Collecting and Caring for Tree-Ring Samples in the Southwest

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Dendrochronology is the most precise and accurate dating technique available to archaeologists, with resolution to the year and sometimes season. Dendroarchaeology is the use of tree-ring samples from archaeological or historical contexts to address questions of anthropological or historical interest. As biological specimens from human-produced contexts, dendroarchaeological samples inherently contain three kinds of information: chronological, behavioral, and environmental (Towner 2002). For more than 70 years, the Laboratory of Tree-ring Research (LTRR) at the University of Arizona has been the leader in tree-ring research and the sole source of archaeological tree-ring dates in the United States; it is the only federally recognized curation facility for tree-ring specimens of all kinds. Other laboratories have developed specialized research programs for dendroclimatology, among other areas, and recent forays into dating historic buildings in the eastern United States (e.g., Grissino-Mayer et al. 2010) are quite welcome (see Grissino-Mayer 2015 for a listing of tree-ring laboratories worldwide).

For the last 50 years, the LTRR has analyzed samples collected and submitted by archaeologists, as well as conducted our own research. The purpose of this short article is to educate archaeologists on how to avoid degrading any of the three types of information through improper sample selection, collection, preparation, or transportation techniques. Analysis, dating, and permanent curation of dendroarchaeological samples remain the responsibility of the LTRR.

ABSTRACT

Dendrochronology is the most precise and accurate dating technique available to archaeologists, with resolution to the year and sometimes season. As biological specimens from human-produced contexts, dendroarchaeological samples inherently contain three kinds of information: chronological, behavioral, and environmental. The purpose of this short article is to educate archaeologists on how to avoid degrading any of these three types of information through improper sample selection, collection, preparation, or transportation techniques. Dendroarchaeology is not without limitations. First and foremost, it is dependent on the behaviors of people who built structures, made artifacts, and burned wood for fuel. If past people did not use wood, or used undateable tree species, dendrochronology will simply not be useful. In some cases, people used dateable species, but their selection criteria did not meet one of the four basic criteria necessary for successful dating. The second most important factor in successful tree-ring dating of archaeological materials is the behavior of archaeologists. Finally, preservation plays an important role in successful dating and the nature of the derived dates, but the paucity of long-lived old trees and degradation of "legacy" wood on the ground have hampered the development of millennia-long chronologies in more mesic areas.

La dendrocronología es la técnica de datación más precisa y exacta disponible a los arqueólogos, con una resolución al año y a veces a la temporada. Tal como las muestras biológicas sacadas de contextos humanos, las muestras dendroarqueológicas contienen inherentemente tres tipos de información: cronológica, conductual y ambiental. El propósito de este breve trabajo es educar y garantizar que los arqueólogos no degradan ninguno de los tres tipos de información a través de una selección inadecuada de la muestra o por sus técnicas de recolección, preparación, o transporte. La dendroarqueología no está sin limitaciones. En primer lugar, ella depende de los comportamientos de las personas que construyeron las estructuras, hicieron los artefactos, y quemaron la madera como combustible. Si la gente del pasado no hizo uso de la madera, o utilizó especies de árboles imposibles de datar, la dendrocronología simplemente no será útil. En algunos casos, la gente utilizó especies fechables, pero sus selecciones no cumplieron con los cuatro criterios básicos necesarios para la datación exitosa. El segundo factor más importante en la datación provechosa por medio de los anillos de los árboles de los materiales arqueológicos es el comportamiento de los arqueólogos. Por último, la preservación juega un papel importante en la datación válida y la naturaleza de las fechas derivadas, pero la escasez de árboles longevos y la degradación de la madera "legada" en el terreno han obstaculizado el desarrollo de cronologías de duración de milenios en las zonas más mésicas.

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GLOSSARY

Complacent Series: A ring series that shows little variability in ring width; most rings are similar in size. Typically the results of relatively wet conditions where water ceases to limit ring growth. Such series are difficult, and sometimes impossible, to date because there is no pattern to match against a master series.

Erratic Series: A ring series that exhibits extreme variation in ring widths. The opposite of a Complacent Series. Often accompanied by missing and locally absent rings. Typically a result of a tree growing at the extreme limit of its elevational or latitudinal range. Difficult, and often impossible, to date because the ring-width pattern does not match the master developed from the overall species population for a given area.

Kerf: The width of a saw blade (or borer wall); can vary slightly due to uneven rotation or pressure on the drill or saw.

Lobate: A growth form when a tree bole forms uneven lobes, thus losing circuit uniformity. Often creates a ring of different sizes around the tree, making crossdating difficult or impossible.

Mesic: An ecological term noting a moderately wet environment. Mesic microenvironments, such as around springs, can make trees more complacent because water is freely available and not limiting ring growth.

Xeric: An ecological term noting an arid environment. Extremely xeric environments often contain trees that do not crossdate because they have no consistent seasonality of available moisture. Ring series are more erratic in xeric environments.

REQUIREMENTS FOR DENDROCHRONOLOGY

Trees are natural archives of information. Through their biological processes, they "record" variations in precipitation, temperature, nutrient availability, and atmospheric and ecosystem conditions; trees are stationary and often quite long-lived. Thus, they retain records of climatic and environmental variation often much longer than documentary records. As specimens from archaeological contexts, dendroarchaeological samples reveal information about past human behaviors, such as how humans viewed wood as a resource and how they used tools, for example. Not all trees are suitable for dendrochronological analysis, however. Some species do not produce annual rings, some exhibit complacent or erratic growth patterns, and some retain too few rings for crossdating. In general, trees must meet four basic requirements in order to be dendrochronologically useful.

First, trees must produce annual rings. Most trees in temperate environments produce cambium during some portion of the year and, more importantly, have a dormant period when cell division (ring growth) does not occur. This annual sequence of growth/no growth over decades or centuries is the basis for developing ring-growth series over extended time frames. It is that pattern of wide and narrow rings that is matched from sample to sample. In the U.S. Southwest, four species are most amenable to archaeological tree-ring dating: Ponderosa pine, Douglas-fir, pinyon pine, and juniper. Depending on the spatio-temporal context, other species, such as cliff rose (*Purshia* spp.) and Mountain Mahogany (*Cercocarpus* spp.) may be useful as well (Ahlstrom 1985). Conversely, trees that do not consistently produce annual rings, such as mesquite (*Prosopsis* spp.), Palo Verde (*Cercidium* spp.), and other desert plants, generally are not dateable.

Second, dendrochronologically useful trees must exhibit "circuit uniformity." In short, the relative width of the rings must be the same around the sample. Trees that have a lobate growth form often, but not always, will not crossdate because ring-width variability and false and missing (locally absent) rings are not consistent around the sample.

Third, dateable samples must exhibit variability in ring growth. Most commonly in the Southwest, the variability is in the size (width) of the annual ring. Other variables, such as ring density or latewood width, can provide important information, but are not commonly used for dating purposes. Southwestern trees that do not exhibit ring-width variability (complacent series) are typically those that grow in favorable microenvironments, such as floodplains or other moist areas. Conversely, some trees exhibit too much variability (erratic series) and respond to individual growth stimuli that do not match the patterns of the larger population.

Finally, samples must contain enough rings to match the growth pattern of the master ring series derived from a larger population. What constitutes a sufficient number of rings to match the master ring series varies across time and space. In the Southwest, 50 rings is typically sufficient, whereas in more mesic areas > 100 or even > 400 rings may be necessary for crossdating (Baillie 1995).

SAMPLE COLLECTION

Due to a variety of factors, not all dendroarchaeological samples will yield dates; indeed, the long-term (70-plus years) success rate of LTRR analysis is approximately 40 percent. Some samples are undatable species, some retain too few rings, and some exhibit aberrant growth patterns that do not patch master ring series. A goal of this paper is to help archaeologists collect samples that will yield high-quality cutting dates. Sample collection and field conservation techniques vary depending on the type of sample and archaeological context. The easiest samples to collect are wood sections sawn or broken from exposed beams (Figure 1); of course, such techniques have deleterious effects on the archaeological record and are rarely used.

Tree-ring samples are scientific specimens, but should be treated like archaeological artifacts. Their associated metadata

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FIGURE 1. Students collecting tree-ring samples with a saw.

should include detailed provenience information and sample attribute data. Recording forms (Figures 2 and 3) can, and should, vary depending on the cultural group, structure type, and archaeological context, but at a minimum should include: site number, field specimen number, structure, room, and wall number, collector, date collected, beam function (roof primary, door lintel, firewood, etc.), beam attributes (bark, beetle galleries, charred, etc.), beam modifications (debarking, limb trim, shaping, etc.), tool marks (stone ax, metal ax, adze, etc.), and beam end treatments (burned, rotted, stone ax cut, etc.); not all attributes are visible or appropriate for all contexts, but as with all archaeological materials, detailed notes are absolutely critical in properly interpreting dates.

The majority (ca. 70 percent) of the samples submitted to the LTRR for analysis are wood or charcoal samples from excavated contexts. Importantly, the conversion from wood to charcoal in natural contexts usually, but not always, leaves the ring structure intact and visible for analysis (Figure 4). Charcoal is an inert substance and, as such, is resistant to decay from bacteria, fungi, or insects; it is, however, extremely susceptible to physical trauma. Wood samples from excavated contexts typically lack outside rings and rarely yield cutting dates (see below). Because wood still contains cellulose, buried wood specimens are attractive food sources for insects, bacteria, and fungi.

Charcoal and buried wood samples require special care and handling in the field, during transport, and in the laboratory. As with any other fragile specimen, excavation of dendroarchaeological samples must proceed carefully in order to preserve the exterior (outside) rings of the sample. Careful excavation and wrapping of the sample in cotton (not nylon) batting and string (Figure 5) protects the sample. Muslin or other cotton batting is preferred; nylon fibers tend to get stuck in the sample and damage exterior rings when unwrapped. The sample can then be stored in a paper bag and boxed with other tree-ring samples if enough padding is provided to keep samples from moving around and impacting each other. Paper tags with unique field sample numbers should be tied securely to each sample. Charcoal samples should never be wrapped in aluminum foil or stored in sealed plastic bags because retained moisture will degrade the sample and make it unusable. In past decades, samples were stabilized in the field using a mixture of melted paraffin and gasoline. This system is no longer used due to dangers in the field and health risks from degassing samples during transport and at the lab. Samples should be packaged carefully and snugly, but they are not so fragile that they cannot be shipped by U.S. mail or other commercial carriers.

The most common method of collecting wood samples from above-ground archaeological or historical sites is by coring beams. Commercially available borers ("Swedish increment borers") used for removing cores from living trees generally do not work on dead wood. Attempted use of such borers on dead wood commonly results in a broken borer or a core so fragmented as to be useless. Therefore, a set of coring tools based on principles different from those of increment borers has been developed for extracting cores from archaeological wood. For wood samples from above-ground structures, the LTRR collects cores using specialized equipment and a drill bit that resembles an elongated hole saw.

The archeological beam coring kit (Figure 6) consists of seven components:

(1) Starting plate

(2) Starting bit

(3) Adapter for attaching bits to the chuck of an electric drill

(4) A coring bit, one end with saw teeth, one end with slot that fits into adapter

(5) Cleaning tube for removing sawdust from the adapter

(6) Wire core breaker for removing core from beam

(7) Plastic tube for blowing sawdust from hole in beam

In addition, the following items complete the coring gear: an electric drill powered by house current, a generator, or batteries; a power source for running a standard electric drill or charging batteries for a portable drill (prior to the development of electric drills, A.E. Douglass, E. W. Haury, and others used a modified brace-and-bit systems that worked well but required hours to extract a single sample); hammer and nails for attaching the starting plate to the beam; a triangular file for sharpening coring-bit teeth; needle-nosed pliers for setting the angles of the coring-bit teeth; a 9.5- to 13mm-diameter wooden dowel for removing stuck cores from bits; and a method for storing cores.

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Navajo Sampling form					Recorder:		Date:	
Field Sample#								
LTRR#								
Sample type								
LAsite#/CMT#								
FE #								
Beam#								
Northing								
Easting								
Function								
Fork								
Leaner								
Loose log								
Ax-cut limb								
Ax-cut stump								
Burned stump								
Proc-tree slab								
Proc-tree bow								
Other								
Attributes								
Bark								
Galleries								
L-cond								
Weathered								
char/black								
shaped								
Tool Marks								
Debark								
Limb trim								
Shaping								
Other								
Beam Ends								
min/max								
MA cut								
Broken								
Sawn								
Burned								
Buried								
Indet								
Other								

FIGURE 2. Recording form used for Navajo archaeological sites.

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Cabin Samping Form							
Site #					Recorders		
Feature #					Date:		
	Sample#	Sample#	Sample#	Sample#	Sample#	Sample#	Sample#
Field							
LTRR							
Wall#							
Beam#							
(bottom-top or left-right)							
Sample Type (core/x-sect)							
Function							
Horizontal Wall element							
Vertical Wall element							
Roof Primary							
Roof Secondary							
Roof support							
Door Lintel							
Door sill							
Window Lintel							
Window Jamb							
Window Sill							
Chinking							
Upright Post							
Other							
Beam Attributes							
Bark							
Beetle Galleries							
L-condition							
Weathered							
Shaped							
Notched (shape)							
Smoke blackened							
Charred							
Fit to room?							
Tool Marks							
Debarking							
Limb trim							
Notching							
Shaping							
Beam Ends							
Min/Max (direction)							
Socketed							
Metal ax							
Sawed							
Broken							
Burned							
Buried							
Indeterminate							
Other							

FIGURE 3. Recording form used for Euroamerican Cabins.

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FIGURE 4. A charcoal sample exhibiting rings.

We use 13-mm plastic tubes, but any technique that keeps the cores and pieces of cores in the correct order is acceptable. In some circumstances, it may be necessary to plug the holes left in archaeological beams by the coring process; plugging is generally done with wooden dowels or with corks acquired from a laboratory or medical supplies vendor. The specially made coring system is somewhat expensive and requires training and practice to use properly. Unfortunately, commercially available archaeological coring kits are not common (but see Grissino-Mayer 2015). Our system was custom-made by specialty machine shops using high-tempered steel alloys. Such an approach is expensive, but the tools last for many years; some of our drill bits were purchased in the early 1960s!

For maximum efficiency, we employ the following routine when coring archaeological beams.

(1) Affix the adapter (Figure 6) firmly to the drill chuck.

(2) Insert the coring tube into the adapter and make sure the tube's T-slot is firmly engaged at the base of the adapter. The bit teeth are designed to cut in a clockwise direction, so make sure that the drill is set for clockwise ("forward") rotation, if there is an option.

(3) Nail the starting plate (Figure 6) to the exterior of the beam, with the large hole aimed as nearly as possible at the assumed middle of the log. It is also critical that the starting plate be positioned over any bark, beetle galleries (Figure 7), or other indicators of a "true outside" of the beam.

(4) Insert the toothed end of the coring bit through the center hole in the starting plate and press firmly against the wood; while pushing hard against the beam, activate the drill on full speed.

(5) After penetrating the wood to a depth of approximately 6 mm, the coring bit should be backed out of the hole and the starting plate removed to prevent friction damage to the bit. The drill should be rotating when the coring tube is pulled out of the hole, but not necessarily at maximum speed. From this point on, the walls of the hole guide the coring process. It is preferable to maintain the same coring angle throughout the process, as changing angles can result in a broken core.

(6) In general, the starting bit (Figure 6) is used only in situations in which the starting plate cannot be affixed to a beam. The central projection of the starting bit should be pressed against the log, the drill engaged, and the bit pressed into the log until it reaches maximum depth. At that point, the starting bit is replaced on the drill with the coring bit, and coring proceeds as outlined below. Using either starting system, extreme care must be used to ensure that the coring bit does not tear the outside rings of the core.

(7) The most important aspect of the coring process is to keep the drill bit aimed in a consistent direction. After the core is started, its orientation should not be changed. Extreme reorientation of the drill bit produces a pencil-sharpener effect in which the core ends in a point. The need to maintain stability during the coring process means that the operator should assume as comfortable a stance as possible (Figure 8). Commonly, however, operators find themselves lying on their backs or assuming other contorted positions in order to access the best location on the beam.

(8) Press firmly against the beam when drilling. The coring bit, however, is not a drill bit, and operators should not expect



FIGURE 5. A properly wrapped charcoal sample.

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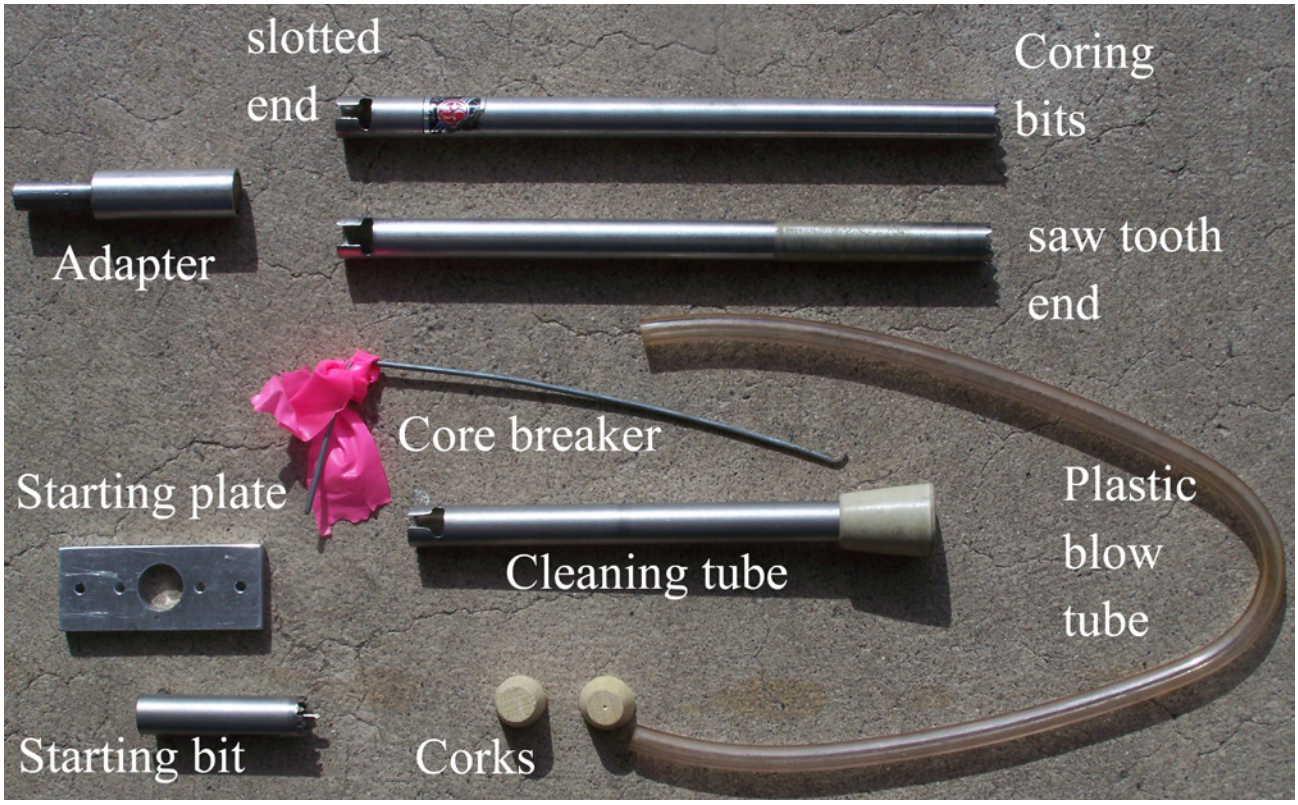


FIGURE 6. The archaeological dendrochronology coring kit.

similar progress in "drilling." Patience is a virtue when coring. Depending on circumstances (hardness of wood, species of wood, pitchiness of wood, length of core, access to the beam, coring angle, operator fatigue, etc.), 30 minutes or more may sometimes be necessary to acquire a single archaeological core. Trying to rush the process, however, often results in a jammed bit and a damaged core, which requires more time to extract and yields poorer quality data.

(9) It also is important to keep the coring bit free of sawdust when coring. In order to keep sawdust from binding the coring tube, the running coring tube should periodically be pushed back and forth in the hole to blow out excess sawdust. Excess sawdust buildup in the coring tube often results in the core becoming jammed in the tube, which then requires more time and energy to remove the core. This is especially true when the wood is pitchy. Therefore, we periodically withdraw the tube from the hole and blow the sawdust out of the hole using the plastic tube. We also disengage the bit from the adapter and blow the sawdust out of the bit. It is important not to inhale. Various kinds of wood leave a bad taste (or worse) in the mouth, and long-term exposure to some wood sawdust can contribute to serious health problems.

(10) About half the time, the core will break on its own and come out whole or in pieces. If the core breaks into pieces, it is critical to keep the pieces in the order in which they came out of the bit (or hole).

(11) If the core (or part of it) remains attached to the beam, the wire core breaker (Figure 6) is used to remove it. Insert the core breaker into the space (kerf) between the core and the wall of the hole to the bottom of the hole. Rotating the wire breaker should cause the angled tip to break the core, snag under it, and permit it to be drawn from the hole. This action doesn't always work, and the breaker may have to be twisted around several times to break the core from the beam.

(12) Occasionally a core gets stuck in the coring bit due to excess heat buildup, sawdust, and/or pitch. Most of the time, the core can be pushed out one end of the tube with a wooden dowel. Sometimes, the core needs to sit in the tube long enough to dry or cool before it can be removed. Commonly, it is necessary to push the core back and forth inside the tube before it loosens enough to be removed. It is preferable to remove the core from the proximal, not distal, end of the tube because the teeth inhibit extraction. It is necessary to exercise extreme care when pushing the dowel into the sawtooth end of the bit; jamming one's fingers into the teeth can be quite painful. Rarely, the core remains permanently stuck, and a replacement core has to be taken and the blocked tube abandoned, or the stuck core must be drilled out with a standard drill bit in the laboratory.

(13) We label the core (and individual pieces if it is broken) immediately upon extraction. Ballpoint pen is best, especially if the core is moist or pitchy. The ink from other implements, such as Sharpies, can run and become illegible. We use a field number keyed to notes on the beam and the sample. The LTRR

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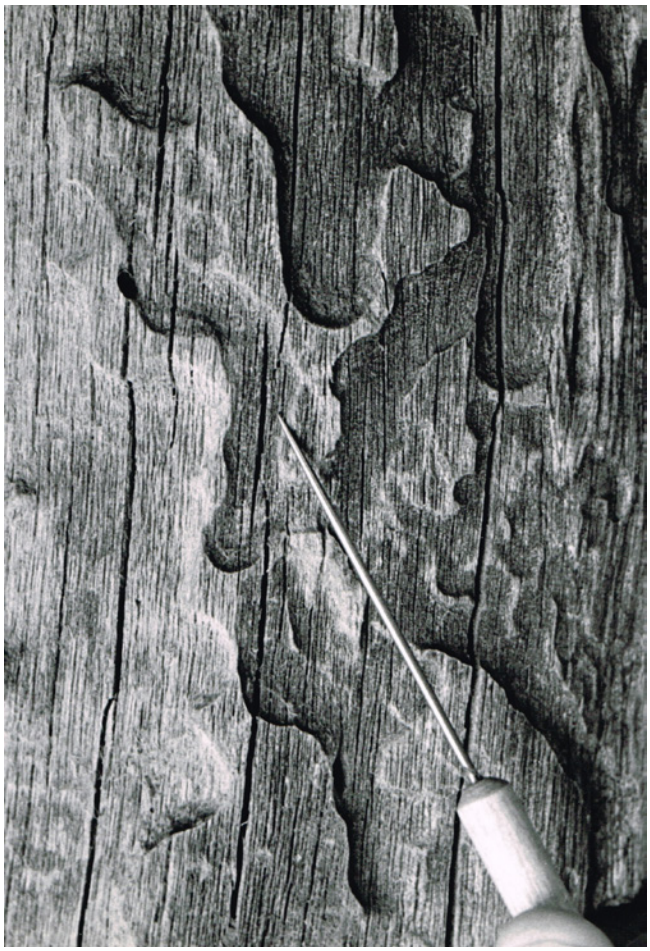


FIGURE 7. Beetle galleries indicating the true outside of a beam.

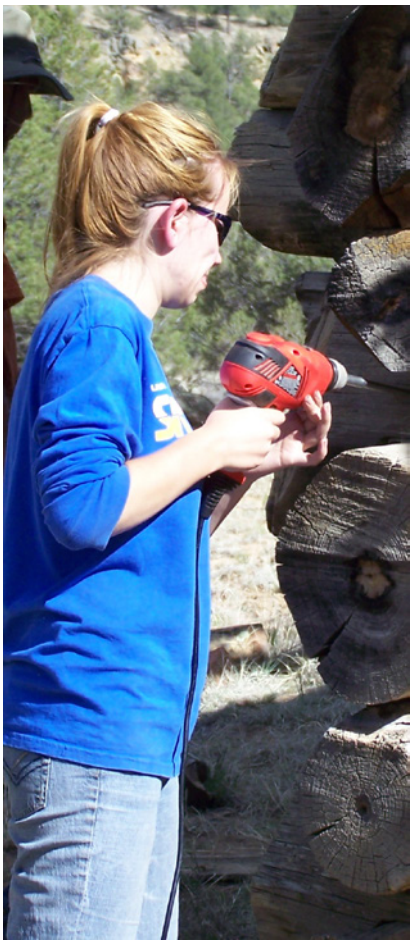


FIGURE 8. A student collecting a core from a standing structure.

assigns permanent catalog numbers to the samples during the analysis process.

(14) If required, plug the empty hole with wooden dowel or a cork.

(15) Store the core in some fashion that preserves it from harm and maintains the order in which any pieces came out of the hole. Small diameter pieces of PVC or other tubing, preferably clear, can be procured at most hardware stores. Any pieces so maintained will, if possible, be glued together in the laboratory; we prefer gluing pieces together in the laboratory where light and visibility are maximum; gluing in the field in rain, snow, heat, dust, and wind is often counterproductive. The resulting cores (Figure 9) are transported to the LTRR, sanded with increasingly fine grit sandpaper (up to 400 grit), and analyzed using the skeleton plotting method.

TREE-RING DATING: HOW IS IT DONE?

There are two general methods for dating tree-ring samples: graphical and statistical. Both methods compare patterns of some ring variable, most often ring width, against a previously developed master time series of that variable. The master itself is developed from a larger tree population and reflects the overall growth patterns of trees in a specific area. Such chronologies reflect patterns of climate—typically rainfall in the Southwest—and have different spatial limitations. In some cases, such as across broad swaths of the Colorado Plateau, ring series may crossdate across hundreds of miles. Such was the case during the development of dendrochronology, when A.E. Douglass was able to crossdate samples from the Flagstaff area with those from the Four Corners (Douglass 1929). When climatic patterns are significantly different, crossmatching of patterns must be done on a much more local scale. For example, the growth patterns in the Taos, New Mexico, area are very different from those near Raton, New Mexico, a scant 60 km on the opposite side of the Sangre de Cristo Mountains adjacent to the High Plains. This is because the Sangre de Cristo Mountains disrupt seasonal precipitation patterns (east vs. west), which results in different ring-growth patterns on different sides of the range.

The graphical method of crossdating was developed by A.E. Douglass, nearly a century ago, and is a relatively low-tech system requiring only a binocular microscope, a pencil, and a piece of graph paper. This skeleton-plotting technique has been used

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FIGURE 9. An archaeological core after sanding in the laboratory.

to date thousands of samples from hundreds of sites (Stokes and Smiley 1968) and is the only one used by the Southwestern Dendroarchaeology section of the LTRR because it produces absolute independent dates with no standard deviation. Samples either match the master pattern and are dateable or do not match and cannot be dated. The method is precise and efficient, but requires at least two years of intensive training for analysts who use it.

The statistical method typically involves measuring each ring to the nearest .001 mm and processing the data through the computer program COFECHA (Holmes 1983). The task is time-consuming, but can be accomplished by student technicians with minimal training. It is ideal for more complacent specimens and widely used in the eastern U.S. and Europe, but less so for specimens with numerous missing rings and high ring-width variability. It is not used for southwestern archaeological specimens for one primary reason. It generates multiple date probabilities—thus eliminating the independence of these biological specimens from their archaeological context—and allows researchers to "pick and choose" which probability best suits their research.

DISCUSSION AND CONCLUSIONS

Tree-ring dating is the most precise chronological control for archaeologists researching the recent past. The technique provides an annual, and sometimes seasonal, degree of resolution for archaeological phenomena, as well as providing behavioral and environmental data relative to past human activities. The generation of abundant, high-quality tree-ring dates has made, and continues to make, important contributions to our understanding of past human behavior in the Southwest and elsewhere. Although some factors in successful dating are beyond our control, archaeologists can contribute to this tremendous database with the use of proper sample documentation, collection, storage, and transportation techniques.

Dendroarchaeology is not without limitations, however. First and foremost, it is dependent on the behaviors of people who built structures, made artifacts, and burned wood for fuel. If past people did not use wood, or used undateable tree species, dendrochronology simply will not be useful. Such has been the case in much of the Hohokam world of the Desert Southwest (but see Dean et al. 1997), where mesquite, palo verde, and acacia trees were the preferred woody materials, In some cases, people used dateable species, but their selection criteria did not meet one (or more) of the four basic criteria necessary for successful dating (see above). The Bristlecone pine samples from the high-altitude site of Alta Toquima, Nevada, are a good example of such nondating (Thomas 1982, 2014). Bristlecone pines have produced some of the longest chronologies in the world, stretching back some 8,700 years. Bristlecone is somewhat complacent, however, and requires several hundred rings for accurate crossdating. Unfortunately, the people who built the structures at Alta Toquima selected small pieces that contained fewer than 100 rings in most cases, so the samples are not dateable either internally or against a master ring series.

The second most important factor in successful tree-ring dating of archaeological materials is the behavior of archaeologists. Simply put, if archaeologists are not interested in a site, culture, or area, and do not properly collect, preserve, and submit samples for analysis, no successful dendroarchaeology will occur. In the past 50 years in the U.S., "archaeological interest" has often been driven by the mandates of CRM projects. Such interest obviously biases the database toward sites and time periods under investigation, even when a large number of samples have been collected and analyzed properly (Nash and Rogers 2013).

Finally, preservation plays an important role in successful dating and the nature of the derived dates. The semi-arid nature of the Southwest promotes excellent preservation, but as Ahlstrom (1985, 1997) has shown, past human wood use practices heavily influence the preservation and integrity of wood and charcoal samples. In more mesic areas, preservation takes on two aspects—living trees and remnant wood for chronology building and interpreting past human behaviors. Interestingly, preservation of archaeological samples—inert charcoal and waterlogged wood—is often quite good in mesic areas such as Alaska (Giddings 1954; Nash 1995), the Mississippi drainage (Speer 2010), and elsewhere. Unfortunately, the paucity of long-lived old trees and degradation of "legacy" wood on the ground have hampered the development of millennia-long chronologies, but this is not an insurmountable problem.

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Data Availability Statement. It is a long-established LTRR data sharing policy that the data produced by our analyses, the paper site and sample information archives, the electronic databases, and the sample collections are accessible to all qualified researchers on request. The only costs involved are cost-recovery charges for providing the databases on disk and per page charges for large photocopying operations. Access to the sample collections is unrestricted except that the samples must be handled with due care and will not be allowed to leave the laboratory; exceptions may be granted for procedures (isotope, elemental, microscopic, etc.) that cannot be performed at LTRR. These policies have furthered numerous research projects including sample reanalysis, refined site dating, the sourcing of

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construction timbers, and the identification of frost damaged rings. Because the data derive primarily from NSF-funded LTRR research, the data are routinely shared without restriction; results of routine analysis submitted by third parties are available approximately one to two years after they have been communicated to the submitting principal investigator.

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