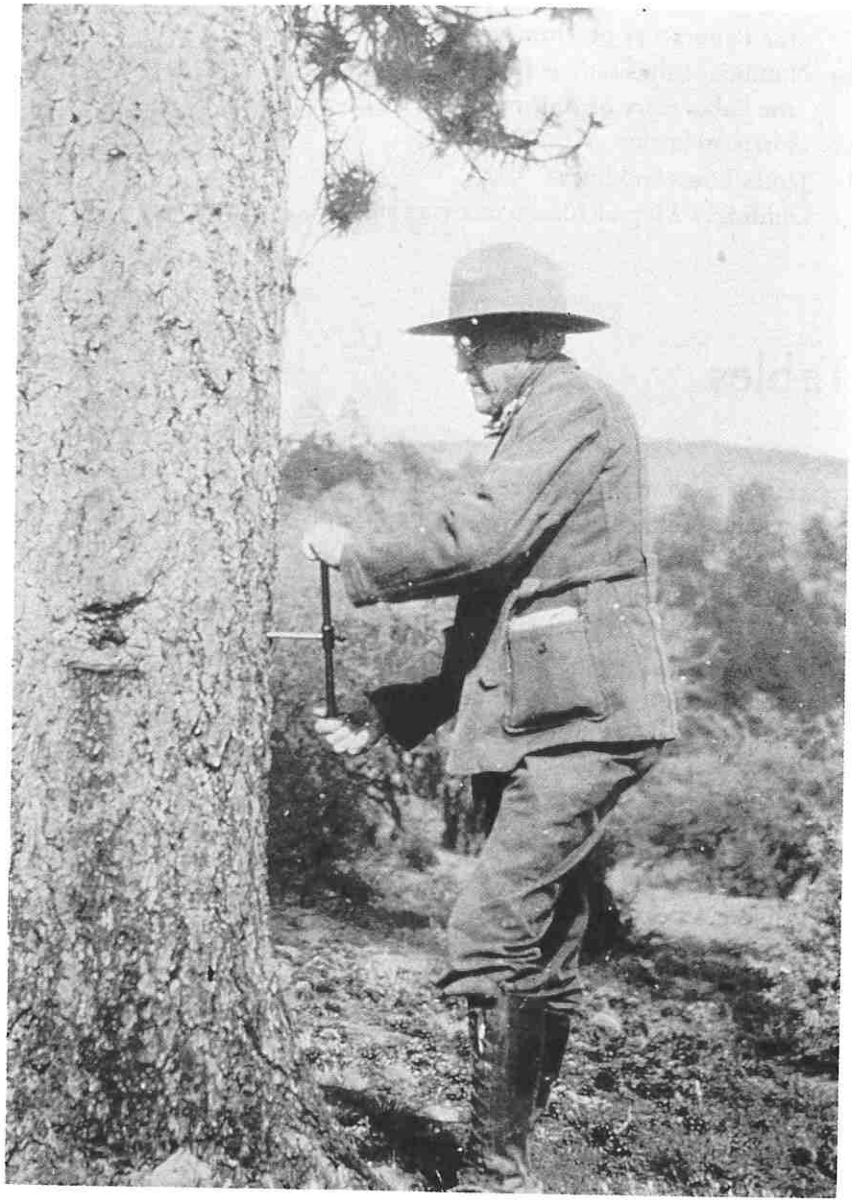

FIGURE 1. Andrew Ellicott Douglass (1867–1962) illustrates the use of a Swedish increment borer to take tree-ring cores from living trees, Forestdale Valley, east-central Arizona, 1929. Courtesy of the Laboratory of Tree-Ring Research, University of Arizona.

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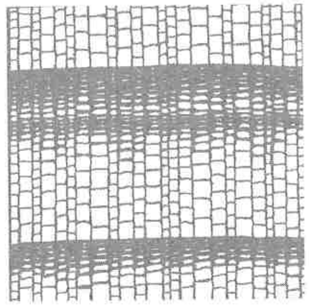
CHAPTER 1

Archaeological Tree-Ring Dating

Origins and Principles



Time, we may comprehend.
SIR THOMAS BROWNE (1605–1682)

In the December 1929 issue of *National Geographic*, astronomer Andrew Ellicott Douglass (Figure 1) of the University of Arizona published common-era calendar dates for some 40 previously undated prehistoric sites in the American Southwest. He dated the sites using a revolutionary new technique he developed called *dendrochronology*, literally, the study of tree-time (Douglass 1929). Six years after this seminal publication, archaeologist Emil Haury (1935a:98) wrote, "It may be stated without equivocation that the tree-ring approach has been the single greatest contribution ever made to American archaeology." Five decades later, dendrochronologists Bryant Bannister and William Robinson (1986:51) stated, "The existence of a reliable chronological framework on which to chart the development of prehistoric cultures not only profoundly changed the structure of Southwestern investigations but also altered the thinking of all New World archaeologists." These are unequivocal endorsements. Haury, Bannister, and Robinson are recognized authorities in archaeological tree-ring dating, having between them well over a century of experience. Their published statements have never been critically evaluated, however, and archaeologists less versed in tree-ring dating may not concur with their assessments. This book, therefore, chronicles the development and application of archaeological tree-ring dating from 1914 to 1950 to test the assertions made by Haury, Bannister, and Robinson. It seeks to determine if, and if so how, the acquisition of precise and accurate dates for previously undated prehistoric sites changed the practice of North American archaeology and the interpretation of North American prehistory.

Chronology is the soul of archaeology.
FAY-COOPER COLE,
Dendrochronology in the Mississippi Valley

Archaeological Theory and Chronology

The study of artifacts and temporal relationships distinguishes archaeology from the other subfields of anthropology. The analysis of material culture is older than the discipline of archaeology itself and traces back to the earliest recognition of prehistoric artifacts in Europe (Daniel 1963). The study of temporal relationships in the archaeological record has a much shorter pedigree, however, and critical examination of published and unpublished documents reveals a rather astonishing lack of interest in time by archaeologists (Chazan 1996; Dark 1995:64; Nash 1997a; Shanks and Tilley 1987:118). Indeed, archaeologists working before the second decade of the twentieth century believed temporal relationships were largely irrelevant to their research and were beginning to consider time only in the most general terms.

American archaeology before 1914 focused almost exclusively on artifact classification, description, and typology (Willey and Sabloff 1980). As archaeologists gained control over these realms, they began, slowly but surely, to examine temporal relationships in the archaeological record by experimenting with stratigraphic excavation techniques (Kidder 1924, 1958; Nelson 1916; see also Nelson 1918; Spier 1931) and serial analyses (Kroeber 1916; Spier 1917a, 1917b, 1931) developed by their European contemporaries and predecessors (see Browman and Givens 1996). North American archaeologists' stimulus to chronological research came not from within their own ranks but from their ethnological colleagues. Ethnologist Berthold Laufer offered his understanding of the task at hand in a review of archaeologist Roland Dixon's (1913) "Some Comments on North American Archaeology." Laufer wrote, "Chronology is at the root of the matter, being the nerve electrifying the dead body of history. It should be incumbent upon the American archaeologist to establish a chronological basis of the pre-Columbian cultures, and the American ethnologist should make it a point to bring chronology into the life and history of the pre-Columbian Indians" (1913:577).

Despite Laufer's admonition, nearly a decade later many North American archaeologists still did not share the interest in chronology already demonstrated by Alfred Kroeber, Nels Nelson, and Leslie Spier. Clark Wissler, of the American Museum of Natural History (Figure 2), explained the situation to his colleague Sylvanus Morley as he described

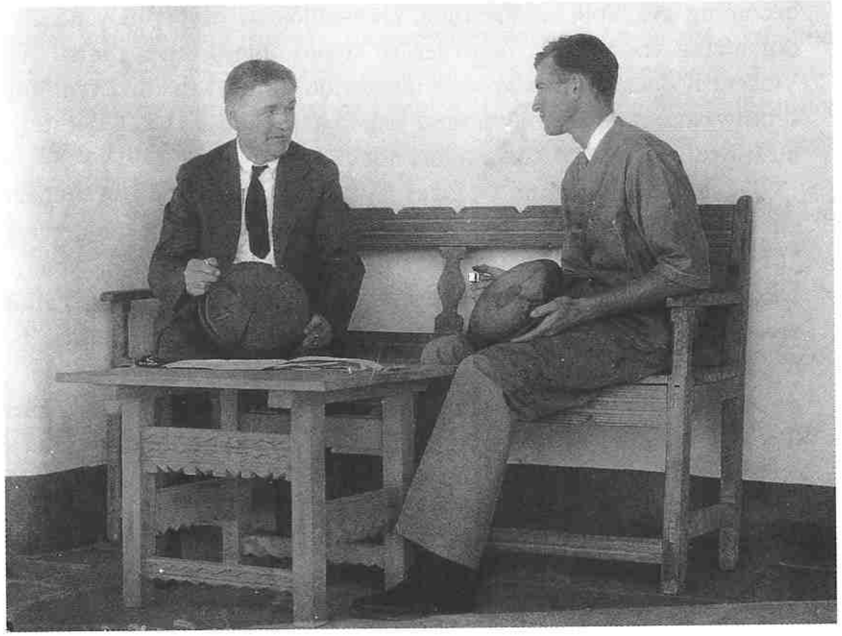


Figure 2. Clark Wissler (1870–1947) of the American Museum of Natural History and W. Sidney Stallings of the Laboratory of Anthropology examining tree-ring specimens from Aztec Ruin and Pueblo Bonito in 1932. Negative Number 280306, by Clyde Fisher, Courtesy Dept. of Library Services, American Museum of Natural History.

debate over the agenda for an archaeological conference to be held at Pueblo Bonito in Chaco Canyon, New Mexico:

> Strange to say, there was among anthropologists in general a considerable indifference and even hostility to the chronological idea. With the waning of [Frederick Ward] Putnam's influence [see Meltzer 1985] this reaction gathered strength until the whole subject [of chronology] was taboo. The time was, a few years ago, when no one dared mention the fact that there might be important differences in our dates [*sic*—no absolute dates were yet available to archaeologists]. Happily the development of anthropology in Europe has brought us to our senses again. We must establish a chronology for the New World and acknowledge our incompetence. Without a true time perspective the data of our subject will be a chaos of facts from which the general reader and even the student will flee as from a pestilence. (August 16, 1921)

Wissler exaggerated by alleging incompetence in his archaeological brethren, but it is clear that, with the sheer mass of archaeological data becoming available at that time, archaeologists desperately needed an organizing framework in order to avoid interpretive chaos. Alfred Vincent Kidder, of the Carnegie Institution, offered the first synthesis of southwestern archaeology several years later (Kidder 1924), but its organizational structure is geographic, not chronological.

Daniel Browman and Douglas Givens (1996:80) explain archaeologists' indifference to chronological matters as a result of the perception "of such [a] short time depth for habitation of the [North American] continent that attention was focused primarily upon the identification of archaeological areas as predecessor to the culture areas then being defined." That is, archaeologists assumed that "very little had changed since the first American Indians had arrived" in North America (Browman and Givens 1996:80), and therefore research centered on geographic and typological issues. Meltzer (1985:255) agrees, arguing that archaeologists of this period did not consider cultural change significant unless it was parallel in scope to that of the Paleolithic-Neolithic transition recently identified in Europe. This attitude may help explain why Richard Wetherill's discovery that the "Basketmaker" culture preceded the "Cliff Dweller" culture in the Four Corners region fell largely on deaf ears. Wetherill inferred this relationship in the 1890s after finding Cliff Dweller remains superimposed on Basketmaker remains in Cave 7 in Grand Gulch, Utah (Blackburn and Williamson 1997). Despite Wetherill's discovery and the obvious sequence in the deposits at this and other sites across the Southwest, however, archaeologists working as much as three decades later still did not acknowledge significant time depth to North American prehistory.

As academically trained southwestern archaeologists, especially Kidder (1924, 1932:2), began openly to consider chronological relationships in their research, their colleagues in geology and the as yet unnamed field of geoarchaeology were about to make a startling discovery that offered archaeologists indisputable evidence of time depth in the prehistoric record of North America. Archaeologists working at Folsom, New Mexico, in 1926 found projectile points in "undeniable association" with skeletons of extinct Pleistocene fauna (Haynes 1986:75). This discovery, as well as others at Whitewater Draw, Arizona, and later Clovis, New Mexico, provided conclusive evidence of long-term human occupation in the New World. Thus, although archaeologists still did not have an absolute chronology on which to hang their archaeological interpretations, the faunal, stratigraphic, and geological evidence demonstrated that humans had been present in the New World since at least the last Ice

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Age, a surprisingly long time indeed. By the mid-1920s, then, the conventional wisdom was that the Basketmaker occupation of the San Juan drainage began "no later than 1000 B.C." (Kidder 1927a:206), that the Basketmakers were replaced by Puebloans "early in the first millennium of our era" (Kidder 1927a:207), and that the San Juan drainage had been completely abandoned by about A.D. 1000.

The increasing complexity evident in the archaeological record led Kidder to call the first Pecos Conference in late August 1927 (Kidder 1927a; Woodbury 1993). The goal was to allow archaeologists informally to present their 1927 fieldwork results and, more formally, to consider the lack of synthesis in southwestern archaeology and the interpretation of southwestern prehistory (Kidder 1927b, 1928). In contrast to the 1921 conference at Pueblo Bonito, where there was a "considerable indifference" to the study of time, chronology was definitely on the agenda of the first Pecos Conference (Kidder 1927a). On August 30, 1927, Douglass presented to the archaeological public, for the first time, a progress report on his decade-long effort to date archaeological sites by the analysis of growth rings in trees. Douglass was still two years away from publicly announcing reliable dates for southwestern sites, but there is evidence that at the time of the Pecos Conference he had a good idea of where many sites dated along the common-era calendar. Whether he baited his archaeological colleagues with his suspicions is not known, but there can be no doubt that interest in his research surged after the first Pecos Conference, especially among the 39 scientists, students, and spouses present. Despite the petulant departure of Edgar Lee Hewett (1930:33) from the meeting (Woodbury 1993) and his subsequent protestations that "the time factors in American [pre]history have received an amount of attention in excess of their importance" (Hewett 1930:156–157), southwestern archaeologists of the late 1920s were excited by the prospect of absolute chronology and time. The introduction of absolute dates, and the concomitant ability to make "empirically testable" assertions (Dunnell 1986:29), led to radical changes in the interpretation of North American prehistory. In so doing, tree-ring dating laid the empirical foundation on which a revolution in archaeological method and theory was built over the following decades.

Archaeological Dating Theory and Dendrochronology

Archaeologists' interest in temporal relationships has a surprisingly short pedigree in North American archaeology, but it is clear today that the construction of accurate and precise chronologies is crucial to the production of reliable interpretations of the archaeological record (Renfrew 1973). Chronology construction is only the beginning, however, for archaeologists interested in any aspect of prehistoric behavior must ensure that the scale of the chronology is manageable when applied to the known and often coarsely refined archaeological record. The level of resolution in any archaeological interpretation depends on the researcher's ability to resolve time intervals appropriate to the question being asked (Ahlstrom 1985). The degree of interpretive sophistication is therefore directly related to the degree of refinement of the available chronometric data. Put another way, it is impossible for archaeologists to consider prehistoric behavior at levels of resolution finer than that offered by the best dating technique applicable in a given situation. Despite the most intensive wishful thinking and even in the best of circumstances, archaeologists who have only radiocarbon dates, for instance, cannot infer behavior more resolved than one or two human generations.

It is not surprising, then, that before the advent of absolute dating techniques, archaeologists employed rather simplistic notions of unilineal evolution, culture trait diffusion, and population migration to explain variability in the archaeological record: none of these interpretive constructs requires chronologic data more resolved than those that can be provided by relative dating techniques such as stratigraphy and seriation. One cannot begin to discuss sophisticated economic, environmental, social, or political relationships between prehistoric sites, and therefore prehistoric populations, unless the relevant archaeological data are demonstrably contemporaneous.[1] It therefore behooves the archaeologist to understand the limitations of any absolute dating and to make considered use of the resulting data in any interpretation of prehistory (Ahlstrom 1985; Mellars, Aitken, and Stringer 1993).

Tree-ring dates are the most accurate, precise, and therefore reliable chronometric data available to archaeologists (Dean 1978a). Tree-ring

1. Contemporaneity, however, is a necessary but insufficient condition for sound archaeological interpretation, for there are intrinsic limitations to absolute dates and dating techniques as well. Contemporaneity established on the basis of radiocarbon dating is qualitatively different from that established on the basis of tree-ring or obsidian-hydration dating. In addition, the demonstration of contemporaneity does not allow one to consider rates of culture change and other diachronic processes; a suite of reliable dates, no matter how derived, is required before such questions may be addressed.

dating is vastly more complicated than ring-counting, however, and successful tree-ring dating requires that a large number of environmental, dendrochronological, and archaeological conditions be satisfied in any given research area (Ahlstrom 1985; Baillie 1982, 1995; Dean 1978a; Stokes and Smiley 1968). These stringent conditions are often met in the American Southwest, and archaeologists working in that part of the world are blessed to have tree-ring dates available to guide their analyses. It is nevertheless the case that, through no lack of effort, tree-ring dating simply does not work in many areas and time periods.

Archaeologists working in areas or time periods in which dendrochronology cannot be applied have since World War II adopted a host of dating techniques developed in the physical and chemical sciences (Mellars, Aitken, and Stringer 1993; Michels 1973; Smiley 1955). Foremost among these is radiocarbon dating, which came to archaeology shortly after World War II as a result of the Manhattan Project (Libby 1955). Despite its own set of limitations, radiocarbon dating can be performed on organic matter younger than about 75,000 years from anywhere in the world. It therefore has become the most widely used absolute dating technique in archaeology (Taylor 1985, 1987). Many other absolute dating techniques have since been added to the archaeological repertoire. Most notable in North America are obsidian-hydration dating (Friedman and Smith 1960), archaeomagnetic dating (Eighmy and Sternberg 1990), and luminescence dating (Feathers 1997). Each of these techniques has its own set of limitations, and none can match the level of resolution offered by tree-ring data. Indeed, tree-ring dates and chronologies are used to calibrate the data offered by many other absolute dating techniques (see Renfrew 1973). As such, and despite its limited applicability, dendrochronology still offers the chronometric grail to which all archaeological dating, and therefore archaeological interpretation, must aspire. It is therefore imperative that we understand the development, application, and impact of dendrochronology in North American archaeology before we attempt to assess the impact of dating techniques whose results are evaluated against tree-ring dates.

History of Archaeological Dendrochronology

Histories of archaeology typically do not consider the development of archaeological tree-ring dating in any detail. Willey and Sabloff (1980:112) devote one paragraph to the subject, as does Steibing (1993:261). Brew (1968:76) allots one sentence. Trigger (1989:305) considers dendrochronology (in the sense of the Douglass method) only in light of radiocarbon dating. Textbooks and regional histories of archaeology do a little better, though discussions typically focus on the interpretation of tree-ring dates and not on the history of the technique. The classic treatment of tree-ring dating contains no discussion of the history of the science (Stokes and Smiley 1968). Scott (1966:9) argues that "the story of the discovery of archaeological tree-ring dating by A. E. Douglass and others has been told and retold and is now familiar to scientists and laymen alike." Michael (1971:49) concurs. I beg to differ.

Conventional discussions of the history of archaeological tree-ring dating are often hagiographic. Douglass was indeed a remarkable scientist, but there were many others involved in the development of archaeological tree-ring dating for whom these treatments to not do justice. George Webb, Douglass's biographer (Webb 1983), provides a typical précis (Webb 1978:105):

> The National Geographic Society financed three "Beam Expeditions" (1923, 1928, and 1929) in an attempt to obtain material to establish a usable calendar. From the first two expeditions Douglass collected a large number of tree-ring specimens which enabled him to construct a growth record extending several centuries. This "Relative Dating" sequence, however, could not be tied to the known chronology from living trees. The Third Beam Expedition provided the missing evidence. Douglass selected the Whipple Ruin in Show Low, Arizona, for excavation during the summer of 1929, because it contained burned beams (charcoal endured better than wood specimens) and a transitional form of pottery believed to date from the absent part of the tree-ring chronology. On July [*sic*—June] 22, his assistants uncovered a seven-by-ten-inch charcoal beam which displayed a ring record bridging the known and relative sequences. From this 1200-year record, Douglass concluded that Pueblo Bonito and other ruins in Chaco Canyon had been inhabited in the eleventh and twelfth centuries. He spent the next six years correlating various floating sequences, eventually completing a record extending back to 11 A.D.

Douglass in fact supervised or conducted seven field trips between 1923 and 1929 that qualify as "Beam Expeditions." He did not actually "select" Whipple Ruin for excavation; the decision was made by him and a team of senior archaeologists who were guided by the relative ceramic and architectural chronologies of Lyndon Lane Hargrave as well as Douglass's tree-ring analysis. Although Douglass had by 1935 extended the tree-ring chronology back to A.D. 11, archaeological tree-ring dating was never a high priority for him: he was already at retirement age, and he spent less and less time in dendroarchaeological pursuits over the next four decades.

In addition to the dendrochronological hagiography of Douglass, the discovery of specimen HH-39 is often presented as nothing less than legend. In these semihistorical accounts, Douglass, on June 22, 1929, performs a candlelight minuet with HH-39, *the* specimen that bridged the gap and allowed calendar dating of southwestern sites (Haury 1962, 1985). In fact, several other tree-ring specimens had bridged the gap as early as 1927, but Douglass's own scientific strictures required that he obtain additional confirming evidence before he could feel confident enough in his chronology to announce publicly (or, for that matter, privately) any dates. The discovery of HH-39 was indeed a dramatic moment in southwestern archaeology, and the "Legend of HH-39" is a fabulous heuristic device. Nevertheless, to reduce the development of archaeological tree-ring dating to such a "eureka" event (Restivo 1994) does not do justice to the brilliant and cumulative dendrochronological research behind that event or to the many contributions of Douglass's archaeologist collaborators in that research. In short, such treatments do not supply the social or the intellectual context of this highly specialized development in the history of science. This book supplies that context and demonstrates that, to continue the metaphor, the history of archaeological tree-ring dating should be characterized as a concerto, not a minuet. As we shall see, Douglass conducted his dendrochronological research while orchestrating the contributions of a number of archaeological soloists through six decades of symphonic cooperation. The discovery of HH-39 is merely the crescendo in this "intense intellectual drama" (Gould 1989:24).

The history of archaeological tree-ring dating before 1950 can be considered in three periods. Archaeological dendrochronology developed, with varying degrees of intensity, between 1914 and 1929, a period of unparalleled prosperity and popular interest in the archaeology of the Southwest. The National Geographic Society's generous sponsorship of Douglass's work and the popular reaction to its publication stand as testimony to the middle-class interest in scholarly research that tends to characterize periods of economic prosperity.

The second phase is marked by the explosion of archaeological tree-ring research that occurred between 1930 and 1942, a period roughly coincident with the Great Depression. The collapse of many economic markets and systems had important ramifications for North American archaeology, affecting the availability of funding, labor, and materials.

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.

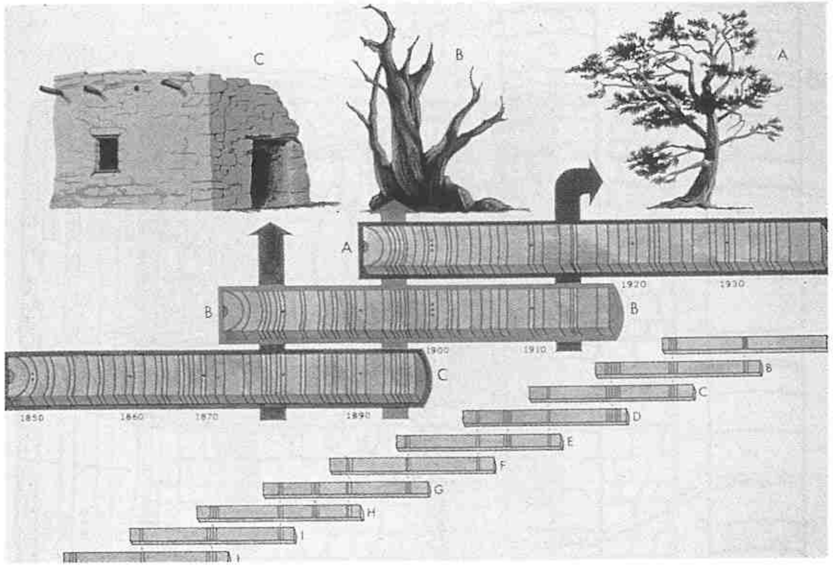

Figure 3. The principle of crossdating as presented by Stokes and Smiley (1968:6).

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

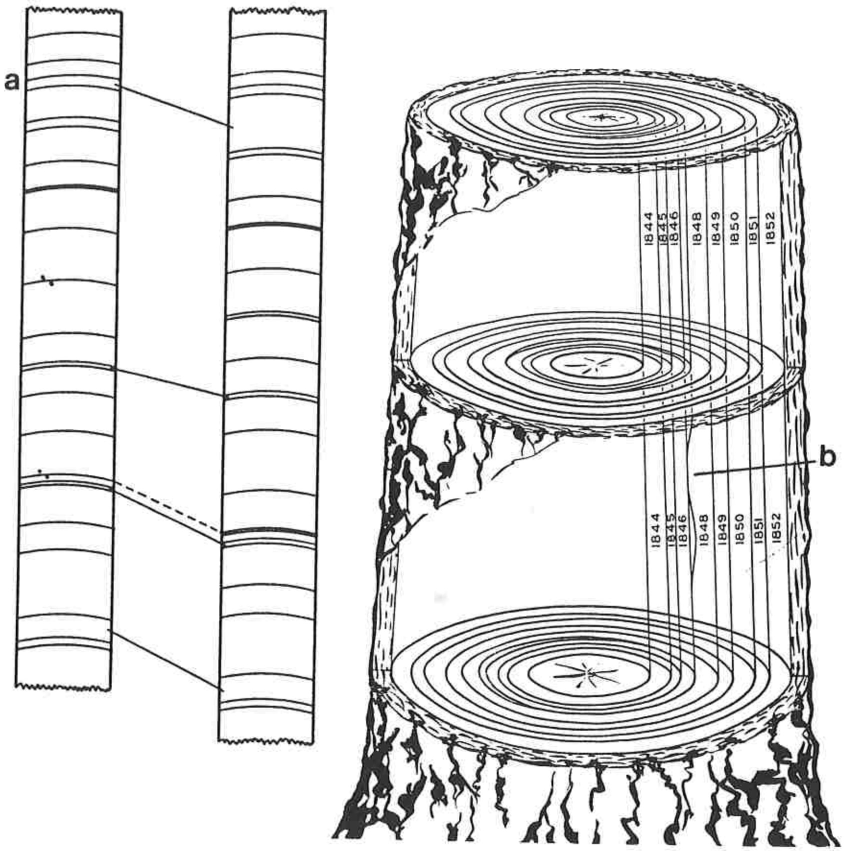

FIGURE 4. Problem rings: (a) missing ring; (b) locally absent ring (A.D. 1847) (Stokes and Smiley 1968:15).

[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

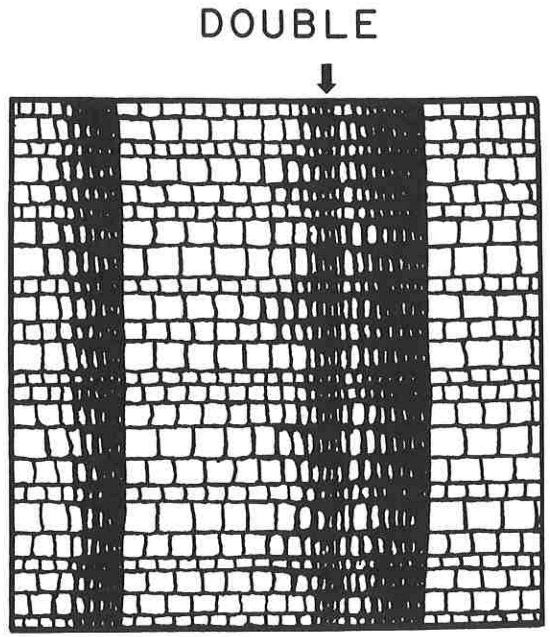

FIGURE 5. Double ring (Stokes and Smiley 1968:17).

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.

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

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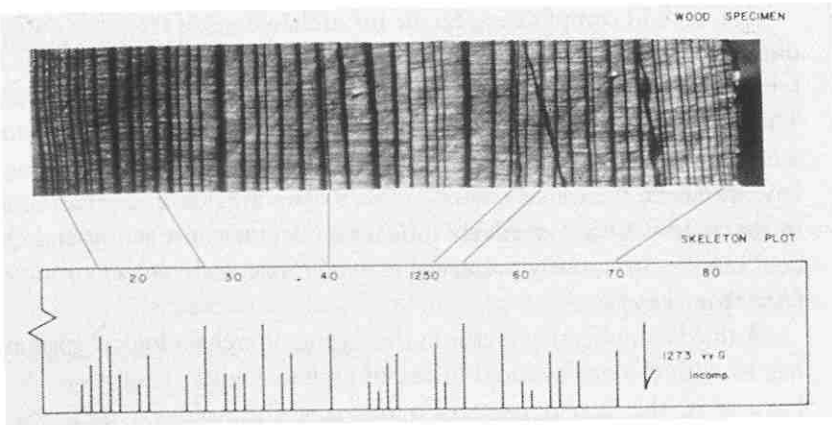

FIGURE 6. The skeleton plot, a schematic representation of ring-width variability developed by Douglass. Courtesy of the Laboratory of Tree-Ring Research.

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).

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 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.