THE INTERPRETATION OF

ARCHAEOLOGICAL TREE-RING DATES

by

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have yielded tree-ring dates. Second, the study presents compilations of chronological information, such as lists of dated structures. It is hoped that the analyses of structures and sites will contribute to studies on the growth and decline of prehistoric communities (Bannister 1962:513), and that these case studies and the data compilations will prove useful for chronology building at both the local and regional levels. Only a small percentage of investigated ruins actually yield tree-ring dates. To be useful to studies of culture history, data from these sites must be integrated with information from the far more numerous sites without tree-ring dates. That task is far beyond the scope of this or any other single study. Tree-ring dated sites do provide particularly valuable information on some issues in Southwestern culture history, however, and a few of these issues are discussed in at least a cursory way.

The Tree-Ring Literature

The three components of the archaeological tree-ring literature have already been identified. They include date lists and information on dated samples, whether published or not, theoretical discussions of the use of tree-ring data in archaeological research, and case studies that analyze the data from a given structure, site, or region. Within recent years, developments in this literature have reached a threshold that makes a comprehensive review of tree-ring dating in the Southwest both more desirable and easier to accomplish than ever before.

Date Lists and Supporting Documentation

In 1975 the Laboratory of Tree-Ring Research completed publication of 16 volumes, known informally as "Quadrangle Reports," which were the product of a decade long reanalysis of practically all tree-ring samples recovered and saved from Southwestern ruins during the preceding half century (Robinson, Harrill, and Warren 1975:ii). Several characteristics of the data presented in these volumes account for their special value to chronological studies. First, the tree-ring dates are highly precise and accurate, for they indicate the year during which the outermost tree ring on a wood or charcoal sample grew. By comparison, dating techniques such as stratigraphy and seriation can reveal only the order in which past events occurred. Other techniques date events to much grosser intervals than tree rings, depend on tree-ring dates for calibration, or both.

The second distinguishing feature of the dates listed in the Quadrangle Reports is their number, especially as compared to dates appearing in previous compilations. In 1951, Terah L. Smiley (1951:6) summarized some 5,600 dates from 365 sites, whereas the Quadrangle Reports contain more than 20,000 dates from more than 1,300 sites (Robinson 1976:16). Much of this increase is due to the systematic reanalysis of old samples. For example, in 1946 Harold S. Colton (1946) had access to approximately 265 dates from 46 sites in the vicinity of Flagstaff, Arizona. This compares to 670 dates from these same sites as listed in the Quadrangle Report for this area (Robinson, Harrill, and Warren 1975). Practically all the new dates are from samples that were available but undated in 1946.

The third characteristic of the data presented in the Quadrangle

Reports relates to the comparability of the tree-ring dates. From the beginning, almost all dendrochronologists have worked according to a single method, sometimes called the "Douglass System" in honor of the founder of dendrochronology. For this reason, it is of minor consequence that the Quadrangle Reports reflect the efforts of fewer than 10 dendrochronologists, whereas Smiley's (1951) summary included dates derived by 18 individuals. What is important is the use of a single reporting format throughout the Quad Books. In contrast, Bannister's (1965) study of previously published dates from Chaco Canyon had to deal with six different formats.

Fourth, whenever possible, the Quadrangle Reports list tree-ring dates according to structure or some comparable provenience designation. Although some previous summaries of tree-ring data provided this kind of information, others did not. Numbers 1 through 5 in a series of date summaries entitled "Southwestern Dated Ruins" appeared in the Tree-Ring Bulletin in 1937 and 1938; Numbers 6 and 7 were published in 1951 and 1960 (Bannister 1960). These compilations, along with Smiley's (1951) summary of dates from throughout the Southwest, did not present individual dates but instead indicated the date range and number of dated samples for each site. This information was potentially suited to the assigning of sites to periods, measured in centuries or by units of the Pecos Classification, but not to the study of individual site histories. According to Breternitz (1966:2), "The nonspecific nature of Smiley's list perhaps accounts for the fact that many archaeologists have, unfortunately, ignored the large body of information contained therein."

In 1953 and 1965 the Laboratory of Tree-Ring Research issued two numbers in what was to be a series of regional summaries of tree-ring data. These compilations listed individual dates by provenience. The first publication dealt with the northern Rio Grande (Smiley, Stubbs, and Bannister 1953). In this case, the value of an itemized date list was diminished by the general lack of published site reports that could give meaning to the proveniences of the dated samples. The second report in the series (Bannister 1965) did not suffer from this problem; it did, however, present data from just one small area, Chaco Canyon in northwestern New Mexico. Thus, the Quadrangle Reports present more dates in a standardized format with more complete provenience information than any previous compilation. Perhaps as important as the data in those volumes is the provenience and site information in the Laboratory of Tree-Ring Research's site files. In addition, the Laboratory has released many thousands of dates since the publication of the Quad Books; some of these dates have been published in site and project reports, though most have not. These dates have been processed and reported exactly as those in the Quad Reports and hence are fully comparable with those older dates. It is the availability of many thousands of equivalent dates, in the Quadrangle Reports and elsewhere, that underlies the claim that a "body" of Southwestern tree-ring data in fact exists.

Theory and Method

The second component of the tree-ring literature consists of theoretical and methodological discussions that, over the years, have produced a coherent body of concepts and principles to guide archaeologists in the interpretation of tree-ring dates. The authors of the most important of these studies have been employees and close associates of the Laboratory of Tree-Ring Research, a reflection of the central role played by that institution in the development of tree-ring studies. Because of this relationship and of the way in which each discussion builds on the ones that came before, the works in question can be seen as the product of a single intellectual tradition. Contributors to this tradition include A. E. Douglass (1935), Emil W. Haury (1935), Terah L. Smiley (Smiley 1951; Smiley, Stubbs, and Bannister 1953), Bryant Bannister (Bannister and Smiley 1955; Bannister 1962, 1965), William J. Robinson (1967), and Jeffrey S. Dean (1969, 1978a, 1978b). The interpretive framework developed by these individuals is described in the next chapter.

Case Studies

Studies that utilize particular sets of tree-ring data comprise the third portion of the archaeological tree-ring literature. A few have used tree-ring dates from many sites to answer narrowly defined research questions. For example, Breternitz (1966) dated the period of manufacture of pottery types with tree-ring dates, Eighmy (1979) used dates as an index of population growth at individual sites, and Berry (1982) used dates as an indicator of population movement across the Colorado Plateau. Far more common than these broad problem oriented studies are the discussions of tree-ring data that occur in scores of site and project reports. In the first such analysis, Haury (1934) reconstructed the building sequence at the Canyon Creek Ruin, a cliff dwelling in east central Arizona. Hall (1944) dated pithouses in the Gobernador District of northwestern New Mexico, and Colton (1946) dated pithouses, pueblos, and ceramic complexes in the area of Flagstaff, Arizona. More recently, Hayes (1981a) has inferred a construction sequence for Gran Quivira, in central New Mexico, on the basis of tree-ring dates and architectural information. These and many similar works have produced an ever growing body of case studies that is essential to the kind of synthesis being undertaken here. Other research has focused on the interpretation of collections of tree-ring data. In the 1960s, Bannister (1965) published a detailed analysis of tree-ring dates from ruins in and around Chaco Canyon, Nichols and Harlan (1967) presented tree-ring data from sites on Mesa Verde investigated by the Wetherill Mesa Project, and Dean (1969) conducted a similar study of cliff dwellings in Tsegi Canyon. More recently, papers have dealt with tree-ring information from Johnson Canyon (Harrill and Breternitz 1976), from the Hopi pueblo of Walpi (Ahlstrom, Dean, and Robinson 1978), and from a restudy of the Canyon Creek Ruin (Graves 1982). These focused tree-ring studies are particularly useful because they tend to employ the full array of concepts and principles developed for use in the interpretation of tree-ring data.

In summation, Southwestern archaeology has at its disposal (1) thousands of tree-ring dates accompanied, in many instances, by detailed contextual information, (2) an interpretive framework developed during the last half century by archaeologists practiced in the use of tree-ring data, and (3) many case studies, including a few that focus on tree-ring data. The goal of the present study is to integrate these three kinds of information through a comparative analysis of the available tree-ring data. Clearly, the research is an outgrowth of a half century of work conducted by dozens of scholars. It has a direct precedent in Bannister's (1965) analysis of data from Chaco Canyon, which applied a single interpretive scheme to a number of sites. The present analysis differs from Bannister's in its wider scope, both spatial and temporal, in its greater concern over the way in which particular concepts and principles are used in interpretation, and in the homogeneity of the tree-ring data base that it employs.

Scope and Organization of Study

The study uses data from Anasazi sites that date from Basketmaker III to Pueblo V, or from about A.D. 475 to 1750, and from Mogollon sites dating from Mogollon Periods 2 through 4, or from about A.D. 300 to 1000. Basketmaker II sites were not included because few structures with tree-ring dates have been described in detail in published reports. Sites considered in the analysis are spread over a large area that extends from the Colorado and Dolores Rivers on the north to just below the Mogollon Rim on the south, and from the Coconino Plateau on the west to the Pecos River and Chupadero Mesa on the east. The locations of some of the more important sites, localities, and areas are shown in Figure 1.

The analysis does not include every structure and site in this temporal and spatial range that has produced tree-ring dates. Instead,

CHAPTER 2

THE TREE-RING DATING OF PAST EVENTS

Events that occurred in the past are not directly observable today, but their products and consequences sometimes are. A dating technique consists of a set of rules and procedures for analyzing evidence of this kind in order to determine the time of occurrence of past events. It is of the nature of dating techniques that they provide a limited range of information about a small number of past events, small at any rate in comparison to the number of events one might like to learn about. To use a dating technique properly requires an understanding of the kinds of information it does and does not provide. Two questions are particularly useful for evaluating any dating technique, including tree-ring dating. First, what temporal information does it convey, and second, what events does it date?

Temporal Information

In examining the kind of information about past time that a dating technique provides, it is helpful to think of dating as a kind of measurement. Dating, like other forms of measurement, consists of assigning an entity, in this case an event, to a position or interval on a scale of measure, specifically a scale of time. All forms of measurement divide the phenomenon being measured into bounded units; in dating these units are intervals of time. Various dating techniques available to the archaeologist make possible the differentiation of intervals ranging in length from hundreds to fractions of years. Although these methods are crude compared to those employed by physicists to discriminate fractions of seconds, they share with these more sophisticated techniques the characteristic of dividing time into intervals. The necessity of measuring time in chunks underlies the previous definition of dating as the assignment of an event to an interval on a scale of time. Dating techniques differ as to (1) the nature of the time scale used, (2) the way in which an event is assigned to an interval on the scale, and (3) the amount of time represented by the increments of the scale and in terms of which an event is dated. The interaction between these three factors determines the level of temporal control provided by a dating technique.

Time Scales

Archaeological dating primarily employs measurement scales of two kinds, ordinal and interval. The term "ordinal scale" is used here to be consistent with mathematical usage, though the common label in archaeology is "relative scale." An ordinal scale consists of a sequence of events or time intervals. Events dated with reference to an ordinal scale "can be recognized as being earlier than, contemporaneous with, or later than other events but the magnitude of the temporal intervals separating events are unknown" (Dean 1978a:225). Unlike the increments of an ordinal scale, those of an interval scale are equally spaced with respect to time. For this reason, the distance — or amount of time — separating two units on the scale can be derived by subtraction. Interval scales frequently used by archaeologists include the Christian calendar and the scale of radiocarbon years (which consists of units that are "equal" with respect to the process of radioactive decay but, as attested by published calibration curves, not with respect to calendar years).

Assignment

The second important aspect of the temporal information conveyed by a technique relates to the way in which an event is assigned to a position on a scale of time. There are three kinds of assignment: similarity, statistical, and absolute. Assignment according to similarity consists of placing an event in the increment on a temporal scale to which that event is most similar. For example, archaeological phase dating employs a scale consisting of increments defined in terms of trait complexes. The derivation of a date involves assigning a site or site component to the phase with which it shares either the largest number of traits or, more commonly, the most "important" traits. Typically, similarity measures rely on the strength of the researcher's opinion, often backed up by a simple numerical or graphical comparison.

In statistical assignment, an estimate is made as to the probability that the event has been dated correctly. That is, a statistical date indicates the probability that a stated interval brackets the actual or true date of an event (Guenther 1973:203-204, Huntsberger and Billingsley 1973:141-142, Thomas 1976:201). For example, a radiocarbon date of "500 $\pm$ 100 B.P." means that the chances are about two out of three (67%) that the interval from 400 to 600 B.P. includes the true date.

Absolute assignment places an event in a definite, circumscribed interval on a temporal scale. In statistical terms, there is a probability of 1.0 that the stated interval includes the true date of the event. Historians typically have access to absolute dates that indicate the year, day, and even hour when an event occurred. Of course, any inference about the past may be incorrect, but in the case of absolute dates the chances of error are small enough to be ignored.

Resolution

Quality of temporal control is also a function of the length of the intervals in terms of which events are dated. That is to say, temporal control is a function of resolution in dating. Webster's Dictionary (1966:1933) defines resolution as, among other things, "the act, process, or capability or rendering distinguishable . . . events occurring at nearly the same time." As applied to dating, resolution is determined, first, by the size or duration of the units comprising the temporal scale. Decreasing the size of the units, that is, dividing a quantity of time into shorter, more numerous increments, increases the resolution of temporal measurement. Thus the statement that an event occurred on March 5 reflects a greater resolution in dating than that it occurred during the week of March 5. Second, resolution is a function of whether an event is assigned to one increment on a scale of time or to more than one increment. Since an event can be assigned to no less than one increment on a scale, the resolution of a date can be no greater than the resolution of the scale to which it applies. The resolution of the date can be less than that of the scale, however. For example, assuming that one is dealing with a scale represented by a calendar of days, months, and years, then the date "March 5" is at the resolution of the scale, whereas "the week of March 5" has a resolution that is less than that of the scale.

Resolution is closely related to the concepts of accuracy and precision. A recent textbook in chemistry discusses these concepts as follows:

> There is some degree of uncertainty in every measurement, which may come from either limitations of accuracy or limitations of precision. . . . Accuracy involves a comparison of the average result found for a measurement with that of a true or accepted value. Precision, on the other hand, involves comparison of a series of measurements, made in the same way, to one another. We can always obtain an exact value for the precision on a given set of measurements, but a true or accepted value must be known in order for the accuracy to be determined. Otherwise the accuracy can only be estimated (Lippincott, Meek, and Verhoek 1974:442).

Figure 2 shows the relationship between accuracy and precision for four hypothetical dating techniques. Techniques 1 and 2 are equally precise, and if the true value were unknown, the use of Technique 2 could result in serious measurement error. Thus, simply because a technique consistently yields the same date, this does not guarantee that the date is correct. When a technique, like Technique 2, gives results that are consistently either greater or less than the true value, it is said to be "biased" (see also Cowgill 1975:263-265 and McCuen 1979). Accuracy and precision are related to resolution in the following ways. First, assessing either the accuracy or precision of a technique requires the comparison of measurements to each other or to a true value. These

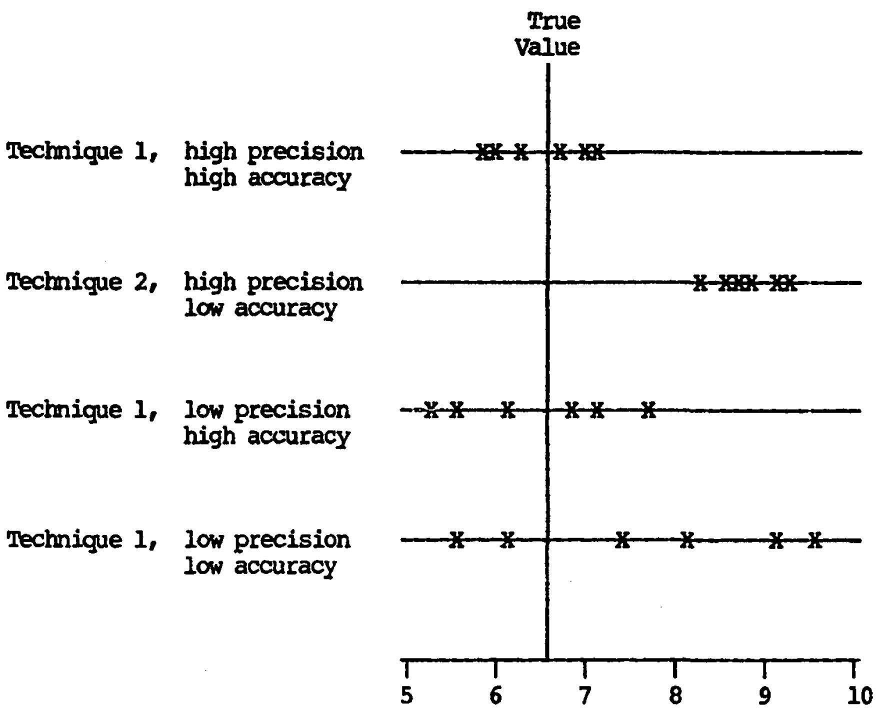

Figure 2. Precision and Accuracy as Displayed by Four Different Measurement Procedures (adapted from Lippincott, Meek, and Verhoek 1974:442, Figure 35-1).

comparisons must be made in terms of units of measure, the size of which depends on the resolution of the scale being used. Second, the resolution of a date depends on its precision. As noted earlier, resolution is the "act" of making distinctions; that is, it requires a decision as to one's confidence that a stated interval includes an event's true date. The more imprecise the date, the longer the interval must be for one to have confidence in it.

Contemporaneity

The concept of resolution focuses attention on the temporal differentiation of events, that is, on the ability to show that events occurred during different intervals of time. The concept of contemporaneity covers the opposite situation, when the goal is to demonstrate that events occurred at the same time. Two kinds of contemporaneity that archaeologists deal with are classificatory and absolute contemporaneity (Dean 1969:198, Wilcox 1972:14). Classificatory contemporaneity applies to events dated to the same interval on a temporal scale. A tree-ring cutting date indicates the year during which a tree died. If two tree-ring samples produce cutting dates of A.D. 1250, then both come from trees that died during that year. Because they died during the same interval, the two events of tree death are classificatorily contemporaneous. This kind of contemporaneity relates to an important aspect of resolution. If one cannot resolve two events, if it is impossible to distinguish them by their time of occurrence, then those events exhibit classificatory contemporaneity (see Renfrew 1973:249-250). It is important to note that two events dated to the same interval did not necessarily occur simultaneously. One may have occurred at the beginning of the interval and the other at the end. For example, the two trees mentioned a moment ago may have died months apart. They did, however, die during the same interval, the growth year 1250. Figure 3a shows some of the possible relationships between two events sharing classificatory contemporaneity. Events A and B may have occurred (I) at different times, (II) during overlapping intervals, or (III) during coincident intervals. Given the temporal scale shown in the figure, it is impossible to determine which relationship actually holds. Nor is it possible to compare the duration of events (IV). All that can be said is that Events A and B both occurred during Interval 5.

Although events that are contemporaneous in the classificatory sense may actually have occurred at different times, this fact may be of little consequence. If the beams in a structure's roof produce cutting dates of A.D. 1250, an archaeologist would be satisfied in most cases to know the the events of tree death represented by those dates occurred at approximately the same time. Often classificatory contemporaneity is not adequate, and one needs to know that two events occurred at exactly the same time. Archaeologists frequently take the number of rooms in a site as an indicator of population size. If only half the rooms were occupied at any one time, and if one knows only that the rooms exhibit classificatory contemporaneity in that they date to the same phase, than a population estimate based on room number would be seriously in error. In this case it would be necessary to know which rooms were contemporaneous in an absolute sense.

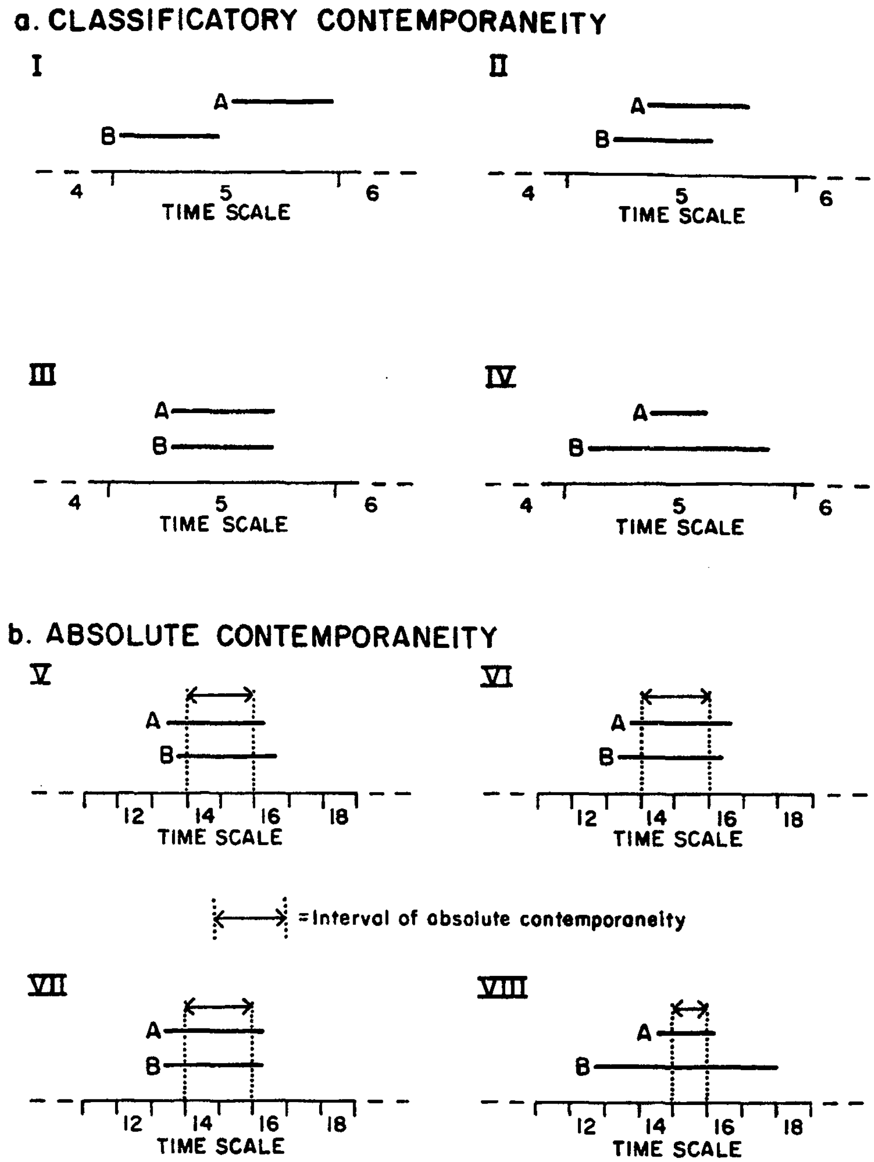

Figure 3. Classificatory and Absolute Contemporaneity, with Respect to the Relationship Between Two Events (A and B).

Absolute contemporaneity refers to events that are simultaneous in the sense that they occur during overlapping intervals of time. For events to overlap in time, they must have duration. The measurement of duration on a scale of time requires that the beginning of an event be dated to one increment on the scale and the end of the event to a later increment. Two dates are required because a single date indicates only that an event took place during some portion of an interval on a temporal scale. The implications of this limitation were discussed above in the context of classificatory contemporaneity. In essence, the measurement of duration requires that an event be divided into two or more component dated events. The term "episode" is applied here to such a group of linked, dated events.

Figure 3b shows some possible relationships between events that are absolutely contemporaneous. The beginning of Episode A is dated to Interval 13 and the end to Interval 16. The same is true of Episode B. The two episodes are absolutely contemporaneous during Intervals 14 and 15. They are also contemporaneous for portions of Intervals 13 and 16. It is impossible to determine during what portion of Intervals 13 and 16 the episodes were contemporaneous, and for this reason situations V through VII cannot be differentiated (Figure 3b). Strictly speaking, one can say only that Episodes A and B were classificatorily contemporaneous during Intervals 13 and 16. This is the case because the beginning of Episode A is an event dated to Interval 13, as is the beginning of Episode B. And, as noted above, a single date shows only that an event occurred sometime during an interval on a temporal scale.

Tree-Ring Dating

How does tree-ring dating, or dendrochronology, fit into this scheme? First, it should be noted that, except in circumstances discussed below, in successfully dating a sample the dendrochronologist determines the year of growth of every ring in the sample. The archaeologist, however, is generally interested only in the date of the outermost ring, that is, the one that grew last. This date provides the best estimate of when the tree that produced the sample died. It was not until after this event that the tree could be converted into a wood artifact for human use. Therefore, throughout this study the expression "tree-ring date" applies specifically to the date of a sample's outer ring (Smiley, Stubbs, and Bannister 1953:8-9). A tree-ring date has two parts, a year in the Christian Calendar and one or more symbols that bear on the date's usefulness in interpretation (Table 1). The symbols can be divided into two groups, based on whether they pertain primarily to the kind of temporal information provided by a technique or to the kind of events that it dates. Symbols of the first group (inc, comp, +, and ++) are discussed here, the others further along.

As noted, a dating technique can be evaluated with respect to the nature of its time scale, to the way in which events are assigned positions on the scale, and to the resolution of the scale and of the dates of particular events. The following is a very compact statement of how tree-ring dating fits into this framework. The points raised are discussed in detail in subsequent paragraphs. Tree-ring dating employs an interval scale, though in the case of dates accompanied by the symbol

Table 1. Explanation of Symbols Used with Tree-Ring Dates. Cutting date symbols are in order of decreasing confidence (Robinson, Harrill, and Warren 1975:6); See Bannister (1962:511) for an alternative order.

	Import		Type of Date		
Symbol	Temporal Information	Events Dated	Cutting	Non-cutting	Explanation
comp	X		NA	NA	The last ring is complete. The tree died or was killed after it had completed growth for that year.[a]
inc	X		NA	NA	The last ring is incomplete. The tree died or was killed during the growing season.[a]
+	X		NA	NA	One to three rings may be missing near the end of the ring series whose presence or absence cannot be determined because the ring series does not extend far enough to provide an adequate check.[b]
++	X		NA	NA	A ring count is necessary due to the fact that beyond a certain point the ring series could not be dated.[b]
B		X	X		Bark present.[b]
G		X	X		Beetle galleries are present on the surface of the specimen.[b]
L		X	X		A characteristic surface patination and smoothness, which develops on the outer surface of beams stripped of bark, is present.[b]

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Table 1, Continued.

Symbol	Import: Temporal Information	Import: Events Dated	Type of Date: Cutting	Type of Date: Non-cutting	Explanation
c		X	X		The outermost ring is continuous around the circumference of a full section.[b]
r		X	X		The outermost ring is continuous around the available circumference of a partial section.[b]
v		X		X	In the absence of direct evidence of a true outside of a partial section, a subjective judgment is made that the date is a cutting date.[b]
vv		X		X	There is no way of estimating how far the last ring is from the true outside.[b]

(a) after Dean (1969:77)

(b) after Robinson, Harrill, and Warren (1975:6) "comp" or "inc," a somewhat complex one. The dates are absolute, or as Haury (1935:102) put it, "to express the cutting date of a log as 1100 A.D. definitely places it; the quantity is unchanging; it is either right or wrong." The exceptions are dates accompanied by "++," which are not in fact absolute, and those with a "+" symbol, which are absolute only if interpreted properly. The tree-ring time scale consists of annual units, except when a "comp" or "inc" is present. The resolution of a tree-ring date is also annual, except when it is accompanied by a "comp," "inc," "+," or "++." In the absence of one or more of these symbols, a tree-ring date is precise and accurate to the year. That is, any two competent dendrochronologists should agree on the date (precision), and it is safe to conclude that the sample's last ring did in fact grow during the year indicated (accuracy).

By convention, the tree-ring scale is interpreted as a sequence of calendar years, though in the Southwest the tree-ring year actually begins in the spring rather than on January 1 (Fritts, Smith, and Stokes 1965). The initiation of radial growth, that is, the production of an annual growth increment or tree-ring, varies with species. For Douglas-fir on Mesa Verde in southwestern Colorado, it begins in late April or early May. Thus, a tree-ring date of 1250 pertains to a "tree-ring year" extending from about May 1 of 1250 to May 1 of 1251. Because of this difference between tree-ring and calendar years, the use of the latter introduces a potential error of four to five months to the interpretation of tree-ring dates. This error is generally insignificant because it is exceeded by error introduced at other points in the interpretation. Nevertheless, it does provide an initial indication of limits to the resolving power of tree-ring dates.

Dating Symbols: "Inc" and "Comp" Dates. Tree-ring cutting dates (discussed below) are in general accompanied by information that makes it possible to resolve time in biannual units. This information indicates whether the outer ring of the sample is incomplete (inc) or complete (comp) (Table 1). If incomplete, the sample comes from a tree cut during the growing season, and if complete, it comes from a tree cut after the end of one growing season and before the beginning of the next. Dates accompanied by this information relate to a time scale that consists of alternating growing and nongrowing seasons, arranged as follows: 1250 (growing season), 1250 (nongrowing season), 1251 (growing season), 1251 (nongrowing season), and so forth. The two seasons are of unequal length. The growing season of Douglas-fir on Mesa Verde lasts from late April or early May to sometime in June, or between one and two months; the nongrowing season takes up the remaining 10 to 11 months of the year (Fritts, Smith, and Stokes 1965). Unlike Douglas-fir, pinyon on Mesa Verde has a growing season three or more months in length that begins in late May or early June and often lasts into September (Jeffrey S. Dean 1985). Because the growing and nongrowing seasons for any one species are of unequal length, the tree-ring scale conceived as a succession of biannual units is not, strictly speaking, an interval scale. Because the seasons are subdivisions of the regular tree-ring year, the scale can be "converted" to an interval scale of annual units by simply ignoring the "comp" and "inc" symbols.

Dating Symbols: "+" Dates. Whereas the symbols "comp" and "inc" apply to intervals less than a year in length, a "+" or "++" indicates that a date pertains to an interval that is more than a year long. A "+" means that a sample's last ring cannot be dated with certainty because it is not possible to determine if one or more rings are missing from near the end of the ring series (Table 1). In particular, the tree may not have grown a ring during the last or next to last year before it was cut, at least not in the portion of the tree represented by the sample examined by the dendrochronologist. Because the missing ring or rings are not accounted for, the tree-ring date may be earlier than the true date. Thus, "+" dates are biased and, therefore, inaccurate estimators of the growth date of a sample's outermost ring. The amount of bias is minimal. Generally a "+" date is correct to within zero to three years, and it is probably never off by more than five. So, rather than providing either annual or biannual resolution, these dates apply to time increments that are between one and six years in length. In many instances, additional data make it possible to argue for an interval only one or two years in length. Finally, "+" dates are as precise as other dates, because two dendrochronologists working with a sample should arrive at the same date.

Dating Symbols: "++" Dates. A "++" indicates that the outer rings of a sample cannot be dated (Table 1). Typically, the rings are uniformly small, making it impossible to recognize patterning in ring widths or to identify particular rings as missing from the series. Because of the possibility of missing rings, a "++" date provides a lower limit for the date of the sample's last ring. That is, the outer ring grew in the year indicated or an unspecified number of years later. Thus, like "+" dates, "++" dates are biased in the early direction. The number of missing rings is related to at least two factors, the length of the interval covered by the ring count and the number of critical rings (those likely to be small or missing in the average specimen) falling in that interval. If the counted interval is short, say no more than ten or twenty years, it may be possible to guess that only a few rings are missing. Otherwise, there is no way of knowing, even approximately, how many rings are absent from the sequence, and so "++" dates apply to intervals that are essentially open on one end. Like those with a "+," dates with a "++" are probably as precise as other dates. They may be extremely inaccurate, however, for tens of missing rings may go unrecognized if the ring count is long.

In the absence of evidence to the contrary, tree-ring dates are precise and accurate to the year. Although this claim has not been verified by means of a formal experiment or test, more than a half century of dendrochronological research suggests that, for any given date, it has an extremely high probability of being true. For this reason, it is assumed herein that all dates released by the Laboratory of Tree-Ring Research are correct. If a sample produced a cutting date (discussed below), and if it has been determined whether the last ring is complete or incomplete, then the date is precise and accurate to the season as well as to the year. Dates accompanied by a "+" tend to be biased, though this bias can be corrected by realizing that the date applies to an interval no more than five years in length. Dates with "++" are also biased, but in their case there are no criteria for determining the extent of the bias and correcting for it. Finally, a "+" or "++" can occur in association with a "comp" or "inc." In these cases, the date indicates the season of the year when the last ring grew but not the year when that event took place.

Information on Dated Events

As just discussed, the first question to be asked about a dating technique is, what sort of temporal information does it provide on past events? The second question is, what events does it date. The dates provided by any technique apply to a limited range and number of past events. Tree-ring dates, for example, apply to the annual incremental growth of trees. As with the events dated by most other techniques, these biological events are themselves of little interest to the archaeologist. They become important as the basis for the indirect dating of human behavioral events related in some way to tree growth. Typically, a date is applied first to a closely related activity, such as the felling of a tree, and then to progressively more remote events, such as the building of a house, the occupation of a site, the settling of a region, and so forth. The problem of identifying the biological event being dated is discussed here. Issues relating to the application of dates to events in human history are covered in a later section.

Tree-Ring Dating

Dating Symbols: Cutting and Noncutting Dates. Dendrochronologists identify two kinds of tree-ring dates, cutting and noncutting. A sample is given a cutting date when there is evidence that the outer ring on the sample is the last ring grown by the tree before it died. For this reason, and because trees could be felled a number of years after they had died, the use of the term "cutting" date is something of a misnomer. It might be better to speak of "death" rather than "cutting" dates, especially if the death is unrelated to human behavior. The use of either term rests on a simple application of indirect dating, in that the date of one event, the growth of a ring, is being applied to another, the death of a tree or perhaps a tree limb. Table 1 gives the symbols that accompany cutting dates. Each symbol stands for a different criterion for identifying cutting dates. The table lists the criteria in order of decreasing confidence, but for the purposes of this study, they are treated as equally valid.

A sample is given a noncutting date when definite evidence for a cutting date is lacking and, as a consequence, there is no way of knowing how many rings, if any, have been eroded from the sample's outer surface. That is, the date applies to the growth of a ring that was probably not the last one grown by the tree. Because of the probability of ring loss, noncutting dates are biased estimates -- always in the early direction -- of cutting or death dates. Noncutting dates are accompanied by a "vv."

Still to be considered is the category of "v" dates. As stated in Table 1, a "v" is assigned when, "In the absence of direct evidence of a true outside of a partial section, a subjective judgment is made that the date is a cutting date." Based on his experience in making these judgments, Jeffrey S. Dean (1985) considers a "v" date to be just another kind of cutting date. The present study considers "v" dates to be noncutting dates, but it takes as a working assumption that the experienced dendrochronologist is often correct in identifying "v" dates as being near or equal to cutting dates (Table 1). In a large collection of these dates, some actually are cutting dates. It should be noted that this assumption applies to aggregate data, and there is no way of knowing for sure whether a particular "v" date is a cutting date.

The meaning of symbols for cutting and noncutting dates is affected by the presence of the symbols discussed earlier, those that relate most directly to the kind of temporal information carried by a tree-ring date. A "++" with one or more symbols of a cutting date indicates that, although the last ring on the sample is the last ring grown by the tree, the ring cannot be confidently dated and the date is not actually a cutting date. In the case of a "+" accompanying a cutting date symbol, there is a cutting date, but with a resolution of several years rather than one year. As noted earlier, a date that combines (1) one or more cutting date symbols, (2) a "+" or "++," and (3) a "comp" or "inc" indicates the season, but not the year when death occurred. Finally, a "++" used with a noncutting date indicates that an unknown number of missing rings from a "++" sequence need to be added to an unknown number of rings lost from the outside of the sample to arrive at a cutting date.

Tree-Ring Dating Events in Human History

The primary objective of the theoretical tree-ring literature has been to devise and perfect a framework of concepts and principles that can guide archaeologists in the interpretation of tree-ring data.

In the present context, a concept is a label that can be applied to observations, or pieces of data, based on a decision as to what those data have to tell us about the past. A principle is a rule, derived from experience, logic, or both, for drawing inferences about the past on the basis of patterning in data.

The Procedure of Indirect Dating

Dean (1978a) has devised a group of concepts to account for the inferential steps used in indirect dating, which is the procedure of applying a date to ever more remote events. The scheme identifies events of four kinds: dated, reference, target, and bridging events. An event directly dated by a technique is a dated event. The dated event of dendrochronology is the growth of a sample's outermost tree-ring. A reference event is the "potentially datable event that is most closely related to the phenomenon to which the date is to be applied" (1978b:228). In most archaeological applications, dendrochronology's reference event is the growth of the final ring in the life of the tree that produced a tree-ring sample. In the case of cutting dates, the dated and reference events are the same, but with noncutting dates ring loss may cause the dated event to precede the reference event by many years. When a date is applied to an occurrence other than the dated event, that occurrence is known as a target event. One example of a common target event is room construction. Bridging events are invoked to account for the time separating dated, reference, and target events. Bridging events that link a tree-ring cutting date to the target event of room construction might include procurement of the dated beam, use of the beam in an earlier structure, and salvaging of the beam for reuse in the structure being dated. Room construction might be considered a target event at one level of analysis and a bridging event at another level. It would be a bridging event if, for example, the target event were the occupation of the site where the room was located. Indirect dating proceeds in just this manner by applying a date to events that are progressively more removed from the actual dated event. Dean's classification has the virtue of linking a series of directly and indirectly dated events and of providing a framework for discussing the intervals of time separating those events.

Table 2 lists a number of bridging and target events that are relevant to the interpretation of tree-ring dates. The events listed are quite diverse, and several classifications exist that help make sense of this diversity. Bannister and Smiley (1955:189) differentiate construction and nonconstruction events. Construction events relate to the erection and repair of buildings, whereas nonconstruction events have to do mostly with the deposition of refuse, collection of firewood, and use of firepits. As Bannister and Smiley note, most tree-ring dates come from roof timbers and other components of buildings, and for this reason, construction events can be dated far more readily than nonconstruction events. A second classification of target and bridging events was proposed by Dean (1978b:147). It distinguishes events in the history of concrete observable units, like pithouses and pueblos, from events relating to analytical abstractions, such as pottery types and archaeological phases. A third classification of events appears in

Table 2. Bridging and Target Events Commonly Identified and Dated by Means of Tree-Ring Data.

Studying the History of:	Event/Episode
a construction beam	procurement seasoning stockpiling initial use reuse
a structure	wall construction roof construction complete construction repair/remodeling abandonment occupation (construction to abandonment) destruction
a piece of firewood	procurement use
a firepit	use
de facto refuse	abandonment manufacture, use, and discard of artifacts incorporated in refuse
site building activity	initial activity accelerated activity normal activity diminished activity final activity
site occupation	initial settlement growth stasis decline abandonment total occupation (from initial settlement to abandonment) reoccupation
other phenomena	construction and use of a structure type manufacture and use of a ceramic type or group an archaeological phase

Table 2. It groups events according to levels of analysis that are familiar to the archaeologist, such as the artifact (or beam), the structure, or the site.

The Steps in Indirect Dating. A final scheme classifies events with reference to steps in the procedure of indirect dating. Figure 4 illustrates this approach, which is basically an application and elaboration of Dean's system of dated, reference, target, and bridging events. As noted previously, each inferential step in the application of tree-ring dates requires justification, and each step has its own pitfalls. A procedural flow chart like that in Figure 4 provides a framework for identifying potential difficulties in interpretation. The following discussion of problems in interpretation is keyed to the numbered steps in the figure.

1. In the case of cutting dates, the dated and reference events are the same. That is, the outermost ring on the sample is also the last ring grown by the tree that produced the dated wood artifact.

2. For noncutting dates, the dated event precedes the reference event by an unknown number of years. The difference results from the removal of rings from the outside of the sample that gave the date. Ring loss can result from shaping of a beam before use or from erosion before, during, or after use.

3. Because most beams were produced from trees harvested while still alive, a beam's procurement date is usually the same as the date of the last ring grown by the tree. Thus, a cutting date can be interpreted as a procurement date. This is not always the case because dead

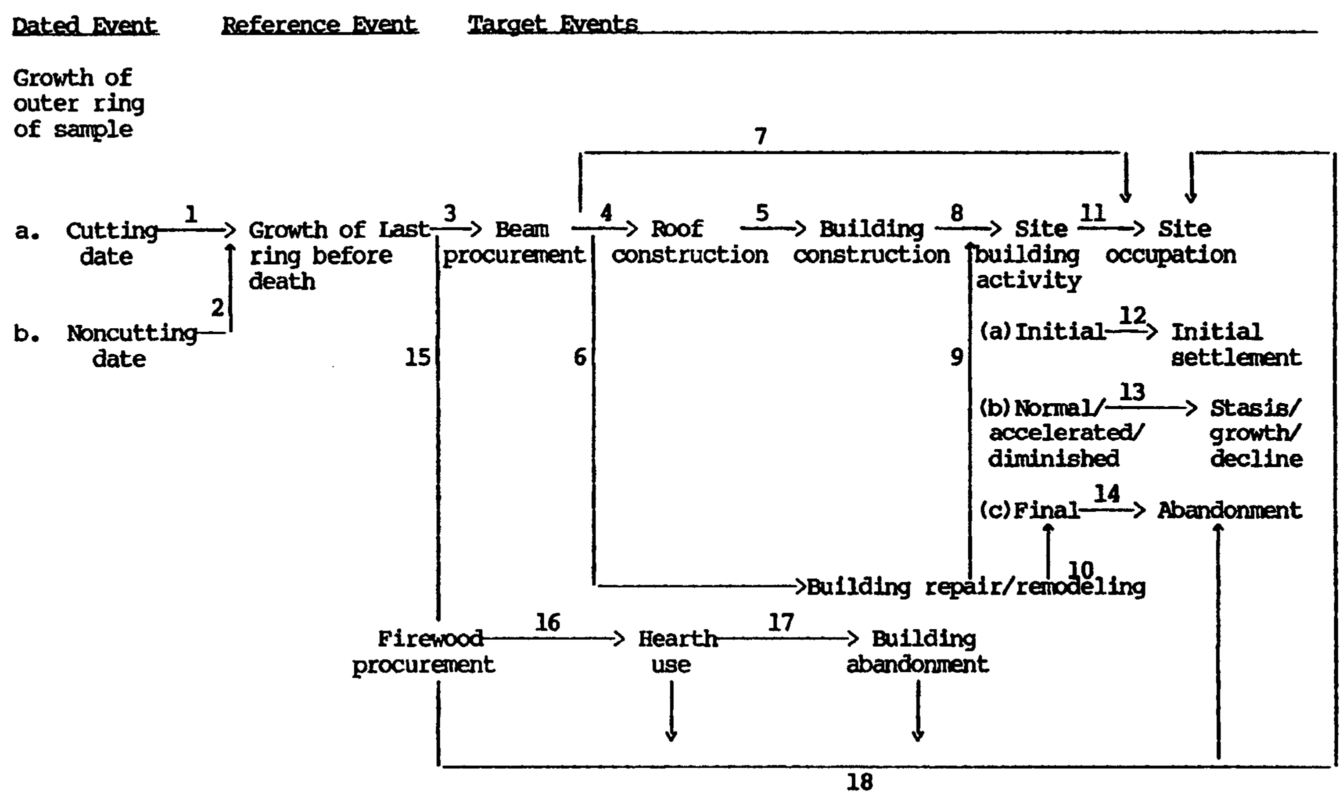


Figure 4. A Chart Summarizing Steps in Indirect Dating as Applied to Tree-Ring Data. Numbered inferential steps are discussed in the text.

wood was sometimes used in construction. Noncutting dates are biased estimators — always in the early direction — of procurement dates, and the amount of bias is increased if the dated beam was produced from a dead tree.

4-5. In studying beam procurement, the individual wood artifact is the primary unit of analysis, but the situation changes in moving to the next level of inference. In dating the construction, repair, or remodeling of a building, interpretation focuses on the structure. This means that interpretation can rely on numbers of tree-ring dates grouped according to structure. Figure 4 distinguishes between the construction of an entire building, including the roof, and construction of the roof alone. This distinction is not relevant to the dating of most pit-houses, in which the roof is actually a superstructure that incorporates much or most of the building's walls. It is potentially important in buildings like masonry pueblos where a roof could be entirely rebuilt without the rest of the structure being significantly affected. In some cases door lintels or intramural logs produce dates, which means that the walls rather than the roof are being used to date the building as a whole.

Three bridging events can intervene between beam procurement and the construction of a roof or building. These are the reuse, seasoning, and stockpiling of timbers. Reuse is the most important of the three, because it was a common occurrence and can lead to considerable error in the dating of construction events. Two factors, the longevity of wooden beams in an arid climate and the discontinuous distribution of wood resources in the Southwest, account for the prevalence of reuse.

Considerable error in interpretation can result if, for instance, a beam were procured, used initially in a structure that stood for a number of years, then reused in the building that produced the dated samples. Also, a beam could go through the cycle of use and reuse a number of times before entering the archaeological record.

After being cut, beams could be seasoned by allowing them to dry out for some months. If so, construction might not have occurred in the same year as procurement, as is commonly assumed. Thus, although the cutting of trees often can be dated to the year or even the season, it may not always be possible to date construction events so exactly. The degree of interpretive error is likely to be minor, probably amounting to no more than a year or two in most cases.

In general, stockpiling is the practice of saving newly procured beams for use at a later date. In the short term, it is essentially indistinguishable from seasoning. Stockpiling of construction wood could be more or less formal. An informal practice would be the opportunistic harvesting of trees — perhaps a few a year — in anticipation of future construction, whether actually planned or not. Also, beams left over from one project might be saved to meet future needs. A more formal sort of stockpiling occurred as well. Cases exist in which social groups are believed to have procured numbers of beams for use, some years down the line, in major construction efforts.

6. The events of reuse, seasoning, and stockpiling could also intervene between the procurement of a beam and its use in the repair or remodeling of a structure. In addition, it is worth noting that

portions of a roof could be repaired while the rest was left intact. Thus, the tree-ring dates from a roof can apply to more than one construction event.

7-8. Archaeologists use tree-ring dates not only to place individual structures in time, but to make inferences about construction activity at a site during particular time intervals. There are two ways of studying site construction history with tree-ring data. First, one can infer a building sequence on the basis of tree-ring dated construction events, in association with architectural and other evidence. Second, beam procurement dates can be used, independently of dated construction events, as an index of building activity at a site. In either case, the main pitfalls to interpretation relate to the representativeness of the available data. For example, it would be impossible to date the initial construction at a site by the building sequence approach if the structures built first were dismantled later in the occupation. Under these circumstances, beam procurement dates might provide a better estimate of when construction began, but only if beams from the dismantled structures were reused in later buildings. Procurement dates might be misleading if beams used in initial construction were salvaged from another site. This could be particularly troublesome if, in moving from one site to another located nearby, the members of a community brought a large number of reusable timbers with them. A representative sample of dated procurement and construction events is also needed to distinguish periods of accelerated or diminished construction from intervals characterized by levels of activity required for the maintenance of worn out or damaged buildings.

9-10. Dated repair and remodeling events can contribute to an understanding of site-wide building activity, particularly with respect to final construction. One would expect the repair of buildings to continue and even increase after the construction of new buildings had slowed or ceased.

11-14. Archaeologists often use information on building activity to study other aspects of a site's occupation history. For example, a date determined for the initial construction at a site should serve as a good estimate of when site occupation began. Also, inferences concerning levels of building activity may provide information on the growth and decline of a community, measured both in terms of its physical extent and its population size. This information can be misleading, however. Accelerated construction may reflect changes in preferred architectural style rather than change in community size. Diminished construction activity may be due to retrenchment in response to economic or other factors, rather than to a decrease in population. Last, the date of final construction may be a poor estimate of when a site was abandoned.

15-18. A number of problems beset the interpretation of tree-ring dates from firewood. Two factors, the common use of dead wood and the intentional burning of firewood, combine to produce a preponderance of noncutting dates. Weathering may have removed many rings from a piece of dead wood before it was collected for use as fuel, and the act of burning the wood is likely to have caused the loss of many more rings. As a result, many years may separate the reference event of terminal ring growth from the events of firewood procurement and use. If beams salvaged from an old structure were used for firewood, then a procurement date might precede the use date by many decades. Conceivably, the archaeologist could employ a combination of construction and firewood dates to determine the uselife of individual structures. As the preceding comments show, there are several reasons why tree-ring dates from firewood may not provide good dates for the last use of the hearth that produced the tree-ring samples. Also, individual structures rarely yield useful dates both from the roof or other structural components and from firepits. Firewood dates have a greater potential when applied to site occupation, for it is to be expected that, from time to time, these dates will fall later than final construction dates. In these situations, firewood can provide a later and, presumably more accurate, estimate of site abandonment date.

Figure 4 does not show the steps in dating all important target events. Not shown, for example, is the deposition of refuse, which can be dated with reference to construction events or by means of dates from samples incorporated in the refuse. As a conceptual scheme, it shows where particular problems, such as unsuspected bridging events, may confuse the analysis, but it does not help in determining which confusing factors are relevant to the interpretation of particular sets of data. The scheme shows how dates are extended from one event to another, but it does not indicate how events are dated in the first place. To accomplish these goals, a different body of concepts and principles is required.

Relating Tree-Ring Dates to Past Events

Four things must be considered in determining the relationship between a tree-ring date and a past event: the tree-ring sample, the date derived from that sample, the physical evidence of a past event observed by the archaeologist, and a past event whose occurrence is inferred by the archaeologist.

Event Identification. Events can be identified in two major ways. Sometimes the fact that an event occurred can be inferred solely on the basis of tree-ring data, particularly tree-ring dates. As we shall see, a tight clustering of dates from a structure may indicate that an event has taken place, specifically the event of roof construction. Second, archaeological remains allow the identification of innumerable events that are unaccompanied by tree-ring data of any kind. For example, the presence of burned roof fall in a collapsed building can provide convincing evidence that a roof was at some time built. A third situation occurs when tree-ring data and associated archaeological remains provide evidence of past events, and the problem is one of determining if these events are the same. Often, as when samples from burned roof fall produce a convincing date cluster, it is obvious that they do. On the other hand, dating the target event of remodeling or repair can present much greater difficulties. As discussed below, a single late tree-ring date following by a few years a presumed construction date is generally interpreted as pertaining to the remodeling or repair of a structure. Sometimes, the structure in question also yields architectural evidence of modification. Although it is reasonable to conclude that the two events are the same, it is important to consider the evidence supporting this inference. The best case occurs when the repair date comes from a beam identified as a repair piece on the basis of architectural data. This rarely happens, and typically there is no direct physical link between the two events. The point is not that such evidence must be available for interpretation to proceed, but that the inference is stronger if it is.

Sample Context. For present purposes, the term "context" is taken to cover three aspects of a tree-ring sample's position in both the past and the present. Context can be thought of (1) as the function, at the time of use, of the beam (or other artifact) from which the sample came, (2) as sample location, or provenience, at the time of collection, and (3) as a series of formation processes that brought the sample to that location. The notion of function was touched on earlier when a distinction was made between construction and nonconstruction events. Because parts of a structure, including portions of its walls and roof, may have been built or remodeled at different times, determining beam function is particularly important to the identification of potentially datable target events. Among the most useful functional categories are the primary roof beam, secondary roof beam, roof support post, door lintel, and intramural log.

Problems relating to the understanding of sample provenience and formation processes are not peculiar to the interpretation of tree-ring samples and are, in fact, best considered in the broader setting of general archaeological method and theory. For this reason, they are only touched on here. Of special note are two situations in which sample provenience and formation processes can confuse the identification of artifact function. First, it sometimes happens that a sample labeled as a support post actually came from a timber found lying horizontally _near to_ a posthole rather than extending vertically from it. In a case like this, the functional inference may be incorrect. Second, in the case of burned structures, it can be difficult to tell whether charcoal samples are the remains of firewood or simply pieces of beams that fell into the hearth when the roof collapsed.

Bannister's Framework. A conceptual framework developed by Bannister (1962) categorizes the errors that can occur when tree-ring dates are applied to past events. The framework (Table 3a) incorporates two variables. First, it specifies the association between two objects, an "archaeological manifestation," such as a pithouse, and a dated tree-ring sample. The association may be "Direct," as when a date from a roof beam is applied to the construction of a building, or "Not Direct," as when a date from a hearth is applied to the same event. Second, the framework considers the relation between the archaeological manifestation and the sample's tree-ring date. Because the framework focuses on interpretive error, it includes only two possibilities: Either the date is "Early" for the manifestation being dated or it is "Late." By combining these variables, the framework identifies four kinds of error in interpretation (Table 3a, c).

A revision appears in Table 3b that makes two changes in Bannister's scheme. First, it deals whith the relation between a tree-ring date and a _target event_ in the history of the manifestation rather than the manifestation itself. This is in keeping with the observation

Table 3. Bannister's (1962) Scheme for Relating Tree-Ring Dates, Dated Samples, and Archaeological Manifestations. A, the original scheme; B, a revised version of the scheme; C, examples of dating possibilities covered by the scheme.

A.

Relation of Tree-Ring Date to Archaeological Manifestation	Association of Dated Sample and Archaeological Manifestation	
	Direct	Not Direct
Date Early	Type 1 Error	Type 2 Error
Date Late	Type 3 Error	Type 4 Error

B.

Relation of Tree-Ring Date to Target Event in History of Archaeological Manifestation	Association of Dated Sample and Archaeological Manifestation	
	Direct	Not Direct
Date Early	Type 1 Error	Type 2 Error
Date Late	Type 3 Error	Type 4 Error
Date Correct	Type 5 Accuracy	Type 6 Accuracy

C. Examples of the six dating possibilities; 1-4 from Bannister (1962).

Type 1 - using dates from reused beams to date construction of a building.

Type 2 - applying the construction date of a room occupied for many years to the room's contents, that is, to de facto refuse.

Type 3 - using dates from repair timbers to date construction of a building.

Type 4 - applying dates from the firepit of a room occupied for many years to the room's construction.

Type 5 - using dates from newly procured beams to date construction of a building.

Type 6 - applying the construction date of a room occupied for just a few years to the room's contents, that is, to de facto refuse.

that we date events and not things. Second, the revision entertains the possibility that the tree-ring date is "Correct." This results in six states — four kinds of error and two situations in which the interpretation, which is to say the date inferred for the target event, is correct.

Interpreting Tree-Ring Dates

To this point, little has been said about how tree-ring dates are actually used to date past events. Most situations requiring the interpretation of dates pertain to one of three levels of analysis - the single beam, the single structure, or an aggregate of structures comprising all or part of a site - and to one of two general categories of events - beam procurement or the construction of buildings. By combining the factors of analytic level and event category, one can identify five common dating situations:

1. beam analysis — beam procurement
2. structure analysis — beam procurement
3. structure analysis — building construction
4. site analysis — beam procurement
5. site analysis — construction

An additional category applies to the interpretation of dates from firewood:

6. firewood and hearth analysis -- firewood procurement and hearth utilization

Each situation gives rise to particular interpretive problems, and a different set of interpretive techniques and principles is appropriate for dealing with each situation. The situations and techniques are discussed below.

Beam Analysis - Beam Procurement

The dating of individual wood collecting events has already been discussed. To reiterate, a noncutting date is earlier than a procurement date by an unknown number of years. A cutting date equals a procurement date, but only if the beam or other wood artifact was cut from a still living tree. Robinson (1967) argues that from the time around A.D. 600 when stone axes became available on the Colorado Plateau, most trees were felled when alive. This conclusion is based on the observation that stone axes are better suited to the cutting of live wood than dead wood (Haury 1935:103). The use of dead trees for building materials may have been common before the introduction of the stone axe (O'Bryan 1949). Even after this event, deadwood was used when available and suited to the task at hand. Positively identifying an individual piece of dead wood is problematic. Several attributes may suggest that a beam was cut from a dead tree, but in most cases one or more other explanations are equally possible. For example, beetle galleries and other signs of insect damage may indicate that a tree had died before it was harvested. Alternatively, these scars may pertain to insect activity that took place after cutting, either before the timber was debarked and otherwise prepared for use (Graham 1965:172-173) or, if the log was not debarked, after it was incorporated in a roof. Similarly, an extremely early date from a structure may result from the use of deadwood, or it may simply indicate the reuse of a very old beam. One reasonably good indicator of deadwood is the presence of root flare at a timber's basal end. Root flare, the expansion of the trunk where it joins the root system, is particularly marked in some juniper and pinyon trees. After a tree has died, root decay can proceed to the point where the trunk, including the flaring portion at its base, can be quite easily blown or pushed over.

Characteristics of a tree's growth pattern may also indicate that harvesting occurred after death. As noted previously, the "++" symbol accompanying a tree-ring date means that the sample's outer rings are highly compressed and cannot, therefore, be dated accurately to the year. Essentially, the rings are so uniformly narrow, each being only a few cells in width, that variations in ring width of the magnitude required for tree-ring dating are not present. Douglass (1935:47-48) noted this growth pattern in beams from Wupatki Pueblo and suggested that it might mean that the trees had died of starvation prior to being cut. He thought that death may have been due to the erosion of soil from around the base of the tree. Stallings (1937:58) commented on a similar growth pattern in samples from Riana Ruin. He mentioned several possible causes of series of compressed rings: "insect pests, burrowing and browsing animals, fire, winter-killing, soil denudation and local erosion, advancing age coupled with considerations of the habitat, or the alteration of physiologic or ecologic conditions by other agencies" (1937:58). Stallings did not suggest that the trees had died before being cut. It would appear, then, that "++" dates apply to trees that were experiencing stress and that may have been dying. Whether death had occurred prior to harvesting is another matter. The best evidence that it had is provided by cases, like Riana Ruin (Chapter 7), in which several timbers have "++" dates, all of which precede known or suspected construction dates by anywhere from a few to many years. It must be noted that, even in these instances, the earliness of the "++" dates may be due to missing rings or, if the dates are noncutting, to the loss of outer rings through erosion. As Stallings (1937:58) noted years ago, this matter of compressed terminal rings requires further study. The use of dead wood can result in substantial interpretive error. In 1960, Hobler and Hobler (1978:38) sampled standing and recently fallen dead trees in the White Canyon area of southeastern Utah. Four of the trees gave dates of 1716++G, 1797vv, 1849++v, and 1850++v. It is worth noting that three of the four are "++" dates.

Structure Analysis - Beam Procurement and Building Construction

Several principles underlie the interpretation of tree-ring dates from particular structures. These principles have never been identified as such, nor have they been presented in a single list. They are as follows:

1. Date clusters provide evidence of construction dates: "Say that six major logs supporting a roof give, in each case, the same bark date of 1300. Little leeway is possible here in interpretation, for the odds overwhelmingly favor that date as the time of construction . . ." (Haury 1935:104). That is, date clusters come from beams that were newly procured for use in construction. Perhaps because this principle is so basic to the interpretation of tree-ring dates, it is rarely

stated explicitly. Nevertheless, adherence to this principle is implicit in most discussions of tree-ring dating as applied to archaeology (Bannister and Smiley 1955:191; Bannister 1962:510; Dean 1978b:149).

2. Construction generally occurred soon after procurement of the beams (Dean 1978b:148). Haury (1935:104) allows a year or two for seasoning between the cutting of a beam and its use in construction.

3. Clusters of noncutting dates can provide evidence of construction and procurement dates:

> The uncertainty of noncutting dates can be offset by the clustering of many such dates. The probability that weathering, burning, or shaping of a number of beams could remove exactly the right number of rings to cause the beams to date within a few years of one another is low. Therefore, a tight grouping of noncutting dates can be confidently applied to the associated material (Dean 1978b:148; see also Smiley, Stubbs, and Bannister 1953:10; Bannister and Smiley 1955:192; Bannister 1962:512).

4. Dates recognized as anomalous with respect to a presumed construction date come from beams that were eroded, reused, stockpiled, or used in the repair of a structure. Dates from repair beams follow the construction date; dates from the other categories of beam precede it. The construction date is usually, though not always, inferred from a date cluster, meaning that some dates from a structure are defined as anomalous in relation to other dates. This is one of the most frequently quoted of the principles (Haury 1935:104-105; Smiley 1951:8; Bannister and Smiley 1955:190-191; Bannister 1962:510; Dean 1978b:149).

5. In the absence of a date cluster, the latest date from a structure may provide the best estimate of when construction occurred (Haury 1935:105). The structure was probably in use as late as or later than the latest date (compare Dean 1978b:148). In general,

interpretations not based on date clusters should be considered suspect, because reliable criteria are not available for recognizing anomalous dates.

Two considerations affect the use of the principles in interpreting tree-ring dates. First, although an interpretation based on one or more principles is likely to be correct, important exceptions do occur. For example, date clusters are sometimes produced by reused beams, and at times beams were stockpiled for more than a year or two before being used in construction. Second, for those principles based on the recognition of date clusters, the more convincing and unambiguous the clustering of dates, the greater the likelihood of a correct interpretation. Decisions as to the presence or absence of clusters, the strength of clusters, and the identification of dates that are anomalous with respect to clusters depend on the analysis of the date distributions. That is, they require the analysis of groups of tree-ring dates that come from particular structures or, more properly, that are deemed applicable to the dating of particular target events.

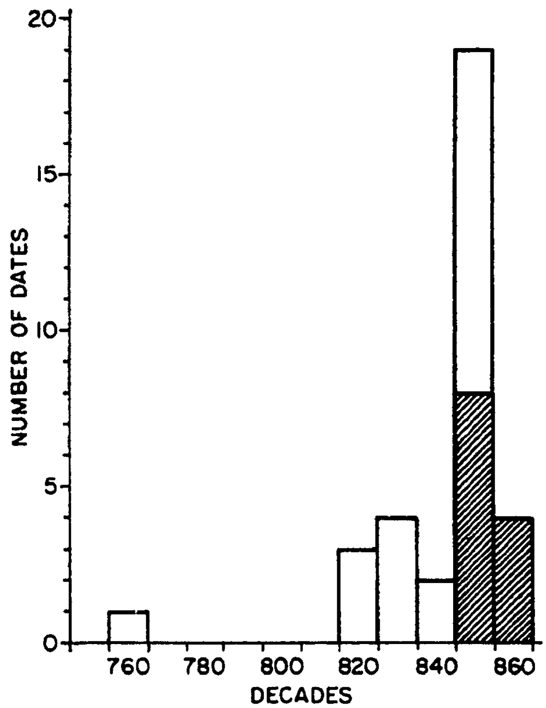
Describing Date Distributions. Several descriptive techniques have been devised to assist in the discovery of patterning in tree-ring date distributions. The roster includes verbal, graphical, and numerical techniques. Verbal description consists, first, of characterizing the dates that form all or part of a distribution as either clustered or scattered. A date cluster consists of three or more dates falling in a brief time interval. The strength of a cluster, that is, its adequacy in providing a convincing date for a target event, is a function of five variables. The first is the number of dates that make up the cluster. The second variable relates to the length of the interval involved. A tight cluster might be said to cover a period of five years or less, a loose cluster one of more than five years. Third, a cluster's strength depends on the relative number of noncutting, "v," and cutting dates. A fourth consideration is the relative strength of two or more clusters in the same date distribution. Fifth, strength is a function of the extent to which a cluster approaches an ideal situation described in detail below. The analyses appearing in Chapters 3 through 8 assign many clusters to one of three classes, labeled weak cluster," "date cluster," and "strong cluster." Although it is hard to be specific and even harder to be consistent, weak clusters tend to include three to nine dates, simple date clusters four to 10 dates, and strong clusters 10 or more dates. The distinction between a weak cluster and a simple cluster rests less on the number of dates than on the other three variables.

To carry this discussion of verbal and other descriptive techniques further requires the use of an actual date distribution. The example comes from Pithouse B at Site 1 (1938) in the Ackmen group of sites in southwestern Colorado (Martin 1939; Robinson and Harrill 1974:13). Figure 5 employs the tree-ring dates from Pithouse B to illustrate several graphical and numerical techniques for revealing patterning in date distributions. Figure 5a shows the simplest format, a listing of dates. The list is interpretive in that the dates appear in temporal order. Also, among dates falling in a given year, noncutting dates come first, then cutting dates. The ordering of dates

(A)

760vv
825vv
827vv
827vv
833vv
838vv
839vv
839++r
841vv
844vv
851vv
852vv
852vv
852++r
854vv
855r inc
855r comp
855r comp
856vv
857vv
857vv
858vv
858v
858r comp
858r comp
858rB comp
858rB comp
859vv
869r
869r comp
869rB comp
869rB comp

(B)



(C)

```
76|0
77|
78|
79|
80|
81|
82|5  7  7
83|3  8  9  9
84|1  4
85|1  2  2  2  4  5i 5c 5c 5c 6  7  7  8  8  8c 8c 8c 8c 9
86|9  9c 9c 9c
```

(D)

	Quartile Ranges			
	1st	2nd	3rd	4th
All Dates	81	14	3	11
Excluding Dates in the 860s	79	15	3	2

Figure 5. Techniques for Presenting Tree-Ring Dates, Applied to Pithouse B at Site 1 (1938) of the Ackmen Group of Sites: (A) date list; (B) bar graph (filled bars - cutting dates, open bars - noncutting dates); (C) stem-and-leaf diagram; (D) quartile ranges (see text for explanation).

follows from the assumption that, due to beam reuse and sample erosion, the latest dates from a structure more often than not come closest to the true date of a target event. The date distribution in Figure 5a includes a scatter of noncutting dates from 760 to about 844 and a strong cluster of cutting and noncutting dates from 855 to 859. There is a second cluster, consisting solely of cutting dates, at 869. Because it falls in a single year, this latter cluster is tighter than the one in the 850s. On the other hand, the cluster in the 850s is much the stronger of the two because it includes many more dates and is relatively tight, though not as tight as the 860s cluster.

Figure 5b is a bar graph that groups the dates from Pithouse B by decade and according to whether they are cutting or noncutting. A bar graph effectively depicts the shape of a date distribution, but unless the horizontal axis is divided into single years, the actual tree-ring dates cannot be derived from it. Thus, Figure 5b does not indicate that the cluster in the 850s is concentrated in the latter half of the decade. Also, it is not possible to determine the temporal relationship between cutting and noncutting dates within decades. Figure 5c presents the dates in what is known as a "stem-and-leaf" diagram (Hartwig and Dearing 1979:16-19). The diagram divides a date into two parts. All digits but the last appear in the column to the left of the vertical line. This column, which forms the "stem" of the diagram, can be read as a sequence of decades. The last digit of a date appears to the right of the vertical line. The last digits of a group of dates falling in a particular decade form one of the leaves of the diagram.

As we shall see, this form of presentation is especially well-suited to the comparison of dates from different structures.

The Laboratory of Tree-Ring Research's Quadrangle Reports, as well as a few other publications (Bannister 1965:200; Anyon, Gilman, and LeBlanc 1981:221) summarize dates by another graphic technique that employs a horizontal line to depict the date range at a site, with highlighted segments of the line corresponding to significant date concentrations. The date concentrations are identified on the basis of subjective criteria that are not described, and thus, the graphs are not strictly replicable. For that reason, this technique of presentation is not used here.

A purely numerical technique for describing a date distribution appears in Figure 5d. It is based on rank order statistics, specifically on the four quartile ranges that are part of a distribution (Hartwig and Dearing 1979:21-23). To find the quartile ranges, one first determines the "lower hinge," median, and "upper hinge" of the distribution. The lower hinge is the point below which lie one-quarter of the dates and above which lie three quarters of the dates, the median is the point below which lie one-half of the dates and above which lie the other half, and the upper hinge is the point below which lie three-quarters and above which lie one-quarter of the dates. These three points divide the distribution into four quartiles. The first quartile range is the numerical distance from the earliest date to the lower hinge, the second quartile range is the distance from the lower hinge to the median, and so forth. The sum of the four quartile ranges equals the date range of the distribution as a whole. Quartile ranges provide a fairly objective means for comparing the shape and spread of date distributions.

An Interpretive Model. A useful approach to the interpretation of date distributions is to view them in relation to an ideal case. This ideal goes as follows: (1) A structure is roofed with newly procured timbers that are cut in the same year, (2) the archaeologist who eventually investigates the structure recovers a tree-ring sample from each timber, and (3) the dendrochronologist who studies the collection derives the same cutting date from each sample. Under these circumstances, one might say that the structure has produced a perfect date cluster, or that it has a tree-ring date distribution that is essentially devoid of shape. There would be little reason to doubt that the roof, if not the entire structure, was built within a year or two of the date indicated by the cluster.

Actual dating situations never achieve this ideal. Rarely, if ever, can the archaeologist state with confidence that every timber that was incorporated in a structure has been recovered and dated. For those samples that do date, the factors of sample erosion, deadwood procurement, the reuse and stockpiling of timbers, and the remodeling and repair of buildings practically guarantee that all dates will not be in the same year and that all dates will not be cutting dates. This is especially so for date distributions that include numerous dates and that are, therefore, less likely than small distributions to be seriously affected by sampling error.

In the light of these sources of confusion, the striking thing is the degree to which actual date distributions approach the ideal. Many distributions have a distinctive shape characterized by a peak at the right end — spoken of here as a terminal date cluster — and by a left tail that falls away more or less gradually toward the early end of the time scale (Figure 6) (Bannister 1962:512). The terminal cluster represents an approximation to the ideal; that is, it results from the use of new and recently procured beams in construction of the roof or other structure that produced the samples. At least two other interpretations of this cluster can also be proposed. First, all of the dates could come from reused beams that were salvaged from older structures. This would require one of two somewhat unlikely occurrences. Either beams from a single old building met perfectly the requirements of a new structure, without the need for any new timbers, or reused beams were pooled from more than one structure and happened to produce a date cluster indicative of a single beam procurement event. Although one or the other of these scenarios probably is responsible for some terminal clusters, it is likely that most are due to procurement just prior to construction.

A second alternative explanation holds that the beams producing the cluster were cut for repairs or remodeling rather than for initial construction. If modifications to a structure are relatively minor, c would not expect the new beams to provide a terminal cluster that could overshadow the dates from beams used in initial construction. If, on the other hand, changes are major enough to result in a date distribution with a terminal cluster and a sloping left tail, then it would be better to say that the structure was rebuilt than that it was remodeled

NA 5166

Pithouse C

70	1									
71										
72	9									
73	0	0								
74										
75	1	5	7							
76	2	8	9							
77	0	0	0	2	3	5	5	5	5	5	5

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[a]Discussed in the text. Dates are from Structure C at NA5166 (Robinson, Harrill, and Warren 1975:13).

Figure 6. A Date Distribution that Approaches the Ideal Situation.[a]

or repaired. Of course, this redefinition of the event being dated does not help in determining whether a particular terminal date cluster pertains to initial construction or reconstruction. Nor does it help in deciding whether dates in the distribution's left tail possibly come from beams reused from a different structure or from an earlier version of the structure that produced the samples. In fact, tree-ring dates, when considered alone, are generally ill suited to making these distinctions.

In a date distribution with a terminal date cluster and sloping left tail, the cluster represents the ideal situation of procurement not long before construction. The left tail, in contrast, reflects the operation of processes that cause the distribution to deviate from the ideal. The early dates making up the left tail are due to ring loss from erosion or shaping of beams, to deadwood procurement, to reuse, or to stockpiling. There are several reasons why these factors should tend to produce a sloping left tail. For example, erosion can be expected to affect some beams in a structure more than others. When the beams in a structure are just beginning to be eroded, the probability of a given beam losing a given number of rings should be inversely proportional to the number of rings involved, at least in general terms. That is, most beams should exhibit little or no erosion, some beams moderate erosion, and only a few beams severe erosion of outside rings. For beams cut at about the same time, this pattern of ring loss will produce a date distribution with a sloping left tail. There is another reason why erosion should have this effect. As more and more rings are lost from a sample, fewer rings remain for the dendrochronologist to analyze. This would tend to decrease the datability of samples that have been badly eroded.

Reuse should also produce a sloping left tail, due to the finite use life of wooden timbers. The longer a beam is in use, the greater is the probability that it will be consumed in a fire that destroys a building, that it will weather or decay to the point of being no longer usable, or that it will break under the stress of prolonged use (compare Schlanger 1980:13). For these reason, reused beams should tend to produce a distribution with fewer and fewer dates as one moves back in time. There are important limitations to this generalization, as discussed below.

In addition to a primary date cluster and a sloping left tail, some date distributions have a truncated right tail. The distribution depicted in Figure 5 provides an example of this situation. The example is typical in that the right tail includes only a few dates, which are within a decade or two of the primary date cluster. As noted earlier, dates like these, which are anomalously late with respect to a construction date cluster, are interpreted as representing the repair or remodeling of a structure. The most likely alternative explanation is that the late dates come from beams cut shortly before construction and that the primary date cluster comes from reused beams. This interpretation has one major shortcoming, for it does not explain how a group of reused beams could produce the date cluster and sloping left tail that characterize all but the latest portion of the date distribution.

The identification of dates in the right tail as coming from repair beams provides a rationale for excluding those dates from certain comparisons of date distributions. The procedure is illustrated in Figure 5d, where quartile ranges are given, first, for all dates and, second, for all dates except those in the right tail. As already discussed, dates in the left tail and primary date cluster come from beams used in initial construction, and they are, therefore, comparable to dates from distributions that lack a right tail. The few late dates refer to a different target event, the repair or remodeling of the structure, and can, for this reason, be eliminated from consideration. It is important to note that this procedure ignores the possibility that dates in the left tail are from beams that were actually used in the repair of the structure but that, due to erosion, reuse, or both, produced early dates.

It is difficult to determine which factor or combination of factors accounts for a particular date in the left tail of a date distribution. Problems in identifying beams obtained from dead trees have been discussed. In general, cutting dates come from reused or stockpiled beams, or in some cases from relatively unweathered pieces of deadwood. It can be argued that many if not most cutting dates that are within five or so years of the end date of a construction cluster are more likely to be from stockpiled than reused timbers. This follows from the idea that most structures stood for a few years before they were dismantled and their beams became available for reuse. Beams that have noncutting dates could have experienced any or all of the processes that produce early dates. If noncutting dates in the left tail of a distribution produce a cluster, then in accord with the third of the principles of interpretation listed earlier, one can infer that the dates are near to cutting dates and, therefore, that erosion alone cannot account for their earliness. Also, it can often be argued that very early noncutting dates probably come from old reused beams, on the assumption that if the requisite number of rings had simply been eroded from the sample, there probably would not be enough rings left for it to be dated. The argument must be used with caution, because it depends on the untestable proposition that the beam in question did not come from an especially long-lived tree. The argument can be bolstered somewhat if, as in Figure 5, the early date is an extreme outlier from the distribution. The gap between this early date and all the others suggests that it may not come from the same population of eroded beams. The outlier may stand out in another way as well. If the sample has an unusually early pith date in comparison to the other samples, then in order for it to come from an eroded beam that had not been reused, the beam must have come from a tree that was not only long-lived, but long-lived with respect to all the other trees that went into the structure. Alternatively, a very old date could reflect the occasional procurement of deadwood.

Deviations from the Ideal. The foregoing discussion of the interpretive model assumes that, in spite of anomalously early and late dates, a primary date cluster exists that can be identified with the ideal situation of procurement shortly before construction. An important implication of the model is that, as a date distribution diverges more and more from the ideal, the identification of a cluster that indicates a construction date becomes increasingly problematic. Such deviation can take one or both of two forms - a change in the shape of the distribution or a decrease in the number of dates that the distribution includes, that is, a decrease in sample size. As an example of a change in shape, rather than exhibiting a gradual rise to a terminal date cluster, a distribution may be more or less flat. One cause of a flat distribution is the heavy erosion of beams in a structure. Assume that all the beams were cut in the same year and that all produced the same cutting date. As erosion increases in severity, this initial uniformity in tree-ring dates has an ever decreasing effect on the shape of the distribution. As more and more beams are eroded, fewer dates fall in the original year, and the distribution spreads to the left. As average ring loss increases, the spreading to the left continues and the terminal cluster becomes less distinct. With increasing ring loss, it becomes less likely that a sizable number of beams will have lost comparable number of rings and, therefore, produce a date cluster. Thus, severe erosion produces a flat date distribution.

A high rate of beam reuse might have several effects on the shape of a distribution. If beams were reused over and over again, then dates from potentially reusable beams might have been distributed fairly evenly through time. Most of these beams would have been too young to have been much affected by the factors, mentioned earlier, that would limit their use lives. For this reason, reuse from such a pool of beams would be as likely to produce a flat distribution as a sloping one. More commonly, the pool of potentially reusable beams probably was not this homogeneous. There was doubtless a tendency for beams that were procured together to be used, salvaged, and reused together. It is quite possible, therefore, for reused beams to produce date clusters. If reuse is extensive, a date distribution might include several clusters, and one or more of those produced by reused beams might be stronger than the cluster from newly procured beams.

The problem with a distribution that either is flat or has several comparable date clusters within it is one of unambiguously determining a construction date in terms of which anomalous dates, whether early or late, can be identified and interpreted. If the distribution is flat, it is difficult to tell if the latest dates come from reused beams, from repair timbers, or if the dates are noncutting, from eroded beams that have lost a number of outer rings. If the distribution has multiple peaks, one must try to decide which of the clusters reflect reuse, which repair, and which initial construction. Often, no convincing decision is possible.

A distribution can also deviate from the ideal because of a reduction in the number of tree-ring dates. That is, dates are available for only some of the beams that were once in a structure. For the purposes of this discussion, one can imagine an "original" distribution that would be available if samples from all beams could, in fact, be dated. As the number of dates decreases, it becomes more and more difficult to determine the shape of this imagined distribution. If the original distribution included a strong terminal date cluster and sloping left tail, the odds are good that one or more of the available dates come from the terminal cluster. In other words, the latest date provides a good approximation of the construction date. If the original distribution were flat or multipeaked, however, the latest date might not come from near the end of the distribution. Anyway, with a flat distribution, the significance of the end date is open to question. The problems is that, with a small sample size, patterning is usually insufficiently clearcut to allow a decision as to the shape of the original distribution from which the sample of available dates is drawn. Sometimes, such patterning is present in the form of a small but tight terminal date cluster. Possibly, this could correspond to one of the early clusters in a multipeaked distribution. Although this is probably not often the case, the point is worth making that, when only a few dates are available, even seemingly useful patterning in the data can lead the archaeologist astray. Clearly, the potential for error is even greater when only a handful of dates are available, and even a modicum of patterning is lacking.

Handling Deviations from the Ideal. There are at least four possible solutions to the problem of interpreting date distributions that diverge significantly from the ideal situation described earlier. The first is to devise better ways of recognizing patterning in the data, particularly the sign of beams cut near the time of construction. Sometimes a date distribution incorporates a sloping left tail and terminal cluster, but the cluster is spread over a number of years and includes many noncutting dates. Under these circumstances, it may be difficult to have much confidence that the latest dates come close to a construction date. The analysis of quartile ranges can increase one's confidence in an interpretation of this kind. The distinctive date distribution discussed previously — with a sloping left tail and terminal date cluster — is characterized by an equally distinctive arrangement of quartile ranges. As in Pithouse B (Figure 5d, excluding the 860s dates), the ranges become progressively shorter from early to late. This pattern may be present in the quartile ranges when a corresponding pattern cannot be identified with confidence either from date lists or from graphical depictions of the dates. This procedure is discussed further in Chapter 4, where it is applied to pithouses on Mesa Verde.

A second solution to the problem of distributions that do not fit the ideal situation involves the comparison of tree-ring dates and other lines of chronological evidence. In particular, a relative sequence based on tree-ring dates can be compared to a sequence based on stratigraphy or bond-abut relationships. If the two agree, it may be possible to argue that construction dates based on tree-rings are probably close to correct. A third, related solution to the problem requires the comparison of tree-ring dates from different structures on a site. Sometimes, a number of buildings will yield dates that are approximately equal, although no one structure produces enough information to be dated with assurance. Barring evidence for noncontemporaneous construction, it is more likely that most of the structures were built at about the same time than that they could have come to produce approximately the same dates in any other way.[6]

A fourth manner of dealing with divergent date distributions requires the analysis of data from particular structure and site types. These types may be based on archaeological culture, morphology, time period, preservation, duration of occupation, environmental setting, and so forth. Thus, if it can be argued that beams were rarely reused in the construction of a certain kind of pithouse, or that datable timbers in the kind of structure under consideration rarely have lost more than a handful of rings, then it might be possible to discount these factors in the interpretation of date distributions. This would mean that even very small collections of dates might provide valuable information. Conversely, if long occupied sites experienced especially high rates of reuse, then unusually stringent procedures might be required to interpret dates from these sites. As discussed in Chapter 1, the posing of these and similar questions is one of the primary goals of the present study.

Strengthening the Interpretation of Anomalous Dates. As noted previously, anomalous tree-ring dates are usually interpreted as resulting from the erosion, reuse, and stockpiling of timbers or from the repair and remodeling of buildings. Information relating to beam attributes and to what might be called "structure attributes" can help confirm these identifications (Dean 1978b:149). Some beam attributes support a particular interpretation. For example, a beam interpreted as reused on the basis of its tree-ring date might be blackened with soot, whereas other beams, including those thought to have been procured at the time of construction, are unstained. The soot on the one beam must have been acquired in another context, and thus, the soot and the tree-ring date agree in indicating that the beam was reused. In other cases, one or more attributes reinforce the distinctiveness of a group of beams, but without suggesting why they should have produced anomalous dates. For example, the beams might stand out with respect to species, size, or evidence of cutting and shaping. Structure attributes relate primarily to the arrangement of dated timbers. Anomalously late dates might occur solely in the upper layer of a roof structure or in one corner of a roof, that is, in locations that either suggest repair or are consistent with it. Conversely, a supposed repair beam might be situated where it could not be reached without dismantling much of the roof, indicating either that a repair did not occur or that it was more extensive than might otherwise have been thought. Finally, there is the possibility of a direct link between the beam producing an anomalous date and architectural evidence for an event, as in the case of a late date from a beam that was clearly added to shore a sagging roof.

Site Analysis — Beam Procurement and Building Construction

Site analysis of tree-ring data differs significantly from structure analysis. Because of the extent to which structural requirements constrain human behavior, a fairly extensive interpretive framework could be proposed for structure analysis. This framework can be applied to structures as reasonably comparable units of analysis. In contrast, patterning in data from sites is much more a function of idiosyncracies in site history, and there is less justification for treating sites as comparable units. For this reason, fewer guidelines can be proposed for the interpretation of site data than structure data.

Approaches to the interpretation of tree-ring data by site can be grouped into two categories. The first consists of the analysis of site data. It holds that a site was probably occupied for only so long after the year of the latest tree-ring data. A variant of this principle looks at the interval between construction events that came late in the history of a site. Let us say that buildings were built or repaired at least every five years. According to this principle, a site's occupation probably continued, at least at previous levels of intensity, for no more than a few of these five year intervals after the latest dated construction events. Like the principles listed earlier, these have rarely been stated explicitly, although they do seem to underlie many interpretations.

Recently, Hantman (1983:111-123) has considered in detail the relationship between a site's latest tree-ring date and its abandonment date. He identifies six reasons why the repair and remodeling of rooms in a pueblo should have been a continuous process. One factor is structural instability resulting from poor initial construction or from the deterioration of beams. The other five reasons relate to social change and include village growth, intra-village change in residence, change in room function, change in social relations between domestic groups, and what Hantman (1983:117) calls "ceremonial ritual cycling" of buildings. These processes should lead to the introduction of new beams into the village at least some of the time. Based on these observations, Hantman (1983:123) derives the following principle: "Given that socioarchitectural change is constant, when beams are no longer recorded within a site over the course of several years, we can assume that the site was abandoned at or about the date of the latest tree-ring date recorded at date distributions. Dates are best presented in bar graphs or stem-and-leaf diagrams like those illustrating dates from Pithouse B in Figures 5b and c. The Laboratory of Tree-Ring Research's Quadrangle Reports, as well as a handful of other publications (Bannister 1965:200; Anyon, Gilman, and LeBlanc 1981:221) summarize dates by another graphic technique that employs a horizontal line to depict the date range at a site, with highlighted segments of the line corresponding to significant date concentrations. The date concentrations are identified on the basis of subjective criteria that are not described, and thus, the graphs are not strictly replicable. For that reason, this technique of presentation is not used here. Because a simple model cannot be applied to the interpretation of site date distributions, analysis consists primarily of identifying date concentrations as marking periods of increased beam cutting, and presumably, construction, and gaps in the record as intervals of diminished beam procurement and construction.

The second approach involves the analysis of aggregate data, including (1) a site's tree-ring date distribution, (2) information on individual tree-ring dated structures, (3) building and stratigraphic sequences, and (4) ceramic dates. Although there are no simple rules for combining these data, two important questions can be asked for any site. First, do all the tree-ring dates, especially the early ones, come from beams procured for use in the site that produced the samples, or were some of the beams reused from other sites? Second, is there any evidence to indicate how long a site was occupied after the latest tree-ring date before it was abandoned? The latter question relates to one of the few principles that seem to be employed in the interpretation of the site." Application of the principle requires "that an adequate sample of tree-ring dates is available for the site under study" (Hantman 1983:123). Two aspects of an "adequate sample" not discussed by Hantman are worth mentioning here. First, tree-ring dates must be available from portions of the site inhabited, though not necessarily built, late in the occupation. Second, use of the principle makes sense only if the site's tree-ring date distribution is continuous, particularly toward the end. Otherwise, there is no basis for arguing that the tree-ring record reflects the sort of recurrent architectural change that underlies the principle. I will return to the question of what constitutes a continuous date distribution in Chapter 10.

Firewood and Hearth Analysis — Firewood Procurement and Hearth Utilization

Many of the techniques and principles discussed above in the context of beam and structure analysis are pertinent to the interpretation of tree-ring dates from the remains of firewood found in hearths, firepits, ovens, and similar features. The occurrence of dates accompanied by the "++" symbol may signal the gathering of deadwood. Also, the third of the principles that underlie the analysis of dates from structures should hold as well when applied to dates from hearths. To paraphrase, clusters of noncutting dates can provide evidence helpful in determining dates of feature use and firewood collection. Identification of these clusters requires the study of date distributions, which can be facilitated through the use of stem-and-leaf diagrams. Because of the likelihood that rings have been lost from firewood samples as a result of weathering before procurement and erosion during burning, the fifth principle should be applied with special caution. This principle holds that, in the absence of a date cluster, the latest date from a hearth may provide the best estimate of when that feature was last used.

Independent Evidence

The most successful interpretations of tree-ring data examine those data in the context of other, independent lines of chronological information. Dates determined for target events on the basis of tree-ring data can be compared to ceramic dates, to stratigraphic sequences, and to building sequences that are based on bond-abut relationships or, in multi-storied structures, based on superposition. For some recent sites, tree-ring data can also be related to documentary dates (Smiley 1951:10). Comparisons of different kinds of dates can take one of two forms. If one line of evidence is strong, then the other can be tested against it. Because the present study is concerned with problems in the interpretation of tree-ring data, it emphasizes the relatively few cases in which tree-ring interpretations can be tested, or at least evaluated, in the light of independent chronological data. Such cases are rare, in part because few archaeologists follow the example of those, like Hayes (1981), who build interpretations one step at a time, indicating explicitly what can be inferred on the basis of architecture, ceramics, tree-ring dates, or any other source of information. Instead, many researchers employ a "stew pot" approach to dating, which throws together different lines of evidence to produce a chronological story without specifying which evidence informs on which episodes.

Frequently, neither tree-ring nor other kinds of dates are adequate to serve as the basis for a test of one line of evidence against another. In these cases, comparison is simply one step in the procedure of combining different kinds of data to arrive at the best possible interpretation. Sometimes, this interpretation can be used, in turn, to evaluate other, as yet uncommitted aspects of the tree-ring data.

Good temporal control over past events has two aspects. The first is an ability to resolve time into intervals that are relevant to a research question. The second is an understanding of just how good — or how poor -- is one's ability to date events. In 1951, Smiley (1951:10) attempted to evaluate the tree-ring dating of sites by characterizing that dating as poor, good, or conclusive. This chapter has presented an interpretive framework that should make it possible to improve on Smiley's categories and on the dating itself.