REPORTS

EVALUATING TREE-RING INTERPRETATIONS AT WALPI PUEBLO, ARIZONA

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The availability both of documentary data on the history of the Hopi pueblo of Walpi and of tree-ring dates from the village provides a rare opportunity to evaluate tree-ring interpretations in the light of independent chronological evidence. Three major events in the history of the community are reflected in the village's overall tree-ring date distribution: the initial settlement around A.D. 1400 of the site of Koechaptevela, located on the flank of First Mesa, the movement of the community around A.D. 1690 to the present location of Walpi on top of First Mesa, and the reconstruction of much of the village between A.D. 1880 and 1940. Analysis of the overall date distribution and of dates from individual rooms shows that many timbers in the village have been reused, sometimes more than once. For this reason, interpretation must rely on date clusters, though even they can be misleading when beams procured at the same time have been reused as a group. The significance of beam reuse to the interpretation of Walpi's tree-ring dates is a function, first, of the relocation of the village over a short distance around 1690 and, second, of the village's survival for almost 600 years. Because of Walpi's size and longevity, patterning in the pueblo's tree-ring evidence is most relevant to the interpretation of large, long-lived prehistoric and protohistoric sites in the Southwest. Historical details provided by tree-ring evidence are also likely to be of special interest to Native Americans, such as the Hopi, who live in these pueblos still.

La existencia de fechas dendrocronológicas así como datos documentales sobre la historia del pueblo Hopi de Walpi proporciona una rara oportunidad para evaluar interpretaciones dendrocronológicas a las luz de evidencias cronológicas independientes. Tres grandes eventos en la historia de la comunidad se encuentran reflejados en la distribución general de fechas dendrocronológicas del pueblo: el asentamiento inicial del sitio de Koechaptevela alrededor de 1400 D.C. en la falda de First Mesa, el traslado de la comunidad a la presente localidad de Walpi en la cumbre de First Mesa hacia 1690 D.C., y la reconstrucción de gran parte de la aldea entre 1880 y 1940 D.C. El análisis de la distribución general de fechas y de fechas correspondientes a cuartos individuales indica que muchas vigas en el pueblo fueron reutilizadas más de una vez. Por esta razón, las interpretaciones deben estar basadas en grupos de fechas, aún cuando inclusive éstos pueden inducir conclusiones erráoneas cuando vigas obtenidas en la misma época han sido reutilizadas como un conjunto. La importancia de la reutilización de vigas para la interpretación de las fechas de Walpi es el resultado, en primer lugar, del traslado del pueblo a corta distancia alrededor de 1690 y, segundo, de la supervivencia de la aldea durante casi 600 años. Debido al tamaño y a la longevidad de Walpi, los patrones en la evidencia dendrocronológica del pueblo son sumamente relevantes para la interpretación de grandes sitios históricos y protohistóricos del suroeste de los Estados Unidos que fueron ocupados durante largos períodos. A su vez, detalles históricos proporcionados por la evidencia dendrocronológica pueden ser de especial interés para los nativos Norteamericanos, como los Hopi, quienes aún viven en tales pueblos.

Prehistoric chronologies in the Anasazi region of the Greater Southwest are among the most exact in the world, thanks largely to the accuracy and precision of tree-ring dating. Many events can be tree-ring dated to intervals of less than a decade, and archaeological periods of a century or less can typically be identified. Other dating techniques cannot match this level of resolution. In fact, techniques like ceramic, radiocarbon, and archaeomagnetic dating rely on dendrochronology for the calibration of their temporal scales. As a result, it is usually impossible to evaluate tree-ring data

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in the light of independent chronological or behavioral evidence. This is not to say that interpretive standards are lacking. In using tree-ring dates, archaeologists can rely on a coherent body of concepts and principles developed over the last half-century on the basis of both experience and logic (Ahlstrom 1985; Bannister 1962; Dean 1978b; Haury 1935). This interpretive framework provides techniques for identifying the kinds of events that commonly affect patterning in tree-ring data—the cutting, use, and reuse of beams, the construction and repair of buildings, and the loss of outer rings from beams and from tree-ring samples. Use of these techniques in a particular instance requires judgments as to the strength of the patterning in the available tree-ring data. Support for these judgments can come from two sources—from controlled comparison of numbers of similar cases (Ahlstrom 1985) *or* from analysis of the rare instances in which tree-ring dates can be compared to other kinds of calendrical evidence. One case of the latter sort involves the Hopi pueblo of Walpi in northeastern Arizona.

In 1977, the Laboratory of Tree-Ring Research, in conjunction with the Walpi Restoration Project, collected 1,189 wood samples from Walpi Pueblo (Adams 1982; Ahlstrom et al. 1978). Tree-ring dates were derived for 462 of the samples (see Ahlstrom et al. [1978] for a complete list of dates). Documentary sources, particularly narratives, maps and drawings, and historical photographs, provide information on Walpi's past that is independent of the tree-ring data. Narrative sources include traditional Hopi accounts of Walpi's history, Spanish records, anthropological and historical studies, and government reports (Laird 1977). Maps of Walpi are available for 1882 (Mindeleff 1891), 1948 (Stubbs 1950), and the mid-1970s (Borchers 1971–1975). Finally, 60 photographs of the pueblo dating between about 1875 and 1940 have been collected from publications and museum archives. These photos, which provide a vivid record of architectural stability and change, can in many cases be dated to the decade or better.

This combination of tree-ring dates and documentary evidence from Walpi can be used in two ways. First, the documents provide an account of Walpi's past that, in a number of ways, can be used to check or guide the interpretation of the tree-ring data. That is, the Walpi case provides an opportunity to test the concepts and principles used in interpreting its tree-ring dates. This methodological approach to interpretation is the focus of the present paper. Second, tree-ring data can enhance the documentary reconstruction of Walpi's past, and in this vein, the paper considers a number of details of the village's history that are revealed by the tree-ring evidence. These historical details are likely to be of greater interest to the nonspecialist than are the methodological implications of the data. Among these nonspecialists, at least potentially, are the Hopi, particularly the people of Walpi. According to Ferguson (1984), the Zuni, who are the Hopi's nearest puebloan Indian neighbors, have found a place for archaeology and prehistory in their conception of the Zuni past. The Hopi have a similar opportunity to make use of archaeological studies like the one reported here.

SETTING AND HISTORICAL BACKGROUND

Walpi occupies the southwestern tip of First Mesa, which rises some 100 m above the adjacent valleys. The pueblo stands at a point where the mesa top is less than 40 m across and, thus, is closely bound by the cliffs that mark the mesa's edge. Northeast of Walpi, the mesa top narrows to a width of about 10 m. This neck and foot trails up the cliff provide the only access to the pueblo. The villages of Sichomovi and Hano lie across the narrows from Walpi, and Polacca sprawls across the foothills below and to the southeast of the three mesa-top villages. Together, the four villages constitute First Mesa Community.

Walpi consists of a linear room block and several smaller clusters of rooms and kivas (Figure 1). The village is much smaller today than it was a century ago: "Once four stories high and comprised of 400 or more rooms, by 1975 Walpi had deteriorated to less than 150 rooms in primarily one and two story sections" (Adams 1982:xiii). Eighty-four proveniences, most of them rooms, yielded tree-ring dates; as is usually the case in puebloan sites, most of the dates are from roof timbers. A typical Hopi structure has walls composed of stones set in mud mortar. The roof consists of layers of construction, with elements of one layer supported by and at right angles to elements of the

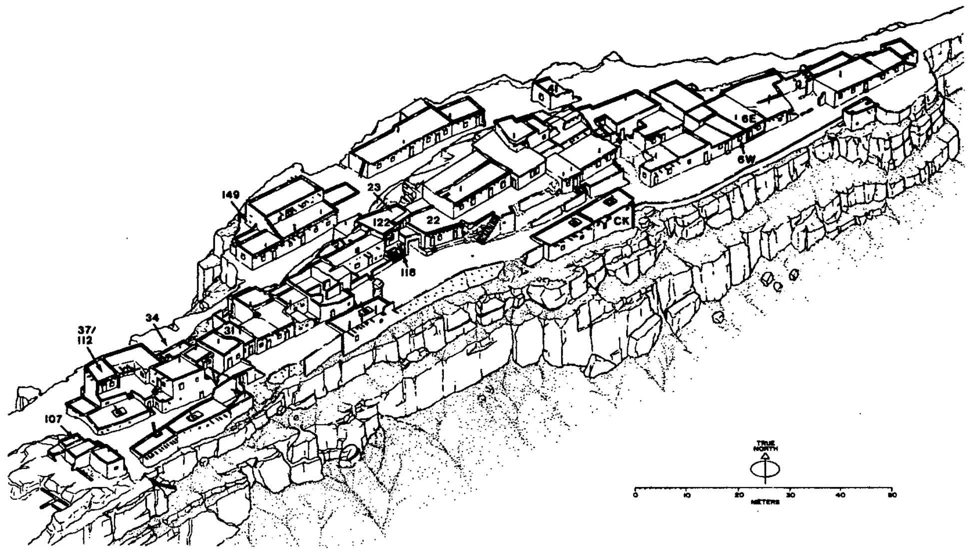

Figure 1. Isometric view of Walpi Pueblo, mid-1970s; CK, Chivato (Goat) Kiva (courtesy of the Museum of Northern Arizona).

underlying layer. Socketed primary beams constitute the bottom layer, and secondary beams rest on the primaries. In some cases, either one or both ends of a secondary beam are socketed in the wall. The roof layers overlying the secondaries include (1) closing material of coarse brush, (2) matting of fine brush or grass, and (3) a mud seal at least .10 to .15 m thick (Adams 1982:51).

To facilitate analysis of the Walpi tree-ring data, the history of occupation on and about First Mesa is here divided into four periods. All period boundaries but one are based on documentary evidence or on occurrences of dated pottery types and hence are independent of the tree-ring evidence. Documentary information on Hopi history has been drawn primarily from Brew (1949), Fewkes (1898), and Hargrave (1931).

The Pre-Walpi period (A.D. 1250–1679) includes an early settlement at the Walpi locus and occupations at the nearby ruins of Koechaptevela and Kisakovi. Excavated ceramics show that the site of Walpi was inhabited during some portion of the interval from 1250 to 1400 (Adams 1979: 5–16). When the occupants abandoned the site, they may have moved to Koechaptevela, located several hundred meters to the west of Walpi on the lowest of several benches that flank First Mesa. Surface pottery collected by Adams (1979:14) indicates that Koechaptevela was settled between 1350 and 1400. This is a revision of Hargrave's (1931) estimate, also based on sherds from surface collection, that the occupation began around 1425.

Although Spaniards first came to the Hopi Mesas in the 1540s, it was not until 1583 that Espejo made the first recorded visit to Walpi. At that time, the community occupied the site of Koechaptevela. In 1629, Franciscans established a mission at the pueblo of Awatovi, located east of Walpi on Antelope Mesa. Soon other missions were founded at Shungopavi on Second Mesa and Oraibi on Third Mesa—both to the west of Walpi. No mission was built on First Mesa. Instead, Walpi was given a *visita*, a church served by the friars assigned to the nearby missions. The *visita* was apparently established between 1629 and 1664 (Brew 1949:17; Montgomery 1949:186). It occupied the site of Kisakovi, situated 100 to 200 m southwest of Walpi on a bench intermediate in level between Walpi and Koechaptevela. This identification, based originally on oral tradition recorded late in the nineteenth century by Fewkes (1894) and Stephen (1936:1003), has been reaffirmed by E. Charles Adams (personal communication 1982). On a visit to Kisakovi in the 1970s, Adams observed what is apparently the *visita*'s foundation and noted pottery types dating to the appropriate interval. At least some of Koechaptevela's residents apparently moved their homes to Kisakovi; according to Fewkes (1898:585–586), the entire community relocated there.

The beginning of the Establishment period (A.D. 1680–1709) is based on documentary sources, which agree that Walpi was moved to its present location atop First Mesa around the time of the Pueblo Revolt of 1680. The revolt drove the Spaniards out of northern Arizona and New Mexico. According to traditional accounts collected by Stephen and summarized by Mindeleff (1891:23), some households moved to the mesa top before the revolt, and the rest after it. On the other hand, some old men in Walpi told Fewkes (1894) in the 1880s that the relocation took place after the revolt. Also around the time of the Pueblo Revolt, the villages of Shungopavi and Mishongnavi were moved from the slopes to the top of Second Mesa. In the fall of 1692, Don Diego de Vargas led a Spanish expedition that reconquered New Mexico and the Hopi Mesas as well. Walpi apparently occupied its present site by that time: according to de Vargas, "I marched about four leagues, finally reaching a very high mesa which is the site of the said first pueblo of Gualpi. As soon as the natives saw me they descended halfway down the slope and approach, which is very rough and steep" (Espinosa 1940:220). Once again, the Hopi submitted to the Spanish Crown, and within a few years the mission at Awatovi was reestablished. Shortly after the reconquest, Tewa-speaking refugees from the Rio Grande Valley founded the village of Hano several hundred meters northeast of Walpi. In 1700, Hopi from First and Second mesas destroyed Awatovi and its mission, effectively terminating the Spanish presence on the Hopi Mesas.

The beginning of the Autonomy period (A.D. 1710–1879) is defined by a dramatic decrease in the number of tree-ring dates per decade. During this period, European-derived societies had little impact on the Hopi. For example, most contacts between Spaniards and Hopi during the eighteenth century resulted from halfhearted attempts by the former to reconquer the latter. By 1775, when the explorer Escalante visited the Hopi Mesas, the village of Sichomovi had been founded in the space between Walpi and Hano. In the nineteenth century, American trappers and Mormons occasionally passed through the Hopi villages. Although the Hopi were for the most part ignored by Spanish, Mexican, and Anglo-American societies during the period from 1710 to 1879, they were not similarly isolated from other Indian groups. During this period, raiding by Utes and Navajos was apparently on the increase (Adams 1982:87; Bartlett 1936; James 1974:71). In the 1770s to 1780s and again in the 1860s, many Hopi went to live for a time at Zuni in New Mexico to escape drought and attendant epidemic (Adams 1982:87; Bartlett 1936:36).

A Readjustment period (A.D. 1880–1975) was ushered in by events of the 1870s and 1880s that brought the Hopi into intimate contact with Anglo-American society. In 1875, Thomas V. Keam opened a trading post in a canyon to the east of Walpi (McNitt 1962:161); in 1883, transcontinental railroad service was established through Winslow, located south of the Hopi villages (Wisbey 1946: 161); and in 1887, school superintendent James Gallaher became "the first representative of the government of the United States to establish his official residence" in Hopi country (James 1974: 106). Two important developments that resulted, at least in part, from these contacts were the founding of Polacca in the 1890s by families from the First Mesa villages and the remodeling between 1880 and 1940 of much of Walpi. These and other events occurring after around 1880 can be viewed as a Hopi response to the ever-increasing influence of Anglo-American society. The population of Walpi declined throughout the Readjustment period as families moved to either Sichomovi or Polacca. According to Adams (1982:xiii), Walpi had 225 to 250 inhabitants in the 1890s, 200 in 1912, 163 in 1932, less than 100 in the 1960s, and about 30 in 1975. The Readjustment period ends in 1975 with the inception of the Walpi Restoration Project, which brought further remodeling and reconstruction to the village.

BEAM ANALYSIS

Beam Size

Traditionally, "tree-ring data" include observations about a beam or other piece of wood in addition to its calendrical date. Among these attributes is beam diameter, or size. An analysis of

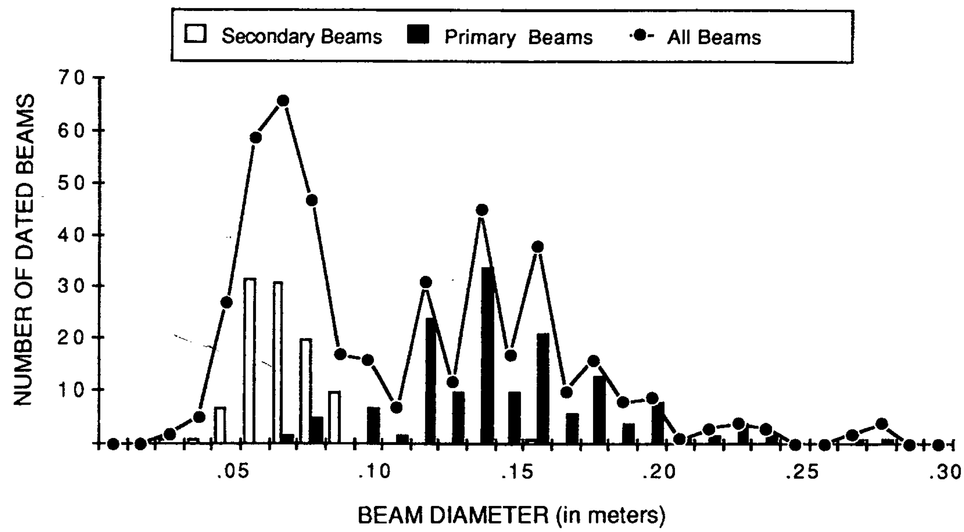

Figure 2. Distribution of diameters of dated beams, by beam function, from Walpi Pueblo; values between .10 and .20 m reflect rounding to an even measure.

beam diameters shows that primary and secondary beams at Walpi can be clearly differentiated on the basis of size (Figure 2). The analysis included 259 dated primary and secondary beams sampled in situ, and it is assumed that these beams are representative of all those in the village. The distribution of beam diameters is distinctly bimodal, with all but one of the secondary beams (n = 102) measuring .09 m or less and all but seven of the primary beams (n = 157) measuring .10 m or more (Ahlstrom et al. 1978:Figure 5). This distribution makes it possible to define two classes of beam, one including large, primary-size beams and the other small, secondary-size beams. It also allows the functional placement of loose timbers from structures that were dismantled by the Restoration Project before tree-ring samples could be collected (Figure 2).

Tree-Ring Date

A basic characteristic of the dating techniques employed in archaeology is that each applies directly to a specific and more or less limited range of events. In the case of dendrochronology, the actual "dated event" is the growth of the outer ring on a sample of wood or charcoal (Ahlstrom 1985:20–81; Dean 1978a). Interpretation consists of applying a date, step-by-step, to events ever further removed from this dated event. The following discussion of Walpi's tree-ring dates focuses on several steps in interpretation—dating of the beam itself, of the roof (and room) in which the beam is incorporated, and of the site.

Probably the most important beam attribute considered in this study is the tree-ring date. Archaeologists are most interested in the date of a sample's outermost ring, which comes closest to the year of the tree's death. A cutting date indicates the year of death; a noncutting date, which comes from a sample that has lost an unknown number of outer rings, precedes death by an unknown number of years. To interpret a tree-ring date, one must infer a relation between the event of tree death and one or more past human acts. It can be assumed that most of the beams in Walpi are from trees that were cut while alive, so the date of the outer ring can be applied most directly to the act of cutting a tree stem or branch. The numbers of tree-ring dates per decade in Figure 3 can, therefore, be taken as a measure of change through time in the procurement of roof beams. Rather less directly, these data reflect changes in the rate of roof and room construction. Both of these

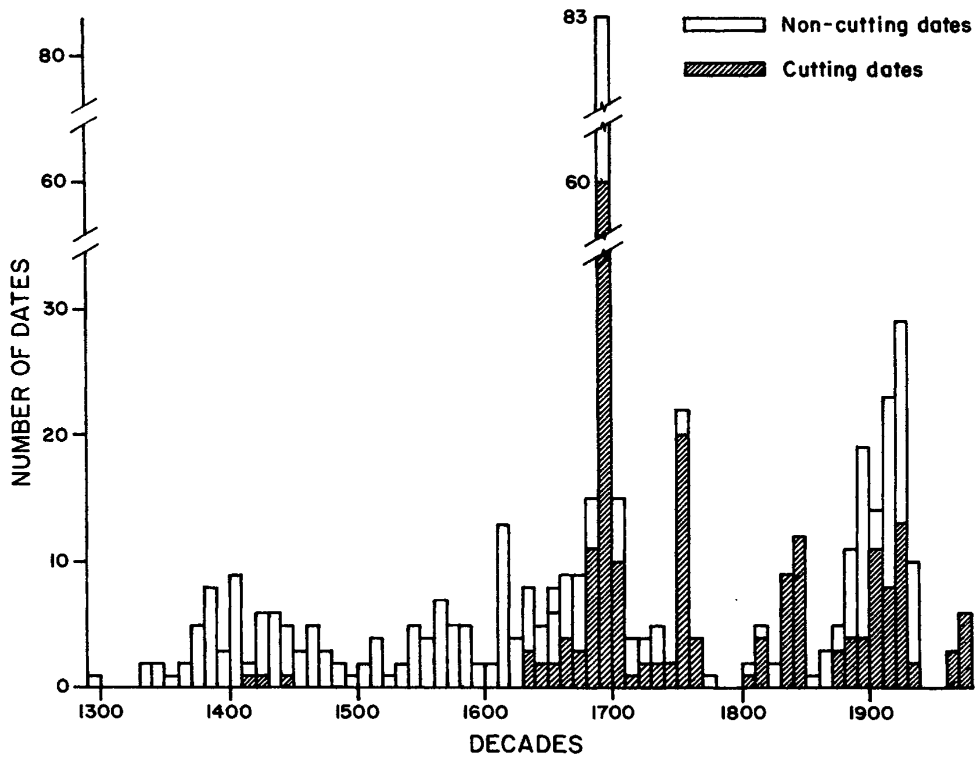

Figure 3. Distribution of tree-ring dates, by decade, from Walpi Pueblo.

assertions assume that the sample of dated beams is representative of the entire population of beams used through time in roofing the village.

Most tree-ring dates of the Pre-Walpi period (A.D. 1250–1679) are probably from beams that were cut for use in Koechaptevela (Figure 3). As noted, ceramic evidence puts initial occupation of this site between A.D. 1350 and 1400. A loose cluster of noncutting dates indicates beam cutting around 1400, possibly back to the 1380s. This patterning in the tree-ring date distribution is in close agreement with the ceramic dating of Koechaptevela. In addition, two cutting dates show that beam procurement was underway by the 1410s to 1420s. Alternatively, some of the dates around 1400 could be from beams that were cut for use in the settlement that occupied the Walpi site sometime between 1200 and 1400. Perhaps the best case can be made for three small secondary beams that produced noncutting dates between 1349 and 1356 and that may have suffered only minor ring loss. If only a few rings are absent, these beams may have been cut during the first, pre-A.D. 1400 occupation of Walpi.

Two aspects of the Pre-Walpi period's date distribution are difficult to explain: the low percentage of cutting dates overall—relative to the percentage of cutting dates in the following periods—and an increase in cutting dates after A.D. 1630 (Figure 3). The prevalence of dates from weathered beams suggests that portions of the village at Koechaptevela stood abandoned for some time before the beams were reused at Walpi. The increase in cutting dates may correlate temporally with the founding of the *visita* (A.D. 1629–1664); if so, a causal relation between the two events remains to be established. In discussing these aspects of the date distribution, it is helpful to return to the interpretation, presented above, linking cutting and noncutting dates from ca. A.D. 1400 to the settling of Koechaptevela. This inference depends on non-tree-ring evidence, specifically ceramic data. In essence, all that is known about Koechaptevela and Kisakovi are their founding and abandonment dates. Thus, there is little information available that could illuminate other aspects of the date distribution from the Pre-Walpi period.

During the Establishment period (A.D. 1680–1709), the people of Koechaptevela moved their village to the site of Walpi. In rebuilding their homes, they utilized both old and newly procured timbers. Most beams dating to the Pre-Walpi period were salvaged from Koechaptevela, or from the *visita* at Kisakovi, and reused at Walpi (Figure 3). The exceptions are beams, not specifically recognizable, that were procured after 1680 for use in Walpi but that, due to weathering or trimming, yielded pre-1680 noncutting dates. Thirty-four percent of the 462 dates from Walpi fall in the Pre-Walpi period. The figures are practically identical when beam size is considered: 35 percent of primary-size beams and 34 percent of secondary-size beams predate 1680. The predominance of noncutting dates from the Pre-Walpi period, especially before 1630 (Figure 3), reflects the weathered condition of the beams and is consistent with the inference that the beams were reused.

Many new beams were also used in rebuilding the village on top of the mesa. The Establishment period, which is only three decades long, accounts for 24 percent of the dated samples from Walpi. The 1690s alone include 18 percent of the dates. Cutting dates far outnumber noncutting dates (Figure 3), probably because many of the beams have remained in the same roofs since they were first used and hence have been protected from weathering. The abundance of Establishment period dates implies a tremendous increase in the rate of beam procurement over that of the Pre-Walpi period. It should be remembered, however, that many beams in Koechaptevela were probably not transferred to Walpi because they were worn out or were not available for reuse. As a result, Figure 3 probably underestimates the rate of beam procurement during the Pre-Walpi period. In any case, it is clear that the community made extensive use of both old and new beams in moving from Koechaptevela to Walpi.

As noted in the discussion of Hopi history, documentary sources indicate, somewhat inconsistently, that the move from Koechaptevela to Walpi began before the Pueblo Revolt of 1680, that it occurred after the Revolt, and that it had at least begun and may have been completed by 1692, the year of de Vargas's reconquest of New Mexico and the Hopi villages. The distribution of tree-ring dates within the Establishment period (Figure 4) suggests that the relocation began after 1680 and may not have been completed until after de Vargas's entrada. The rate of beam procurement shows no appreciable increase until after about 1688, and more than half the beams of this period postdate 1692. Given this date distribution, it is not surprising that date clusters indicative of individual room construction at Walpi do not appear until about 1689. Of the 11 structures that are at least moderately well dated to the Establishment period, one appears to have been built in 1689, a second in 1691, and the rest during or after 1692 (Ahlstrom et al. 1978:56). If the relocation did not begin until around 1690, it may have been precipitated by news that Spanish forces were preparing to return to New Mexico from south of the Rio Grande, where they had been driven during the revolt of 1680. An alternative interpretation is that the rebuilding of the pueblo began soon after 1680, but with the predominant use in the early stages of timbers salvaged from Koechaptevela and Kisakovi. In that case, the increase in the rate of beam procurement after about 1688 would be a biased indicator of when construction commenced on the mesa top.

The beginning of the Autonomy period (A.D. 1710–1879) is defined on the basis of a post-1710 decrease in the number of tree-ring dates per decade (Figure 3). Overall, the period is characterized by a paucity of dates: only 18 percent of Walpi's dates fall in this 170-year interval. In the rare cases of a decade having more than about five dates, those dates come from just one or two structures. For example, all 20 cutting dates in the 1750s are from a single roof that was built during that or the following decade. There are at least two plausible explanations for the small number of dates per decade. First, construction activity throughout most of the eighteenth and nineteenth centuries may have been limited to the repair and replacement of existing structures, in which case the reuse of old beams and the procurement of small numbers of new ones would have sufficed. Such limited construction could have resulted from population stability or decline in response to the droughts, famines, and epidemics documented for this period. If this interpretation is correct, the large village recorded by Mindeleff (1891) and others in the 1880s may have looked then much as it had in

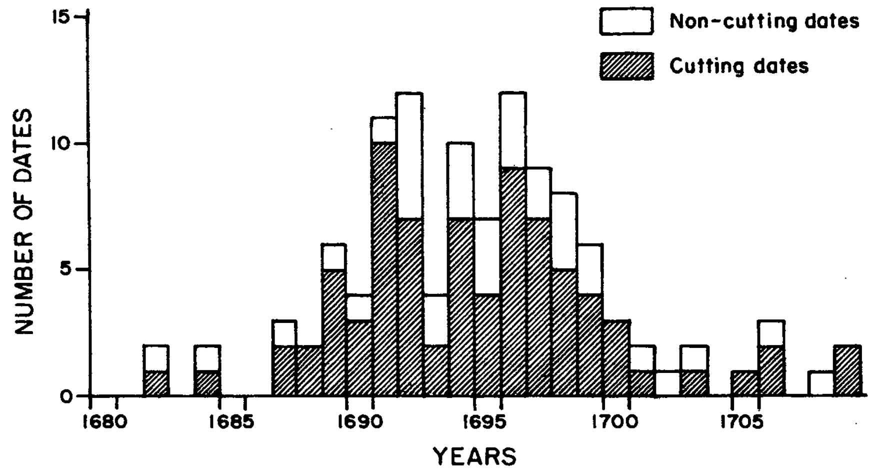

Figure 4. Distribution of tree-ring dates, by year, from the Establishment period (A.D. 1680-1709) at Walpi Pueblo.

1710, just after the relocation. Second, the lack of tree-ring data may be a sampling problem. Many structures that were present in the 1880s were dismantled or extensively remodeled after that time. For reasons discussed below, many beams from old structures were not used in the new construction. The rebuilding may have preferentially removed structures built during the Autonomy period, which because they were abutted to the exteriors of the pre-1710 room blocks, would have been the first to be modified.

The Readjustment period (A.D. 1880–1975) accounts for 24 percent of Walpi's dates. The relative abundance of dates per decade (Figure 3), especially between 1880 and 1939, indicates that many new beams were procured and that many new structures were built at this time. The analysis of documentary data and of tree-ring dates from individual structures, discussed below, confirms that many new buildings were erected. The documentary evidence indicates, however, that this construction activity was accompanied by a decrease in the size and population of the village. Much of this decline occurred between 1880 and 1940, the period of most intensive new beam procurement. According to Adams (1982:xiii), Walpi's population was 225 to 250 in the 1890s, 200 in 1912, 163 in 1932, and less than 100 in the 1960s.

Beam Preparation

Analysis of three beam attributes—shape, tool marks, and date—reveals three traditions of beam preparation at Walpi: Hopi, Spanish, and Anglo-American. In the Hopi tradition, which accounts for the majority of timbers, tree branches or stems were modified just enough to make them usable. This entailed removal of limbs and most bark and reduction of a beam to the desired length. Beams prepared in this way span the entire range of Walpi's dates, from 1294 to 1962.

Beams prepared in the Spanish tradition are distinguished by more or less elaborate shaping and, sometimes, by shapes that imply functions unknown to the Hopi tradition. The timbers, listed in Table 1, resemble those described and illustrated in Montgomery's (1949) monograph on the mission at Awatovi. Most of the timbers are squared, and two have tenons on one end. The most elaborate item is a corbel, shaped on the underside with stepped and rounded surfaces. One beam was definitely and others were possibly sawed, and several were cut with metal axes or adzes. An inventory for the caravan of 1631 that brought supplies from Old to New Mexico lists the following tools "for every friar for building his church": 10 axes, three adzes, one medium-sized saw, one chisel, two augers, and one plane (Montgomery 1949:149). The timbers listed in Table 1 were doubtless fash-

Table 1. Timbers Prepared in the Spanish Tradition.

Sample Number	Species[a]	Tree-Ring[b] Date	Description
WRP-66	PP	undated	squared; metal ax/adze cut
WRP-575	DF	1337vv	squared; tenon at one end
WRP-60	DF	1388vv	squared
WRP-574	DF	1389vv	squared; tenon at one end; sawed, metal ax/adze cut
WRP-10	DF	1432vv	squared
WRP-600	DF	1433vv	squared
WRP-765	PP	1537vv	flattened on opposing sides; pierced by two holes .12–.13 m in diameter and .70 m apart
WRP-714	PP	1548+vv	squared; sawed (?)
WRP-9	PP	1579vv	squared; 3 sides sawed (?), 1 side metal ax/adze cut
WRP-53	PP	1581vv	squared; metal ax/adze cut (?)
WRP-515	PP	1618vv	corbel; sawed
WRP-716	PP	1617+vv	squared; sawed (?)
WRP-715	PP	1619+vv	squared; sawed (?)
WRP-713	PP	1634vv	squared; sawed (?)

[a] PP = ponderosa pine; DF = Douglas fir.
[b] See Table 2 for explanation of dating symbols.

ioned during the mission period (A.D. 1629–1700) either by Spaniards or, more probably, by Hopi workers under Spanish supervision. The people of Walpi lacked the tools, the knowledge, and the need to produce timbers of this kind prior to the arrival of the missionaries. As for the period following the destruction of the missions, it is unlikely that the Hopi had reason to produce corbels or squared- and-tenoned beams.

Tree-ring dates from the timbers can add little to this argument. All of the dates listed in Table 1 are noncutting dates, so an unknown number of rings has been removed from the outside of each beam. Given the degree of shaping of the beams, the ring loss may have been substantial. Assuming that all of the timbers were produced after 1629, it is worth noting that nine of the 13 beams predate 1600, and five even predate 1500. The most one can say about the dates is that they fall before 1700 and are, therefore, consistent with a procurement date between 1629 and 1700. Clearly, shaped timbers can yield biased dates that are too early by many decades.

Beams of the Anglo-American tradition consist of milled timbers and boards that were manufactured elsewhere and that needed only to be cut to the proper length. The Hopi probably did not obtain milled lumber until after about 1880, that is, after the arrival of the railroad and trading posts. Timbers in this tradition cannot generally be tree-ring dated, because they have short, complacent ring series, come from outside the portion of the Southwest where tree-ring chronologies have been developed, or both.

DATING INDIVIDUAL STRUCTURES

The preceding discussion of beam attributes used the individual dated wood artifact, usually a roof beam, as the primary unit of analysis. The study of individual timbers yielded information on three activities, the procurement of beams, their preparation, and their use in construction in the village as a whole. Activities of equal interest to archaeologists are the construction, remodeling, and repair of specific buildings. Study of these activities requires that the structure, or more precisely the roof of a structure, be the focus of analysis. Groups of dated beams and, to some extent, undated beams and other roof elements provide information relevant to determining a room-construction date (Dean 1978b).

Dates from roof beams are easiest to interpret if they cluster, that is, fall into a brief interval. In the following discussion, a cluster is labeled "terminal" if it includes the latest date from a structure,

Figure 5. Photograph of Room 22, Walpi Pueblo, taken by Emil W. Haury, October, 1938; note presence of overhanging roof cornice (courtesy of the Arizona State Museum).

that is, if it comes at the end of the date distribution. A cluster is "nonterminal" if it does not include the latest date. Date-cluster analysis assumes that the larger and tighter the cluster, the more likely it is that the beams contributing to it were procured shortly before construction, and the less likely it is that those beams were badly weathered, reused from earlier structures, stockpiled prior to construction, or added as repair timbers after construction (Haury 1935). If the dates from a structure fail to cluster, interpretation is more difficult. It might be assumed that the latest date provides the best estimate of a construction date. This estimate may be off by many years, however, if the latest date is from a beam that was weathered, shaped, reused, stockpiled, or used in the repair of the building. Unfortunately, in the date-cluster approach to interpretation, these events in the history of a beam are best identified with reference to the relation between the beam's tree-ring date and a construction date *indicated by a date cluster*; in other words, these events are difficult to identify in the absence of a construction date cluster (Ahlstrom 1985:57–59).

Documentary evidence provides two baselines that are useful for dating individual rooms at Walpi. First, although the sources are somewhat equivocal on this point, it is likely that any structure present today was built after 1680. As discussed previously, analysis of the site's overall date distribution supports this interpretation. The second baseline concerns a style of roof that includes an overhanging coping or cornice located on the "front" of the structure, that is, on the side with the main door and the most windows (Figure 5). Mindeleff (1891:151–152) noted that in the 1880s this style, though common at Zuni, was rare at Walpi. Dated photographs confirm Mindeleff's observation and show that the overhang was uncommon as late as 1890. The numerous buildings that have this feature today are assumed, therefore, to have been built or reroofed after 1880.

Ten rooms in Walpi produced relatively strong *terminal* clusters of four or more dates falling in intervals of five years or less. The construction or remodeling of seven of these rooms can also be dated on the basis of documentary evidence. In six of the seven cases, the two dates are in agreement. In the cases of Rooms 23 and 122 (Table 2), for example, the dating applies to the reroofing of a structure that was probably built before 1882. Tree-ring dates indicate that work was done on Room 23 during or soon after 1927 and on Room 122 during or soon after 1926. In the case of the seventh structure, Room 41, there is a slight disagreement between a documentary date and a terminal date cluster. Seven cutting dates in 1903 from primary-size roof beams indicate that this structure was probably roofed in 1903–1904 (Ahlstrom et al. 1978:83). Dated photographs show, however, that construction did not take place until sometime between 1906 and 1920 (Adams 1982:127–130). In

Table 2. Tree-Ring and Documentary Dates from Selected Rooms in Walpi.

Room Number	Documentary Date	Beam Function	Tree-Ring Date
6E	1928–1934; before Room 6W	primary	1855vv
		primary	1868vv
		primary	1884vv
		primary	1889vv
		primary	1915vv
6W	1928–1975; after Room 6E	primary	1910vv
		primary	1926vv
22	1928–1938	primary	1893LGB
		primary	1895*LGB*
		primary	1899+LGB
		primary	1929*LB*
		primary	1929*LB*
		primary	1935LB
23	1901–1938	primary	1923vv
		primary	1924v
		primary	1926v
		primary	1927vv
		primary	1927B
		primary	1927B
		overhang secondary	1927B
31	1882–1938	secondary	1830+*L*
		secondary	1830+*L*
		secondary	1831*L*
		secondary	1832*L*
		secondary	1832*L*
		secondary	1832*L*
		secondary	1832*L*
		secondary	1832B
		secondary	1832B
		primary	1923vv
		primary	1924*L*
34	1882–1975	primary	1420vv
		secondary	1468vv
		secondary	1575vv
		primary	1614vv
		primary	1693v
		secondary	1708vv
107	1922–1938	primary	1560vv
		primary	1885*G*
		door lintel	1886*LG*
122	1901–1938, possibly 1925–1938	primary	1921vv
		primary	1923vv
		primary	1925v
		primary	1926vv
		primary	1926vv

Note: All dates A.D. Dating symbols (for further details see Dean [1969:19] and Ahlstrom et al. [1978:66]): L, *L*, G, *G*, B, *B* = cutting date; v = probable cutting date; vv = noncutting date; + = one or more rings may be missing near the end of the ring sequence; as a result, the date may be early by up to two or, rarely, three years.

all probability, the beams cut in 1903 were stockpiled for a few years before being used in Room 41's roof. Although dates from prehistoric sites are occasionally identified as coming from stockpiled beams (Ahlstrom 1985:627–629; Dean 1969; Graves 1982), it is likely that this aspect of wood use often goes unrecognized.

Two other rooms yielded *nonterminal* clusters that disagree with the documentary dating and that apparently come from reused timbers. Room 149 has a small nonterminal cluster consisting of one cutting date at 1660 and three others at 1663. There are two reasons for not inferring a construction date from this cluster. First, such an interpretation would contradict our assumption that no standing room was built before 1680. More important, 19 dates from the same structure cluster between 1694 and 1703, showing that construction occurred some 40 years later than the cluster in the 1660s would indicate. A second structure, Room 31, has nine cutting dates from secondary beams that form a particularly strong nonterminal cluster in the 1830s (Table 2). Two lines of evidence indicate that these dates are from reused beams. Maps, photographs, and the presence of an overhanging roof cornice show that Room 31 was reroofed and otherwise remodeled between 1882 and 1938. Also, the dated secondary beams are supported by primary beams that were cut in the 1920s (Table 2). In the case of both Room 149 and Room 31, beams that were cut at the same time, presumably for use in the same structure, were later reused as a group. In the absence of later dates or of documentary evidence like that available for Walpi, the date clusters from these reused beams would probably be interpreted as providing reliable construction dates for the rooms in question.

Other rooms have minimal clusters incorporating two or three dates or else lack date clusters altogether. A two-date cluster from a roof beam and a door lintel in Room 107 (Table 2) suggests that both the roof and the doorway were built or remodeled in the 1880s. Photographs indicate, however, that the door in question did not exist prior to 1922, so the lintel, at least, is reused. Room 22 (Figure 5) has three dates—two cutting dates at 1929 and one cutting date at 1935—from primary beams that are consistent with the construction date of 1928–1938 indicated by documentary evidence (Table 2). According to Room 22's owner, the structure was built in 1936; if so, the two dates in 1929 are from reused or stockpiled timbers. Three other dates from primaries form a loose cluster in the 1890s that precedes roof construction by 30 or more years; these beams may have been reused as a set.

Data from Room 34 illustrate how, in the absence of any date clustering, the latest date from a structure can be too early by many years for the event of interest. The latest tree-ring date from this room is more than 170 years earlier than the construction date as inferred from comparison of maps of Walpi in the 1880s and the 1970s (Table 2). Unclustered, noncutting dates from Rooms 6E and 6W are also misleading, although the magnitude of potential error is far less than with Room 34. Documentary sources indicate that these two rooms, which are contiguous, were reroofed after 1928 and that Room 6E was reroofed before Room 6W. As compared to this documentary dating, the latest tree-ring date from 6E is too early by more than 13 years, and the latest date from 6W by at least two years (Table 2). Interestingly, comparison of the latest dates from the two structures gives the correct remodeling sequence—Room 6E before 6W. This occurrence is apparently fortuitous, given that both events took place after 1928, whereas the latest dates from both structures precede that year. These examples demonstrate that interpretations based on weak clusters including just a couple of dates, often noncutting, or on the latest date from a structure can be in error by anywhere from a few to many years.

REUSE OF TIMBERS

Clearly, the reuse of timbers can confuse the analysis of tree-ring dates. Given the scarcity of trees in the immediate vicinity of Walpi, it has probably always been easier to salvage beams from old structures than to cut new ones. Furthermore, in the 600 to 700 years that Walpi has existed as a community, there has been ample time for structures to be abandoned or remodeled and for roof materials to become available for reuse. Even old ladder poles, which can be identified by the presence of notches or holes for the attachment of rungs, were frequently reused as secondary beams (Ahlstrom et al. 1978:36–39). As previously discussed, as many as one-third of the beams that were in the village as of 1977 probably were used originally in Koechaptevela and Kisakovi.

Documentary evidence from Walpi makes it possible to identify a special class of reused beams—those that have been reused twice. One can guess that many beams recovered from southwestern sites were used in three or more contexts; the amount of such multiple reuse should be a function, primarily, of how long a site was occupied. The multiple reuse of beams is generally difficult to recognize. In the case of Walpi, however, it can be shown that a timber was reused twice if it predates

1680 and is incorporated in a structure built after the Establishment period (A.D. 1680–1709). This assumes that all salvageable timbers from Koechaptevela were reused by the end of that period. According to this argument, four beams from Room 34 were probably reused twice; they range in date from 1420 to 1614 (Table 2) and come from a structure that, because it is missing from Mindeleff's map of 1882, presumably was built after his visit. Room 34's other two dates fall in the Establishment period and are probably from beams that were reused at least once. All six of these reused beams from Room 34 yielded noncutting dates, which indicates some degree of weathering. Room 118 also provides evidence of multiple reuse (Ahlstrom et al. 1978:105–106). Dates from the roof's two primary beams place construction in the 1730s; it is likely that two secondary beams, one with a probable cutting date in the 1540s and the other with a cutting date in the 1630s, were used first in Koechaptevela, then in Establishment period structures in Walpi, and finally in Room 118's roof.

The most unusual case of multiple reuse involves four of the mission beams discussed earlier (Table 1). When sampled, these timbers (WRP-713 through 716) were standing upright to form a screen or wing wall adjacent to the exterior of the side door to the Chivato (Goat) Kiva. Without doubt, these are the same beams described by Mindeleff (1891:119) nearly a century ago: "In the roof of the 'Goat' kiva, at Walpi, are four well hewn pine timbers, measuring exactly 6 by 10 inches, which are said to have been taken from the mission house [Kisakovi] built near Walpi by the Spanish priests some three centuries ago." The sampled beams fit this description closely: they are neatly squared, are made of ponderosa pine, and measure .15 by .24 m (5.9 by 9.4 inches). They also predate 1700, as mission beams should (Table 1). Dated photographs show that the roof of the Chivato Kiva was probably rebuilt between 1912 and 1920, and it is likely that the timbers were removed at that time. Another photo indicates that neither the side door nor the screen had been added as of 1928. Thus, it would appear that the four timbers were produced for use in the *visita* at Kisakovi between 1629 and 1680, reused in the Chivato Kiva after 1680, removed from that structure between 1912 and 1920, set aside for future use, and reused for a second time in a screen set against the outside wall of the same kiva after 1928.

The Chivato Kiva provides an example of timbers being salvaged and reused in a group rather than individually. Because the beams lost substantial numbers of rings when they were shaped, their tree-ring dates do not cluster. In two other cases mentioned earlier (Rooms 31 and 149), groups of reused beams produced date clusters. On the one hand, these structures show how date clusters might provide misleading information. On the other, the reuse of groups of beams hints at an important factor in the allocation of wood resources. Buildings, even abandoned ones, have owners. The same is true of stockpiled beams, such as the squared timbers removed from the Chivato Kiva by 1920 but not reused until after 1928. Thus, when the inhabitants of Koechaptevela moved to Walpi, there was probably no single pool of beams that could be salvaged from the old village. From the point of view of the individual builder, only the timbers in a few specific rooms or stockpiles were available for use. This constraint might help explain why so many new timbers had to be obtained when the village was moved. Individual builders would have had little leeway in balancing the need to accumulate construction materials for use on the mesa top against the need to keep a roof over their heads until their new houses were completed.

In one episode in Walpi's history, old beams, though available, were apparently not suitable for reuse. Fifteen roofs in the village have overhanging cornices and yielded 90 tree-ring dates from primary beams. These dates, combined with documentary evidence, indicate that all of the roofs in question were built after 1880, during the Readjustment period. Only six percent of the dated primary beams in these roofs have dates earlier than 1880, and just one percent predate 1680. Primary-size beams were presumably available for reuse from old structures that were being replaced at the time. Nevertheless, the roofs were built almost entirely with new timbers. The potentially reusable old beams were probably rejected for two reasons. The cornice that characterizes the new style of roof is supported by the primary beams, which must extend a half meter or so beyond the front wall of the building. This would have required longer primaries than were used in the past. A possible increase in the size of habitation rooms during the Readjustment period would also have contributed to the need for longer beams. A second reason for the failure to reuse old beams relates to the availability of new ones. The "cost" of a new primary beam was substantially less in the late 1800s and early 1900s than it had been previously. Among the reasons for this change were the end to hostilities between the Hopi and their Ute and Navajo neighbors, the founding of trading posts, the opening of U.S. Government offices near the Hopi villages, the acquisition of wagons, and access to steel tools (Adams 1982:117, 138, 146). Both the role of the government and the importance of transport are evident in an episode recorded by A. E. Douglass in 1928. During a visit to Walpi to look for old timbers, he observed that "the Government had recently brought in a large number of fresh spruce logs from Black Mesa, 40 miles away" (Douglass 1929:758).

The primary beams in a number of post-1880 roofs have the appearance of a matched set, in that they are the same size and species and have been debarked or otherwise prepared for use in the same way. This degree of selection is not apparent in older roofs and provides further evidence for a new procurement system that encouraged the use of new primary beams.

Evidence from two roofs suggests that these changes in beam procurement did not affect secondary beams, at least not to the same extent as primaries. Room 31 has nine pre-1880 secondary beams, though dates from two primary beams indicate that the structure's roof was built in the 1920s (Table 2). Similarly, Room 37/112 has six pre-1880 dates from probable secondaries—that is, secondary-size beams that were sampled for tree-ring analysis after the roof was dismantled. The roof had an overhanging cornice, indicating that it was built after 1880 (Ahlstrom et al. 1978:82). The secondary beams from these and other old structures could be reused, because the distance between primary beams did not change in the new-style roofs. Milled boards do, however, begin to take the place of traditional secondary beams in roofs constructed after about 1900.

DISCUSSION

The Walpi case provides a rare opportunity to evaluate tree-ring data in the light of independent calendrical dating. The hope is to apply lessons learned at Walpi to the interpretation of tree-ring evidence from other sites, particularly prehistoric ones. The major difficulty with this approach is assuring the comparability of Walpi and the other sites. Walpi is larger than the majority of prehistoric settlements on the Colorado Plateau, and only a handful of communities, such as Oraibi and Acoma, have been in existence as long. Little is known in a systematic way about the effect on patterning in tree-ring data of variables such as site size and longevity.

The combination of tree-ring and documentary evidence from Walpi is most informative about two general kinds of analysis. The first concerns the interpretation of a village's, or an archaeological site's, overall date distribution. Eighmy (1979) has used data of this kind to reconstruct population growth in a dozen prehistoric communities in the Southwest. His analysis assumes, first, that log cutting, represented by cutting dates, reflects roof construction and concomitant increases in the amount of roofed space in a village and, second, that roof construction is a measure of population growth. The first assumption, linking log cutting and roof construction, finds support at Walpi, where periods of construction during the 1690s and from 1880 to 1940 are apparent both in the site date distribution and in the roof construction dates inferred on the basis of the tree-ring evidence. On the other hand, the shortage of both tree-ring dates and inferred room-construction events during the Autonomy period (A.D. 1710–1879) may result from a lack of evidence rather than a lack of construction activity. More important, Walpi violates Eighmy's second assumption linking roof construction and population growth. Roof construction in the 1690s marks the relocation of the village, and that in the late nineteenth and early twentieth centuries reflects a major rebuilding program. In neither case is there reason to think that population growth was involved. As Schlanger (1980) has observed, many events in the history of a site, both during and after occupation, can affect the relation between beam cutting and population growth. For this reason, it is difficult to apply a general interpretive "model," whether relating to population growth or to some other phenomenon, to site date distributions. This is noteworthy, given that such a model has been developed for interpreting date distributions from individual structures (Ahlstrom 1985:64–75; Bannister 1962; Dean 1978b; Haury 1935).

There is one sense in which Walpi's date distribution appears to stand out from the sample of distributions from prehistoric sites. This is in the amount of wood in the village that was brought from another, though admittedly nearby, site. Approximately one-third of the dated beams from Walpi were probably salvaged from Koechaptevela and reused in Walpi. An analysis of tree-ring data from 10 prehistoric pueblos (Chetro Ketl, Aztec, Salmon, Moon House, Mug House, Betatakin, Kiet Siel, Canyon Creek, Pindi, and Gran Quivira) found evidence of reuse from "elsewhere" in only four or five cases (Ahlstrom 1985:644–650); in two of these, beams apparently came from older room blocks on the same site. Unlike Walpi, the sites in question produced only a small number of dates from beams that were originally used in another location. This would suggest that these sites were not, like Walpi, simply the product of an established community relocating over a short distance.

The Walpi data also bear on a second kind of analysis, that is, the interpretation of dates grouped by structure. A pertinent example is Di Peso's (1974:8–24) analysis of 53 noncutting tree-ring dates from Casas Grandes in Chihuahua, Mexico. Casas Grandes resembles Walpi in that it was a large community inhabited for more than 100 years. Di Peso uses the tree-ring evidence to date the construction of rooms and room clusters and, in conjunction with radiocarbon dates, the boundaries between three archaeological phases. Most of the rooms involved produced only a few dates, and there are almost no clusters. In addition, most of the beams were shaped or have been severely weathered, resulting in the loss of outside rings from the samples. Evidence from Walpi suggests that this sort of data is likely to provide inaccurate dates for events at Casas Grandes as well as at many other southwestern sites. Several construction events at Walpi can be dated both with tree rings and by some other means. These examples show how a date distribution that lacks clustering or that ends with a grouping of two or three dates can provide misleading information concerning a date of construction. This potential source of error has two major causes, the reuse of beams and the loss of outer rings, either from the beams as such or from samples of those beams that have survived to undergo tree-ring analysis. Squared mission beams from Walpi constitute a special case in which an entire category of timbers has suffered substantial ring loss. The similarity of these artifacts to the shaped beams from Casas Grandes should be apparent. Other evidence from Walpi does not have close parallels at Casas Grandes, but may be relevant to other sites. That is, several date clusters were obtained from beams that had been reused as a set. Such a cluster could indicate an incorrect construction date, if it includes the latest dates from a building.

Beam reuse and ring loss have had a major impact on the tree-ring dates from Walpi. Both influences are a function of the relocation of Walpi some 300 years ago and, in a more general sense, of the longevity of Walpi as a continuously occupied, wood-using community. Walpi's relatively large size may have played a role as well, to the extent that it increased the pool of beams available for use and reuse. As noted, however, ownership of wood resources may have reduced the effective size of the beam pool, from the perspective of the individual builder. In any case, the problems of beam reuse and weathering could, in principle, affect the data from any site. No doubt they are important at a large site like Casas Grandes. The question is whether they are likely to be as major a concern at more typical sites, that is, those possessing a few dozen rooms and occupied for no more than 50 years. It is important in this regard to distinguish between the possibility of interpretive error and the magnitude of likely error. With respect to the amount of error, one need mention only the pre-1680 beams that are incorporated in post-1880 structures at Walpi. Beam reuse and weathering might be as common at another site as at Walpi, even if the dates from reused and weathered beams are nowhere near as old.

During the occupation of a pueblo, beams become available for reuse as rooms are abandoned. Because rooms built of stone masonry, like those in Walpi, can last for decades if properly cared for, decay is probably a secondary factor in the abandonment of buildings. In other words, a room is more likely to deteriorate because of disuse and neglect than it is to be abandoned because it is no longer usable. The most common reason for abandoning a structure is probably a change in the requirements for roofed space of a household, lineage, or other social unit. A community should experience such changes more or less continuously, which is to say, almost from the moment it occupies a site (Hantman 1983:111–118). It is not certain, however, that these changes will have an immediate effect on the rate of beam reuse within a settlement. Many prehistoric settlements appear to have grown rapidly for several decades after being established. In these cases, the procurement of new beams to support this growth might swamp any increase in the reuse of timbers. Reuse might be more apparent, on the other hand, in settlements that reached a period of relative stability in size, whether they did so immediately or only after a number of years.

CONCLUSION

Few inhabited pueblos in the American Southwest have been the subject of in-depth tree-ring investigation. This is unfortunate, given that the histories of these communities can be reconstructed, to a greater or lesser extent, on the basis of documentary evidence. Tree-ring studies of a sample of these pueblos could be used to increase our understanding of the strengths and weaknesses of tree-ring data from relatively large, often long-lived communities. Until such time, if ever, when this larger data set becomes available, we must make do with the rare exceptions, such as Walpi. Several factors have shaped the body of tree-ring data from Walpi. These include the size and longevity of the community as well as two particular events in its history—the wholesale relocation to the mesa top in the 1680s to 1690s and the rebuilding program of the 1880s to 1930s. Because of these influences, any interpretation of tree-ring data from Walpi must take into account two likely sources of error—the reuse of beams and the loss of rings from beams with noncutting dates. It would be a mistake, in analyzing tree-ring data from a prehistoric site, to assume that beam reuse and ring loss present as big an obstacle to interpretation as they do in the case of Walpi. Nevertheless, Walpi does provide a benchmark, albeit in some ways an extreme one, against which to consider the influences on a site's tree-ring record.

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