BEHAVIORAL SOURCES OF ERROR IN ARCHAEOLOGICAL TREE-RING DATING: NAVAJO AND PUEBLO WOOD USE

JEFFREY S. DEAN

Laboratory of Tree-Ring Research, The University of Arizona, Tucson, Arizona 85721 USA

ABSTRACT. Serious problems often arise in relating archaeological tree-ring dates to the features with which they are associated. Although several different factors may create disparities between actual feature dates and associated tree-ring dates, human behavior is the most common cause of such anomalies. Date distributions from Navajo and Pueblo sites in the American Southwest illuminate the ways in which wood-use behavior affects archaeological tree-ring dating. Such differences in wood use require the development of specific sampling strategies for each type of site and of different principles for evaluating the dates. Both sampling strategies and interpretive principles are derived in part from conceptual models of the behavior associated with the use of wood in individual cultures.

INTRODUCTION

Dendrochronology provides archaeology with chronological information that is unequaled in terms of accuracy, precision and resolution (Ahlstrom 1985). Tree-ring dates are absolutely accurate in specifying the exact year in which a particular ring was grown, are absolutely precise in having no associated statistical error, and have a fundamental resolution of one calendar year. Despite these exemplary chronological qualities, it is sometimes difficult to relate tree-ring dates to the past human events that produced the archaeological features with which the dates are associated. Failure to establish the correct link between dates and associated archaeological remains can create serious misconceptions about the dating and nature of behavioral events (Dean 1978).

The greatest problem that afflicts the analysis of archaeological tree-ring dates is that of anomalous dates. This term does not refer to erroneous dates, which, given the nature of dendrochronology, are rare and can be corrected. Rather, anomalous dates are dates that, although correct, do not apply to the events with whose physical remains they are associated. For example, the dates from repair beams or reused timbers are anomalous (respectively, later or earlier) with regard to the construction of the rooms in which they are found. Obviously, the uncritical acceptance of anomalous dates can result in the erroneous temporal placement of sites and associated material and skew local and regional chronologies. The development of procedures for identifying anomalous dates so they can be eliminated from consideration or their effects corrected is necessary to realize the maximum potential of archaeological tree-ring dating. Such procedures are most profitably based on a thorough understanding of the ways in which anomalous tree-ring dates can arise in archaeological contexts. Dating anomalies have many different causes, including the natural weathering and decay of wooden elements and the excavation and postexcavation activities of archaeologists and dendrochronologists. By far the most important cause of anomalous dates, however, is the behavior of the people who produced the archaeological site. A group's behavior toward trees as a natural resource and wood as a raw material can involve a wide range of practices (the use of dead wood, the reuse of elements salvaged from older contexts, the introduction of repair timbers into existing features, and many others) that create temporal disjunctions between the date of a piece of wood and the activity with which the element was associated. Adequate understanding of wood-use behavior materially improves our ability to devise productive sampling designs and to develop principles for evaluating the dates from these sites.

Tree Rings, Environment and Humanity, edited by J. S. Dean, D. M. Meko and T. W. Swetnam. RADIOCARBON *1996, pp. 497–503*

In practice, archaeologists' evaluations of tree-ring dates usually involve definite, though often unstated, ideas about the wood-use behavior of the people who produced the sites. Nearly a century of archaeological tree-ring dating in the U.S. Southwest has produced fairly standard procedures for collecting and documenting tree-ring samples and widely accepted assumptions and principles for interpreting the dates (Dean 1969: 10–11; 1986: 144–150). Perusal of the literature reveals that these guidelines for sampling and evaluation are based primarily on an implicit conceptual model of wood-use behavior derived from prehistoric and modern *Puebloan* practice. This dependence on a Puebloan model is understandable because most Southwestern archaeological tree-ring material comes from Puebloan contexts, and archaeologists have been confronted with evaluating these dates.

PUEBLOAN WOOD-USE BEHAVIOR

The behavior that underlies the Puebloan wood-use model is exemplified by study of the modern Hopi pueblo of Walpi (Adams 1982; Ahlstrom, Dean, and Robinson 1991) on First Mesa in northern Arizona. This analysis revealed a use cycle for wooden construction elements that took centuries to run its course and involved the following sequential stages: procurement, initial use, one to several reuses, and termination. Procurement included the felling of trees, transportation of logs to the village, and the fashioning of construction elements from them. Initial use involved the incorporation of the wooden elements into various construction contexts, principally roofs and entries, where they remained until the present or until structures were dismantled. Reuse began with the removal of timbers from their original contexts and their incorporation into new contexts that involved either original or new functions for the elements. Depending on circumstances, a beam could pass through several reuse episodes as it was removed from and incorporated into a succession of contexts. The career of a timber could terminate in one of four ways: 1) abandonment when the structure or site was vacated; 2) discard into the trash when deemed no longer usable; 3) accidental or intentional destruction by fire; or 4) consumption as fuel. Different elements did not necessarily pass through the cycle at the same rate or in phase with one another. When the present Walpi was begun in the 1690s, most primary roof beams were already in the reuse stage, having been salvaged from a nearby precursor of Walpi, while freshly cut secondary roof beams were in the initial use stage. Thus, primary beams predated construction by one to three centuries and produced dates that are anomalous relative to the founding of the modern village. In contrast, most secondary beams dated to the actual time of construction. By the early 1900s, the old, worn-out primary beams were being consumed as fuel, newly cut primaries were in the initial use stage, and many secondaries were in the reuse stage. For this building phase, the secondaries produced anomalously early dates and the primaries accurately dated construction. Subsequent investigation revealed this cycle to characterize most historic and prehistoric pueblos dating back to the 10th century, although in most cases the sites were not occupied long enough to generate the full cycle, which was truncated during the initial use or reuse stages by site abandonment.

Combining the results of the Walpi study with previous archaeological analyses allows explication of the implicit wood-use model that has governed the interpretation of archaeological tree-ring dates in the Southwest. Puebloan wood use is driven by several requirements determined by the Puebloan mode of construction. The need to coordinate the activities of large groups of people and to fit new construction into the limited space available within villages entails advanced planning of construction, which promotes the stockpiling of wood. The contiguous nature of pueblo rooms induces rectangularity, which requires fairly long and straight timbers. The use of masonry or adobe walls restricts wood use largely to roofs, jacal walls, the linings of apertures such as doorways and vents, and nonstructural items such as ladders. Reliance on ground stone axes during the prehistoric period promoted the use of freshly cut wood rather than dead wood, which is difficult to work using stone tools. The location of many pueblos in treeless areas and the large size of these villages makes suitable construction wood a scarce, difficult-to-obtain and valuable commodity that must be carefully conserved and wisely used.

The foregoing requirements produce wood-use behavior characterized by seven principal attributes: 1) the selection of tree species that yield long, straight elements strong enough to support heavy superstructures, primarily ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), fir (*Abies* spp.), spruce (*Picea* spp.), aspen (*Populus tremuloides*) and cottonwood (*Populus* spp.); 2) large-scale tree felling operations involving large numbers of trees and people; 3) the systematic, often fairly long-term (1–5 yr) stockpiling of logs; 4) the maintenance and repair of existing structures; 5) the salvaging of beams from unused structures for reuse in newly built features; 6) the relatively infrequent use of dead wood elements; 7) the long-term cycling of wood through the various use stages to termination.

The Puebloan model of wood-use behavior underlies the field sampling procedures and the principles and rules for evaluating tree-ring dates that have dominated Southwestern archaeology. Given the modest number of wooden elements per room and the frequent poor preservation of such material, standard sampling practice has called for the collection of a sample from every piece of wood or charcoal found in the site. This procedure maximizes the number of dates from each feature. Rules for evaluating the dates are based on the assumptions implicit in the model and emphasize 1) the concept of cutting dates, which record the years in which the trees died; 2) the principle of clustering, the tendency of dates from a single feature to span a short time interval; and 3) the relationships between the samples and their archaeological contexts.

In the 1970s, the analysis of large quantities of wood from nonpuebloan Navajo sites drastically altered prevailing perceptions of the analytical situation. Application of the conventional assumptions and principles of archaeological tree-ring dating to sampling and dating Navajo sites produced unsatisfactory results. The magnitude of the problem is exemplified by comparing two sites. Chetro Ketl, a 600-room, 23,395 m^2 (Powers, Gillespie, and Lekson 1983: 313) prehistoric pueblo in Chaco Canyon, New Mexico, is estimated to have contained wood from *ca.* 25,000 trees (Dean and Warren 1983), roughly one tree per m^2 or 42 trees per room. Standing in sharp contrast to Chetro Ketl is a one-room Navajo corbelled hogan at site AZ D:7:206 on Black Mesa, Arizona. This small (20 m^2) structure contained >200 individual pieces of wood, *ca.* 10 trees per m^2 or 200 trees per room. In addition to the hogan, AZ D:7:206 has a sheep and goat corral fashioned from >5000 pieces of wood, a circumstance that widens the gap between the two sites. Obviously, the contrast between Chetro Ketl and AZ D:7:206 reflects fundamentally different behaviors toward wood. Even more clearly, these differences dictate major adjustments in prevailing sampling strategies and interpretive systems. The standard Puebloan-site sampling design of taking a specimen from every piece of wood present manifestly would not work on a Navajo site containing >5000 pieces of wood. Nor would the standard, Puebloan-derived interpretive assumptions and principles account for the type of behavior represented at Navajo sites.

NAVAJO WOOD-USE BEHAVIOR

In order to better understand Navajo wood-use behavior, Scott C. Russell and I undertook an ethnoarchaeological study of Navajo wood use on Black Mesa. Our goal was to determine how Navajo behavior toward wood affected the distribution of dates in different types of structures and sites.

Important structure types include human residential structures (hogans, cabins, houses, pueblitos, windbreaks, circular summer shades, ramadas), sweatlodges, storage facilities, livestock enclosures (lamb pens and sheep, cattle and horse corrals), fences, and miscellaneous items such as watering troughs and wool bag racks. Site types include residential loci and a wide variety of limited activity loci such as gathering camps, field houses, herding stations and ceremonial sites. We investigated how behaviors such as choice of tree species, season of wood procurement, tool use, stockpiling of materials, deadwood use, structure repair and element reuse varied among these types of structure and site. Russell interviewed several experienced Navajo builders about these matters in order to learn their perspective on wood resources and use. With the informants' viewpoints in mind, we thoroughly examined a number of structures and sites to see if the practices they described were evident in the archaeological record. We wished to determine the degree to which actual behavior, as represented in the archaeological record, conformed to or departed from the ideal behavior represented by the builders' statements.

Thanks to the cooperation of Southern Illinois University's Black Mesa Archaeological Project (BMAP), the archaeological phase of the study was blessed with an abundance of data. Archaeological and ethnographic information was available for >500 Navajo sites in the 240 km^2 BMAP study area. In addition, we acquired large numbers of tree-ring samples and detailed data on wood associations and conditions from many different structures and sites. Combining the ethnographic, archaeological and wooden element data with the dates derived from the samples produced an exceptionally detailed and accurate picture of Navajo wood use and its effects on tree-ring dating.

This research established that the wood-use practices specified by the informants could, in fact, be recognized archaeologically and corroborated all but one of the builders' statements. The only discrepancy between actual and stated behavior was that actual species use reflected the arboreal composition of the immediate vicinity of a site rather than the stated preference for juniper (*Juniperus* spp.). The seasonality of tree cutting revealed by analyses of the wood samples confirmed that hogans and windbreaks are usually built in the autumn, summer shades are built in the summer, and summer and winter sheep corrals are built, respectively, in the spring or fall. Tool marks on logs verified that tree felling, beam length reduction, limb removal, debarking, and shaping were done almost exclusively with metal axes; saws were used only to cut milled lumber. Stockpiling proved to be rare except for the short-term accumulation of construction materials for specific structures. Element attributes and date distributions revealed the frequent use of dead wood, which is most common in sweatlodges and corrals, is present in windbreaks and some kinds of hogan, and is virtually absent from summer shades. Date distributions confirmed that structures other than hogans, ramadas and sheep corrals rarely are repaired. Finally, the dates verified that reuse of wooden elements is common only in ramadas, hogans and corrals that are dismantled, moved and reassembled elsewhere.

Navajo wood use exhibits a high degree of between-structure variation, which has important consequences for the tree-ring dating of these features. Each structure category comprises many subtypes, each of which has unique wood use characteristics. In fact, different parts of some structures exhibit consistently different wood-use practices. The traditional Navajo residential structure, the hogan (Warburton 1985), comes in several styles, each with its own wood-use behavior. For example, the oldest variety, the forked-pole hogan (Mindeleff 1898), is built mostly with freshly-cut wood and is sometimes dismantled and moved, with unsound elements being replaced by newly cut timbers. In contrast, corbelled hogans often are built mainly of dead-wood elements that are stacked and interwoven to form a domed structure. Other types—pallisaded, many legged, log cabin, stacked log and ad hoc forms—feature combinations of freshly cut, dead-wood, reused and repair elements. Whatever the hogan type, however, entries almost always are made of freshly cut wood, and if the struchogan is moved, the old entry is left behind and a new one built. Thus, although each type of hogan has different sampling and dating potentials, entry elements are likely to provide accurate dates for the current version of the structure.

Windbreaks are unroofed structures used to temporarily shelter hunters, gatherers, herders, hogan builders and participants in ceremonies. Commonly, these structures are made of a mixture of freshly cut and dead wood and must be carefully sampled. Another temporary shelter, the summer brush shade, is always made from live-cut, foliated juniper branches and is rarely dismantled, moved or reoccupied. These structures provide point dates for the summer activities associated with them. Ramadas, on the other hand, are frequently moved and present a mixture of dead, freshly cut, reused and repair elements. Often, ramadas are roofed with live-cut, foliated juniper branches that provide point dates for each roofing episode.

Sweatlodges, structures in which sweat baths are performed, are commonly built of dead-wood elements and are poor sources of dates for the sites with which they are associated.

Livestock enclosures exhibit a variety of wood-use behaviors. Horse corrals, usually built to hold a single animal, are made of heavy freshly cut and deadwood elements. The much larger cattle corrals include huge quantities of large logs, most of which represent dead trees or timbers salvaged from abandoned structures. Entry and wall-top elements, however, usually are freshly cut and provide accurate dates for the structures. Sheep corrals (Russell and Dean 1985) contain large numbers of dead-wood timbers along with freshly cut entry and wall-top elements. The regular repair of sheep corrals with foliated pinyon (*Pinus edulis*) and juniper branches, however, provides accurate dates for individual use episodes. Lamb pens feature a variety of elements including freshly cut logs that accurately date these structures. Wood and brush fences have wood use attributes similar to those of sheep corrals.

This research produced a model of Navajo wood-use behavior suitable for creating realistic sampling designs and for developing assumptions and principles for interpreting tree-ring dates from Navajo sites. The model still is somewhat rough and is limited to wooded areas such as Black Mesa, the Defiance Plateau, the Chuska-Lukachukai Mountains and other upland areas where wood resources are comparatively abundant. Wood use in these areas is conditioned by several circumstances. The single or extended family composition of the typical Navajo residential unit involves small groups of people, promotes expedient construction strategies that require little advanced planning and preparation, and militates against stockpiling. The absence of structural contiguity eliminates the need for rectangularity and allows a wide range of wooden elements and tree species to be used. These factors, coupled with the use of metal tools, which (unlike ground stone tools) are equally effective on dead or live wood, foster the use of dead wood. The preference for wood rather than masonry promotes the use of large quantities of wood and a variety of wood-use practices. Location in wooded areas, brief site occupation spans, and the relative mobility of the population favor the cutting of living trees for construction material, inhibit structure repair and the recycling of used elements, and counter the tendency toward dead-wood use induced by the availability of metal tools.

The provisional model of Navajo wood-use behavior includes the following features: 1) the lack of a need for long, straight timbers favors the use of pinyon and juniper over larger trees, although other species may be employed when convenient; 2) small-scale tree felling operations involving few people; 3) little stockpiling; 4) scant maintenance and repair of structures except sheep corrals; 5) reuse of beams primarily in structures that are moved and in sparsely wooded areas where wood sources are limited; 6) use of dead-wood elements, especially in certain types of structure; 7) minimal cycling of wooden elements due to short site-use spans.

Navajo wood-use practices dictate site sampling and date evaluation strategies quite different from those that guide the collection and analysis of tree-ring data from Puebloan sites. Given the number of wooden elements in a large Navajo residential site (upwards of 5000 individual trees may be represented), the practice of sampling every available piece of wood is totally unrealistic. Such a collection from but one Navajo site would take weeks to amass, overwhelm sample processing systems, require months to analyze, and swamp available storage facilities. Clearly, collecting tree-ring specimens from Navajo sites requires sampling procedures designed to exploit the types of chronological information inherent in different types of structure. For example, a summer shade provides different chronological information than does a corral, the former specifying a single-use episode, the latter reflecting the duration of site use. Furthermore, far fewer samples are needed to date a summer shade, all of whose elements were cut in the same year, than to date a corral that has undergone regular repair for a decade or more. Sampling should reflect these and other between-structure differences. Similarly, assumptions and principles that reflect the unique aspects of Navajo wood use must be developed for evaluating tree-ring dates from Navajo sites. For example, Puebloan-derived assumptions about frequent stockpiling and reuse and the scarcity of dead wood must be replaced by postulates that more accurately reflect Navajo practices.

CONCLUSION

The major contrasts between Puebloan and Navajo wood-use behavior arise in part from different approaches to trees as a natural resource and wood as a raw material and in part from the differences in architectural forms and building tools and techniques that characterize the two traditions. Puebloan construction involves a limited range of structure types, featuring primarily rectangular, often contiguous, masonry or adobe rooms and circular or rectangular semisubterranean and above-ground ceremonial structures. This architectural tradition limits wood to a few contexts, primarily roofs, entries and occasional jacal walls, a situation that simplifies both sampling for tree-ring specimens and the evaluation of the resulting dates. In contrast, Navajo construction entails many structure types and specifies wood as the principal construction material. As a result, wooden elements occur in large numbers and serve numerous functions, circumstances that complicate sampling and date evaluation but at the same time significantly increase the amount of chronological and behavioral information encoded in this data domain.

The different effects of these distinct cultural patterns of wood use on tree-ring dating potential show that evaluating archaeological tree-ring dates must be accomplished within the framework of accurate models of wood-use behavior. In fact, research indicates that more than two such models are needed in the Southwest. In an intensive analysis of tree-ring dates from Southwestern archaeological sites, Ahlstrom (1985) detected consistently different patterning of dates from pueblos and pithouses and suggested that this contrast represents differences in wood-use behavior between the builders of these types of structure. In some respects, particularly the passage of wooden elements through sequences of residential structures (pithouses and hogans), pithouse wood use resembles the Navajo pattern more closely than the Puebloan one. Thus, the Navajo wood-use model may contain elements that help evaluate tree-ring dates from prehistoric pithouses. Based on these observations, it seems probable that the wood use of other groups (Indians, Spaniards, Anglos and others) differs significantly from that of Puebloans, Navajos and pithouse builders. Adequate models of each group's wood-use behavior are crucial for developing realistic sampling strategies and productive protocols for evaluating the resulting dates.

Tree-ring dating the archaeological manifestations of past human activities is far more complex than is commonly supposed, mainly because the behavior of the people who produced the archaeological record is a prolific source of anomalous dates and dating situations. The confounding effects of this complexity can be at least partly controlled by developing theoretical models of people's treatment of the wood resources in their environment. Such models pinpoint potential behavioral sources of dating anomalies, provide bases for designing productive sampling procedures, and constrain the assumptions and principles that can be developed to aid in evaluating the dates. The enhanced chronological control that will inevitably result from improved sampling procedures and evaluation principles will maximize dendrochronology's contribution to the study of human behavioral change, adaptation and evolution.

REFERENCES

Adams, E. C. 1982 *Walpi Archaeological Project: Synthesis and Interpretation.* Flagstaff, Museum of Northern Arizona: 199 p.

Ahlstrom, R. V. N. 1985 *The Interpretation of Archaeological Tree-Ring Dates.* Doctoral Dissertation, Department of Anthropology, The University of Arizona, Tucson. Ann Arbor, University Microfilms International: 688 p.

Ahlstrom, R. V. N., Dean, J. S. and Robinson, W. J. 1991 Evaluating tree-ring interpretations at Walpi Pueblo, Arizona. *American Antiquity* 56(4): 628–644.

Dean, J. S. 1969 Chronological analysis of Tsegi phase sites in northeastern Arizona. *Papers of the Laboratory of Tree-Ring Research,* No. 3. Tucson, The University of Arizona Press: 207 p.

____1978 Independent dating in archaeological analysis. *In* Schiffer, M. B., ed., *Advances in Archaeological Method and Theory* 1. New York, Academic Press: 223–255.

____1986 Dendrochronology. *In* Zimmerman, M. R. and Angel, J. L., eds., *Dating and Age Determination of Biological Materials.* London, Croom Helm: 126–165.

Dean, J. S. and Warren, R. L. 1983 Dendrochronology. *In* Lekson, S. H., ed., *The Architecture and Dendrochronology of Chetro Ketl, Chaco Canyon, New Mexico.* Reports of the Chaco Center 6. Albuquerque, New Mexico, National Park Service Division of Cultural Research: 105–240.

Mindeleff, C. 1898 Navaho houses. *Seventeenth Annual Report of the Bureau of American Ethnology,* Part 2. Washington, D.C., Government Printing Office: 469–517.

Powers, R. P., Gillespie, W. B. and Lekson, S. H. 1983 *The Outlier Survey: A Regional View of Settlement in the San Juan Basin.* Reports of the Chaco Center 3. Albuquerque, New Mexico, National Park Service Division of Cultural Research: 437 p.

Russell, S. C. and Dean, J. S. 1985 The sheep and goat corral: A key structure in Navajo site analysis. *The Kiva* 51(1): 3–18.

Warburton, M. 1985 *Culture Change and the Navajo Hogan.* Doctoral Dissertation, Department of Anthropology, Washington State University, Pullman. Ann Arbor, University Microfilms International: 429 p.