The Morris Site 1 Early Navajo Land Use Study:

Gobernador Phase Community Development in Northwestern New Mexico

Volume 2

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CHAPTER 14: TREE RINGS AND THERMOLUMINESCENCE: CHRONOLOGY AND DATING ISSUES OF THE EARLY NAVAJO OCCUPATION

by Douglas D. Dykeman, James K. Feathers, and Ronald H. Towner

A major research problem of the Morris Site 1 project data recovery plan is to establish a high-resolution chronology of the early Navajo settlement system. The resulting fine-grained temporal control of the site population is essential for addressing social organization issues like site complex and community. In the data recovery plan, dating resolution is characterized as a chronic problem for non-pueblito sites that form the majority of the early Navajo settlement. These sites, both residential and special use, typically contain little in the way of diagnostic material culture or other datable materials. The tree-ring and thermoluminescence (TL) techniques are chosen to refine the chronology for two reasons. First, the tree-ring technique offers the highest possible dating precision and the wood samples necessary for analysis are sometimes available from Navajo pueblitos and other structural sites. Second, TL dating can be used to date surface ceramics or burned rocks that are common at early Navajo sites and readily available for sampling during archaeological inventory (Dunnell and Feathers 1995). However, the precision and accuracy of TL dating have been regarded with some skepticism (e.g., Reed and Horn 1990), therefore the Morris Site 1 research design cites the need to establish some confidence in TL dates.

Three objectives are developed to refine the Morris Site 1 project chronology. The first objective is to develop tree-ring and thermoluminescence chronologies, based on a large sample of dates, for the early Navajo occupation. The second objective establishes a level of confidence in thermoluminescence dating by correlating TL results with dendrochronology. The last objective evaluates the utility of TL dating as an independent and objective method suitable for cross-referencing with other dating techniques.

To address these issues a complex and extensive dating program was implemented involving inventory, testing, and excavation phases of the Morris Site 1 project. Large suites of tree-ring and thermoluminescence dates were obtained as a result of this program, and are reported separately in chapters 12 and 13 of this volume. The purpose of this chapter is to apply the dating results to the stated objectives.

The Problem

Archaeometric dating techniques such as a radiocarbon, dendrochronology, archaeomagnetism, and obsidian hydration are valuable tools for Southwestern archaeologists because these techniques date materials that are relatively common at sites in the region. Unfortunately, these techniques are usually applied to excavated sites and this limits their utility for temporally ordering large populations of inventoried sites. Yet, archaeological issues such as settlement pattern and social organization would benefit greatly from high-resolution spatial and temporal controls. And, while spatial resolution can be addressed with sophisticated survey techniques, the issue of temporal control is not easily resolved. In the Southwest, typically, the techniques of ceramic cross dating and/or seriation are employed to place large populations of sites into a coarse temporal framework. For individual sites this produces a dating resolution of 200 years or so, which represents approximately 10 generations of people. This resolution is less than ideal for studies of social organization that would prefer to evaluate relationships within one or two generations.

Another problem peripherally related to resolution is dating relevance. The dates returned by any archaeometric technique must be relevant to the archaeological problem at hand—usually the date at which a site was occupied. Dean (1978) distinguished the "target event," which is the event of interest to the archaeologist, and the "dated event," which is the event addressed by the particular dating technique. Where these events do not coincide, the construction of bridging arguments is needed to link the two and establish dating relevance.

The radiocarbon technique often produces dates not directly relevant to the past use of the site. Radiocarbon age consistently overestimated target events by 200-300 years in Lomolai phase (Basketmaker II) sites on Black Mesa (Smiley and Ahlstrom 1997). Fetterman (1996) demonstrated similar error ranges in a comparative study of radiocarbon dates obtained from wood charcoal and carbonized annual

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plants recovered from early Navajo sites. He found that the vast majority of wood charcoal samples predate A.D. 1500, which is at least 200 years earlier than the expected ages indicated by tree-ring results. Other studies have shown that radiocarbon dates consistently overestimated the age of Dinetah phase sites by 150 years (Brown and Hancock 1992; Dykeman 2000). Simply adding 150-200 years to all dates is unsatisfactory in the absence of rational bridging arguments (Dean 1978; Smiley and Ahlstrom 1997).

Fetterman (1996) suggests that some of the age overestimation is attributable to old wood use and the cross-section effect (sometimes referred to as "built-in age" [see Hogan 1989]). Such problems are associated with radiocarbon dates derived from wood charcoal. Consequently, a potential solution is to date annual plant remains, like corn. In Fetterman's case study, dates derived from annuals appear to be more accurate, but produced calibrated ranges of more than 400 years (Fetterman 1996). This range spans much of the late prehistoric period, all of the protohistoric period, and much of the historic period. Fetterman's case is not unique, because similar ranges have been reported from other excavated Navajo sites in the area (Ayers and Reed 1993; Dykeman and Wharton 2000; Kotyk and Cater 1998; Wharton et al. 1996). Thus, in the protohistoric period, the poor resolution often returned by radiocarbon-dated annuals is too coarse for most archaeological site interpretation purposes.

Ceramic cross dating is a time-honored site dating method in the Southwest because change in ceramic style and technology has temporal sensitivity (Blinman 2000; Breternitz 1966; Colton 1953). The technique requires a tree-ring-dated sequence of discrete and recognizable ceramic types that can be used to approximate the age of otherwise undated sites. The similarity between the ceramic assemblage of a site and ceramic types keyed to a tree-ring-dated sequence provides the cross-reference for determining site age. Primary causes for error in ceramic cross dating are unsupported dates for ceramic assemblages and a lack of temporal sensitivity due to little or no change in style or technology. Also, dating resolution is usually no finer than about 200 years and varies directly with the production period of individual ceramic types.

Ceramic cross dating of early Navajo assemblages tends to suffer from both these dating problems. First, although ceramic variety is apparent at some sites, only two ceramic types are commonly found at early Navajo sites: Dinetah Gray and Gobernador Polychrome. Dinetah Gray is the most common ceramic type, but its technology remained largely unchanged from about A.D. 1500 to about A.D. 1800 (Brugge 1981; Hill 1995). Consequently, cross dating by the occurrence of Dinetah Gray has resolving power only slightly better than calibrated radiocarbon dates.

The production of Gobernador Polychrome ranges from about A.D. 1640-1800 (Brugge 1981; Langenfeld 1999; Marshall 1995; Reed and Reed 1996; also see chapter 8), and thus has potentially good resolving power for ceramic cross dating. Unfortunately, it is rarely abundant and sometimes absent from Navajo sites known to date in the A.D. 1700s. Therefore, although the presence of Gobernador Polychrome is a good indicator of a seventeenth- or eighteenth-century site, its absence in site contexts is not necessarily indicative of an earlier (or later) occupation. Ceramic cross dating with sufficient precision to distinguish Gobernador phase can be successful only when Gobernador Polychrome is present at early Navajo sites.

Relief from problems of poor resolution and accuracy can be found in tree-ring dating. The ability of the technique to produce relevant dates is dependent upon recovery of well-preserved wood samples. Wood is perishable, but can be found intact, or nearly so, in the roofs of Navajo pueblito structures (Towner 1997). This does not fully resolve the dating problem, because these stone structures represent less than 2 percent of Navajo sites in the Morris Site 1 project. Moreover, if we regard the project site distribution as a sample of a larger region, this value may accurately reflect the density of pueblitos in the whole of Dinétah. Most residential sites contain forked-stick hogans that are burned or dismantled, or in a collapsed and eroded state, which make tree-ring dating ineffective. There is little direct evidence indicating the temporal relationship of pueblitos to the vast majority of residential and nonresidential sites; therefore, there is little basis upon which to apply pueblito dates to the greater settlement pattern. Establishing this relationship is critical for both the land use study and broader issues of early Navajo chronology.

Thermoluminescence dating shows good potential in this regard because it only requires samples of burned cultural materials from surface or subsurface contexts (Dunnell and Feathers 1995). TL is widely used in Europe but has received less attention in the United States, in part because of cost and questions about accuracy and precision (Feathers 2000). Evaluating the level of correspondence between TL results and secure tree-ring dates can serve to test the accuracy of TL dates and provide a measure of confidence in the technique. The character of the Morris Site 1 project area and the nature of the early Navajo occupation are not only suitable for tree-ring and TL techniques, but may provide nearly ideal conditions to perform this test. The use of both dating techniques is facilitated by: the customary use of both wood and pottery by the early Navajo inhabitants; the good preservation of exposed perishable materials combined with the lack of significant postabandonment disturbance of sites; and the relatively recent time frame of the occupation. These factors,

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combination with the large project size and high site density, indicated that we could be reasonably assured of obtaining suitable tree-ring and TL samples in surface and near-surface contexts (Figure 162).

The primary goal of the tree-ring and TL comparison is to evaluate the accuracy and precision of TL dating results in terms of the resolution possible for protohistoric sites. The tree-ring results are used as the standard for accuracy for identifying the target event. Consequently, the accuracy of Morris Site 1 project tree-ring dates is critically evaluated to assure that only valid dates are applied to the comparison. Valid, in this sense, means dating results that represent individual tree harvesting events or date clusters that indicate construction of site features. TL results are not expected to agree completely with the tree-ring dates because the two techniques date different events: the death of a tree in the case of tree-ring dating and the heating of an object in the case of TL. However, early Navajo sites represent relatively short occupations and the probability is high that wood use and firing of objects (either ceramics or stone) are reasonably close in time. We assume for now that wood and burned objects found together at the same site represent relatively contemporary events in an archaeological time scale, but revisit this assumption later on. First we evaluate the tree-ring and TL results and then consider their correspondence.

Tree Ring Dates

Two types of tree-ring samples, architectural and arboreal wood, were collected to date the early Navajo sites in the Morris Site 1 project area. Samples of architectural wood were collected from preserved structural remains and arboreal wood was collected from trees that had been modified by cultural activities (Towner et al. 1998). Samples extracted from architectural wood, which was the traditional method for dendrochronological sampling (Stokes and Smiley 1968), were somewhat scarce, but were obtained from the remains of sweat lodges, collapsed forked-stick hogans, or pueblitos in the project area. Sampling arboreal wood from culturally modified trees has been developed for early Navajo sites in the Dinétah area (Towner et al. 1998). This method entails extraction of samples from axe-cut stumps, limbs, and tree boles, both living and dead, in the vicinity of early Navajo sites (Towner and Johnson 1998; Towner et al. 1998). It is made possible by good preservation of wood due to the recentness of the Navajo occupation and the

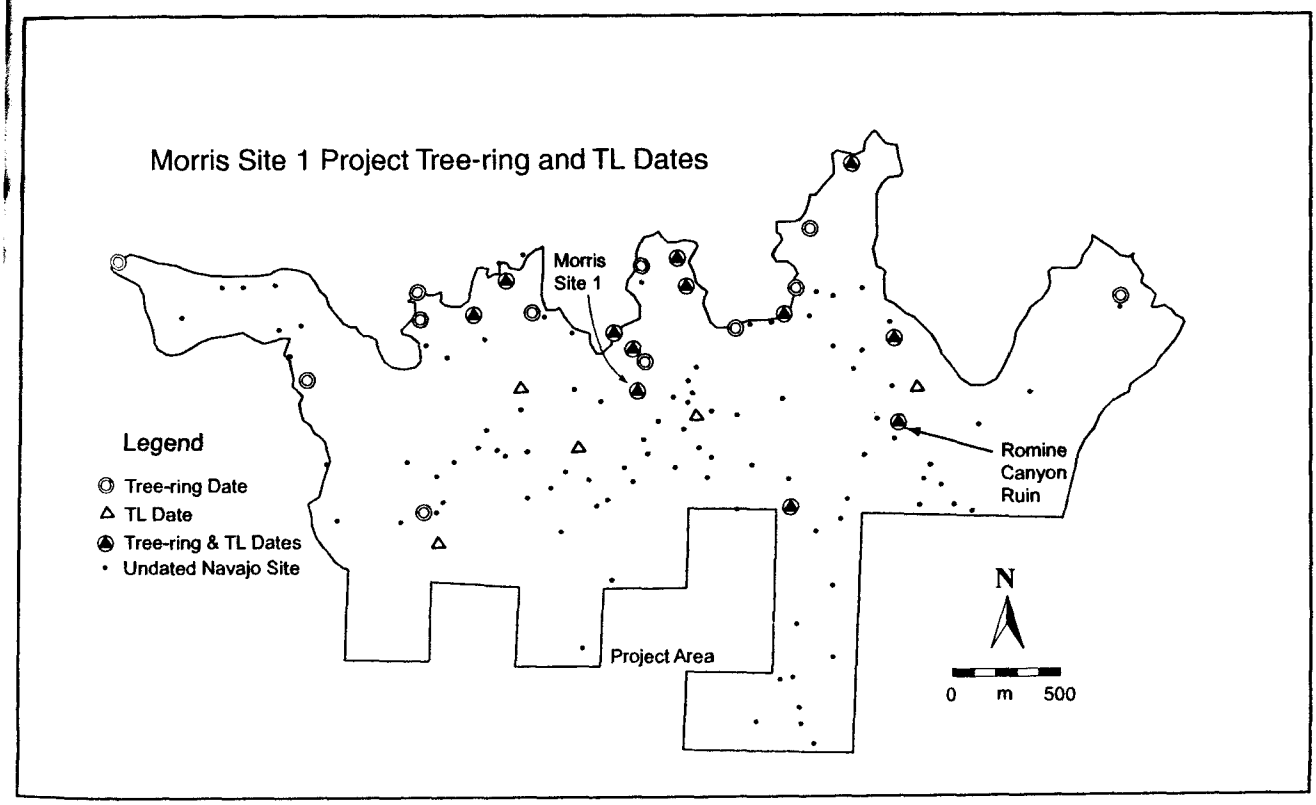


Figure 162. Distribution of sites dated by tree-ring and TL techniques.

distinctiveness of Navajo wood procurement. All samples were obtained from surface contexts on or adjacent to recorded archaeological sites, and were processed by the University of Arizona, Laboratory of Tree-ring Research. The reported tree-ring dates were then interpreted in consideration of site context to determine the best date (or range) for each site.

In the site-based tree-ring analysis, each site must have yielded a large enough sample of dates to assess date clustering, cutting date distributions, etc. This method and the results are fully detailed in chapter 12, but summarized here in Table 91. Twenty-nine occupational components at 25 sites were tree-ring dated. In addition, six episodes of tree harvesting were documented at five stumps recorded as isolated manifestations not spatially associated with sites. Specimens listed as a cutting date are of the highest confidence possible in tree-ring dating. Good confidence may be assumed for interpreted dates from specimens that exhibit a heartwood boundary and some preserved sapwood rings. Low confidence is indicated for specimens that lack sapwood or exhibit other problems at the heartwood-sapwood boundary.

A histogram comparing the distributions of site-based tree-ring analysis dates (from Table 91) with all reported tree-ring dates was prepared to demonstrate the temporal distribution of site occupation and tree harvesting in the Morris Site 1 project area (Figure 163). The tree-ring dates are presented as a histogram with dated sites classed into bins of equal 20-year intervals. Histogram categories are designated by the center date within the interval. The raw site frequencies were converted to relative frequency in percent. Tree-ring dates could be treated in this fashion because each date represents a single value or in some cases a very narrow range of possible values.

The distribution of reported tree-ring dates shows two rather continuous periods of tree harvesting: one period representing the early Navajo occupation from A.D. 1600 to A.D. 1750, and the other representing an historic occupation after A.D. 1800. Higher frequencies of dates in the late A.D. 1600s and early to middle A.D. 1700s suggest that most of the Navajo occupation correlates with the use of the Morris Site 1 and Romine Canyon pueblitos (A.D. 1720s-1750s).

The analyzed tree-ring dates are derived from the reported dates and a similar distribution is evident, but only in a most general sense. Two main cultural periods of tree harvesting representing early Navajo and historic occupations are indicated, but the distribution in the Navajo period is discontinuous and historic period tree harvesting appears narrowed to the late A.D. 1800s and early 1900s. This distribution indicates three separate occupations in the Morris Site 1 project area between A.D. 1600 and 1940. The first occupation is indicated by only 5 percent of tree-ring dates in the A.D. 1620 interval (A.D. 1610-1630). The second occupation appears to be longer, spanning four intervals between A.D. 1670 and A.D. 1750. This is followed by a long occupational hiatus spanning six intervals between A.D. 1750 and A.D. 1870. After A.D. 1870, historic wood harvesting indicates an early Lucero phase occupation.

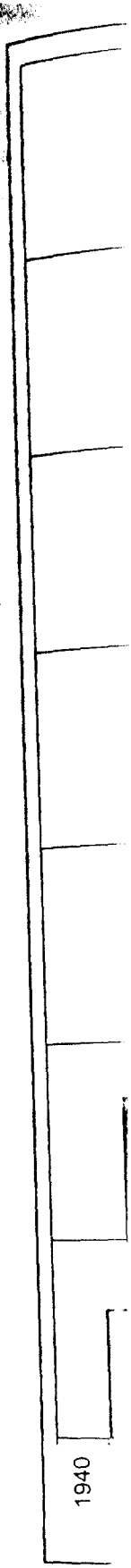
The 120-year range for the early Navajo occupation occurs entirely within the Gobernador phase (A.D. 1625-1775), but the continuity of tree harvesting in the middle A.D. 1600s indicated by raw dates is not apparent in the site-based analysis results. The main reason for this is the lack of cutting dates in this time frame. Most of the reported dates from this period were interpreted to support later cutting dates or could not be included in the site-based analysis due to insufficient supporting data. Some tree harvesting is projected for the mid-A.D. 1600s, based on the evaluation of stem-and-leaf plots, which are more refined indicators of continuity and discontinuity than histograms (see chapter 12 for the detailed evaluation of stem-and-leaf plots).

The historic period is represented by six dated site components and one dated isolated manifestation in the late nineteenth century and early twentieth century. This corresponds well with an increase of homesteading during the Lucero phase (A.D. 1870-1960) documented by Dittert et al. (1961). Most of the historic tree harvesting is probably associated with homesteads established by the Lobato, Jacquez, and Romine families in the first quarter of the twentieth century (Wooderson 1998). Interestingly, two dates in the early twentieth century may be related to Earl Morris' work in the Gobernador area (see Table 91).

Thermoluminescence Dates

The basic theory and procedures of TL dating are detailed in chapter 13, but certain technical issues are summarized here to support the comparison of dating results. Pottery and burned sandstone are suitable materials for TL dating and are relatively common at early Navajo sites. TL techniques are sufficiently refined that most pottery dating is considered rather routine (Feathers 1997), and accurate dating has been demonstrated by several studies where independent dating evidence has been available (e.g., Barnett 1999; Feathers and Rhode 1998; Kojo 1991). Nevertheless, because TL depends on a host of local variables, it is useful to demonstrate accuracy for any given case.

There is also the possibility that the event dated does not correspond with the archaeological event of interest or target event (Dean 1978). For example, the last heating event,



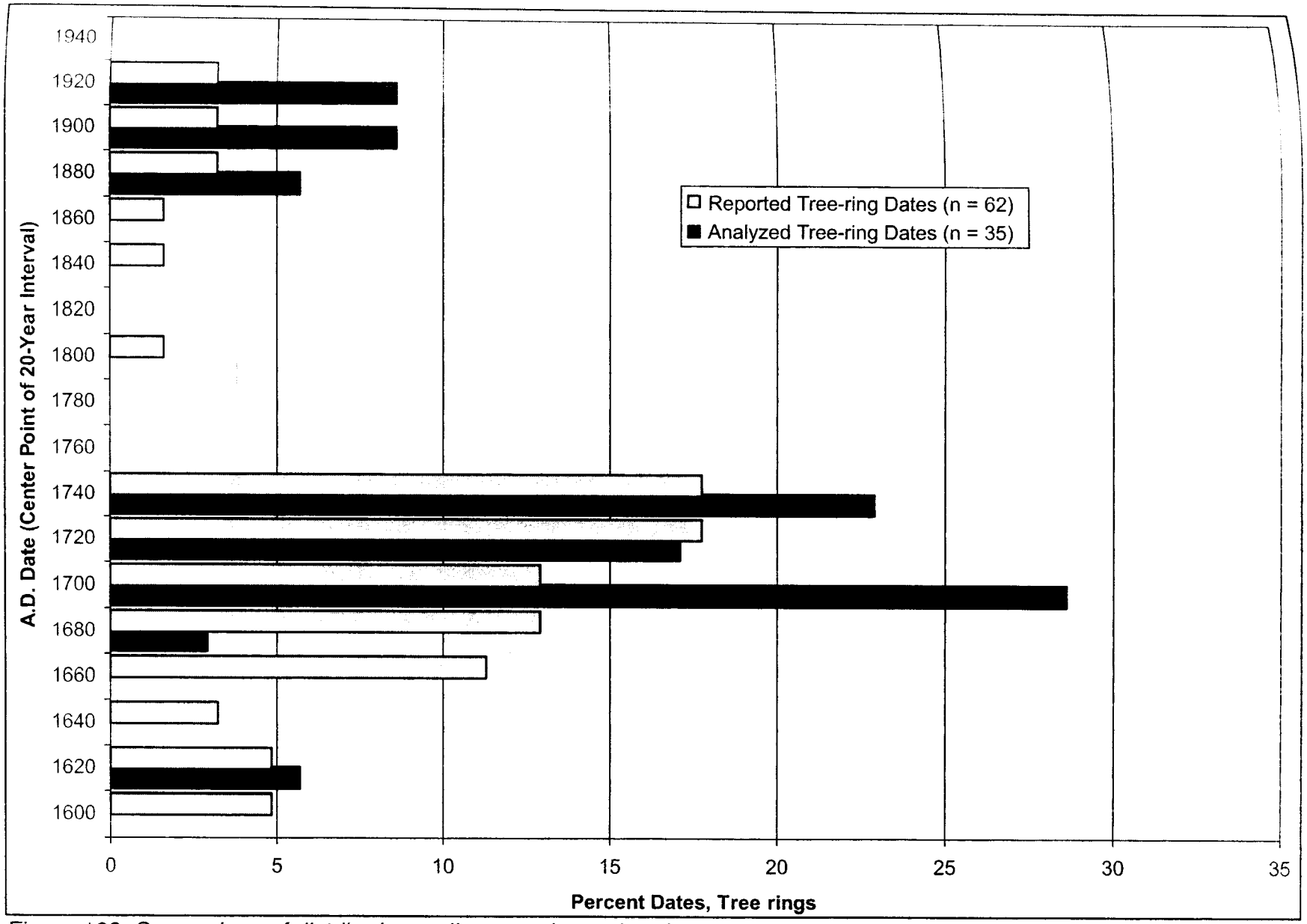


Figure 163. Comparison of distributions: all reported tree-ring dates plotted against dates derived from site-based tree-ring analysis.

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Table 91. Site-based Analyzed Tree-ring Dates for the Morris Site 1 Project

Site/IM Designation	Reported Dates[a]	Estimated Site Date[a]	Confidence	Note
IM-12(E1)	1629B	1629	Cutting Date	Harvested during the juniper growing season (May-October)
IM-12(E2)	1664+vv	ca. 1700	Interpreted	46 sapwood rings; very eroded
IM-18	1605vv	late 1600s-early 1700s	Low	Heavily eroded heartwood
IM-78	1859++vv	early 1900s	Interpreted	28 sapwood rings; probably harvested as deadwood
IM-1000	1608vv	late 1600s-early 1700s	Low	No sapwood present
IM-1001	1654+vv	late 1600s-early 1700s	Low	No sapwood present
LA 11196	1698vv	1720s	Interpreted	22 sapwood rings are present
LA 55836	1723vv	ca. 1728	Interpreted	Some ring loss noted on specimen; supported by 7 noncutting dates in the late A.D. 1600s and early A.D. 1700s
LA 83529(E1)	1748+GB	1749	Cutting Date	Drought in A.D. 1749 prevented ring formation; supported by another cutting date of the same age; other results include 6 noncutting dates from A.D. 1652 to A.D. 1747
LA 83529(E2)	1901++vv	1910s	Interpreted	Perhaps procured during Morris' work at this site
LA 105425	1701vv	1710s	Interpreted	Retains 75 rings; minor erosion indicated
LA 105428	1728vv	1740s	Interpreted	Sapwood present; heavy erosion indicated
LA 105479	1730vv	mid-1730s	Interpreted	Probably fewer than 10 rings lost; supported by 4 noncutting dates in the late A.D. 1600s
LA 105481	1712vv	1720-1750	Low	No heartwood-sapwood boundary; supported by 2 noncutting dates in the late A.D. 1600s
LA 105483(E1)	1629v	1629	Cutting Date	1st occupation-, probable cutting date
LA 105483(E2)	1740vv	1740s	Interpreted	Substantial amounts of sapwood remain; supported by 2 other dates of similar age
LA 105484	1840vv	1850-1900	Low	No sapwood rings present
LA 105529	1566vv	late 1600s- early 1700s	Low	Piñon; many rings missing; possible use of deadwood
LA 105530	1719++vv	1720s	Interpreted	Sapwood present; even erosion; supported by 1 noncutting date (1714vv) with few missing rings
LA 105627	1731vv	1730s	Interpreted	Sapwood rings present; diffuse heartwood-sapwood boundary
LA 105629	1679+vv	early 1700s	Interpreted	40 sapwood rings present but specimen is unevenly eroded
LA 105630(E1)	1644vv	ca. 1700	Interpreted	34 sapwood rings present but badly eroded
LA 105630(E2)	1915rB	1915	Cutting Date	Hispanic or Anglo-American; harvested between April and August; possibly procured during Morris' excavation of LA 83529
LA 105925	1695v	1695	Cutting Date	Harvested in May to October
LA 105929	1695rB	1695	Cutting Date	Harvested in May to October
LA 105929	1695rB	1695	Cutting Date	Harvested in May to October

Note: (E_) = tree harvesting episode
[illegible] A.D.

Table 91.—Continued

Site/IM	Reported	Estimated		
[illegible]	[illegible]	[illegible]	Confidence	Note

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Table 91.—Continued

Site/IM Designation	Reported Dates	Estimated Site Date[a]	Confidence	Note
LA 105930	1695vv	1695	Cutting Date	Near cutting date indicated by reevaluation of ring structure and erosion; supported by 1 noncutting date (1666+vv)
LA 105945	1889++B	1890s-early 1900s	Interpreted	52 sapwood rings present; loss of many rings is possible; probably harvested as deadwood
LA 106105	1807vv	late 1800s	Low	Only 9 sapwood rings present
LA 106106 (E1)	1883++vv	1890s	Interpreted	First of 2 episodes of historic period (Lucero phase) harvesting
LA 106106 (E2)	1927rB	1927	Cutting Date	Second of 2 episodes of historic period harvesting
LA 106199	1750B	1750	Cutting Date	Harvested during the juniper growing season (May-October); supported by two noncutting dates (1731+vv and 1747vv)
LA 110273	1622vv	1660-1699	Interpreted	68 sapwood rings are present but exterior ring loss is indicated
LA 110278	1699+vv	mid-1700s	Interpreted	65 sapwood rings; uneven erosion
LA 110280	1727+vv	1730s	Interpreted	64 sapwood rings present; minimal erosion is indicated
LA 110284	1641vv	late 1600s	Interpreted	41 sapwood rings present

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which TL measures, could have occurred much more recently due to natural causes such as forest fires or a later cultural event that involved fire. In the Morris Site 1 project area a catastrophic event, such as forest fire, in the last 300 years was unlikely, as demonstrated by the unburned condition of tree-ring specimens collected from live trees and stumps.

A more serious problem might be what we term "the old pot effect," which causes disparity between the TL-dated event, which usually corresponds to firing the pottery, and the event of pottery disposal or discard. After firing, the use life of pottery may be of considerable duration, therefore, the dated firing event may predate the site by a significant margin. Heirloom pieces may have been manufactured several generations prior to occupation of the site targeted for dating. Sherds were also functional, as ladles or scrapers for example, long after the ceramic vessel was broken. Such reuse of pottery in the Southwest was common.

The old pot effect is more likely to apply to pottery types that have a longer use life as vessels (Nelson 1991; Skibo 1994). Well made, nonutilitarian pottery, like decorated ware, may not have been subject to the hard, daily use of gray ware. Decorated or imported pottery types were also more likely to be reused as sherds. Under such circumstances the TL date may reflect an event much earlier than the occupation of archaeological interest. Cooking vessels, because of the stresses to which they are subjected, have shorter use lives and may be more appropriate for dating. Neither postdepositional firing nor old pot effects can be evaluated intrinsically by luminescence methods and the comparison with tree-ring data can be helpful in this regard.

The TL dating results from the Morris Site 1 project are described in detail in chapter 13, but are summarized in Table 92. The precision of the dates, reflecting only analytical errors, ranges from 6.9 to 18.8 percent, with a mean of 10.4 percent, which is about average for luminescence dating of pottery. There was no tendency for better precision among different types or between surface and subsurface samples. The sherds from the immediate surface, with one exception (UW251) tended to be somewhat younger than those a few centimeters below the surface, which would be expected on stratigraphic grounds. Dinetah Gray and Jemez Black-on-white sherd samples, as a group, tended to be older, while the polychromes tended to be younger, with a few exceptions. Two exceptions, a Jemez Black-on-white sample (UW236) and Dinetah Gray sample (UW246), suffered from anomalous fading, which could explain their younger age. However, two other samples that indicated fading produced ages similar to others of their ceramic type. Excepting the anomalous date (UW254) the sandstone pieces dated in the same age range as the gray and white wares, w[illegible] comparable precision.

TL dates represent a broad range of values indicat[illegible] by the reported mean and one standard deviatio[illegible] consequently, a statistical method was used to produ[illegible] histogram comparable to that constructed for tree-ring date[illegible] The TL dates were summarized using Kintigh's ^{14}C rou[illegible] (Kintigh 1994), which was originally designed as a graphic[illegible] analysis of radiocarbon dates reported at one standa[illegible] deviation. Instead of assuming each date as a single poin[illegible] in time, the routine treats each date as a normally distribute[illegible] probability about the mean. For any time interval, a give[illegible] date will have some probability of falling within that interval. For each time interval in the histogram, the probabilities fo[illegible] each date in that interval are summed, giving a total probability for the number of dates for each interval. Th[illegible] histogram values are converted and reported as relativ[illegible] frequencies. The resulting distribution indicates one or more modes that reasonably demonstrate archaeological occupations (Kintigh 1990, 1994).

The distribution of TL dates appears to be negatively skewed with a single mode evident in the A.D. 1680 category (Figure 164). If 100 percent of the distribution spanned by the TL curve is accepted, then the total possible range of the occupation extends from A.D. 1360 to A.D. 1860. This range contains all variation given by the dates, but is excessively broad for the purposes of this analysis. Similarly, a ninety-fifth-percentile adjustment (two standard deviations) is too broad for comparative purposes. One standard deviation (sixty-sixth percentile) might be suitable for evaluating data from a single site, but with multiple site[illegible] represented, some temporal variation must be accepted. We use the seventy-fifth percentile here, because it falls between one and two standard deviations. At the seventy-fifth percentile an occupation span of 200 years from A.D. 1540 to A.D. 1740 is indicated. The unimodal distribution suggests that a single occupation is dated by the TL technique. The TL distribution does not reflect the historic occupation of the project area because there was no attempt to date historic remains with this technique.

Tree-Ring and TL Correlation

The purpose of comparing the tree-ring and TL results is to ascertain the degree of correspondence obtained from the two techniques. This is largely a measure of confidence in the TL results, because the precision and accuracy of tree-ring dates are very high. Thus, the tree-ring results are treated as a control for evaluation of TL dates. Two types of comparison are presented. Direct comparison refers to an evaluation of dating accuracy within site contexts. In other words, the TL dates from any given site are compared with tree-ring results

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Table 92. TL Dates for the Morris Site 1 Project

Site Number	UW Lab No.	Context	Sample Type	Reported Date[a]
11196	254	Subsurface	Sandstone	17271±4361 B.C.
11196	253	Subsurface	Sandstone	1535±49
55836	251	Surface	Jemez B/W	1491±41
55836	252	Surface	Gobernador Polychrome	1753±43
79456	239	Subsurface	Dinetah Gray	1597±66
83529	147	Surface	Dinetah Gray	1734±32
83529	238	Subsurface	Gobernador Polychrome	1685±28
105428	144	Surface	Gobernador Polychrome	1766±30
105428	241	Subsurface	Rio Grande Matte Paint	1612±39
105475	237b	Subsurface	Dinetah Gray	1489±55
105475	237a	Subsurface	Dinetah Gray	1569±41
105479	145	Surface	Sandstone	1665±50
105483	142	Surface	Gobernador Polychrome	1745±19
105530	143	Surface	Gobernador Polychrome	1624±32
105630	240	Subsurface	Dinetah Gray	1615±38
105929	242	Subsurface	Gobernador Polychrome	1661±27
105930	244	Subsurface	Dinetah Gray	1592±42
105938	146	Surface	Dinetah Gray	1718±21
106168	246	Subsurface	Dinetah Gray	1726±24
106199	245	Subsurface	Gobernador Polychrome	1676±22
106203	236	Surface	Jemez B/W	1681±26
110278	243	Subsurface	Dinetah Gray	1649±39

[a]Years A.D. unless otherwise noted

from the same context. The second comparison evaluates the results as aggregates of tree-ring-dated sites and TL results from the Morris Site 1 project area. This would represent the temporal distribution of the early Navajo occupation of the project area. Once the comparison of dating results is complete, the utility of TL dating may be evaluated with respect to other kinds of archaeological dating.

Direct Comparison

We use direct comparison of dates from same site contexts to evaluate the correspondence of the TL results with respect to target events described by tree-ring dates. This analysis is based on the 12 sites from which the results of both techniques are available. Tree-ring dates for these sites are represented by cutting dates or estimated dates, derived by the terminal ring and sapwood analysis and TL assays are represented by one- and two-standard-deviation ranges. The dates are charted (Figure 165) by site number and ranked from left to right in decreasing order of correspondence to facilitate the comparison. Dating correspondence is indicated when the tree-ring date occurs within the two-standard-deviation error range of the reported TL mean. A bridging argument is required to make sense of results where tree-ring dates occur outside TL ranges.

The precision of TL dates is an important consideration in the direct comparison, because poor precision usually yields very large error ranges that increase

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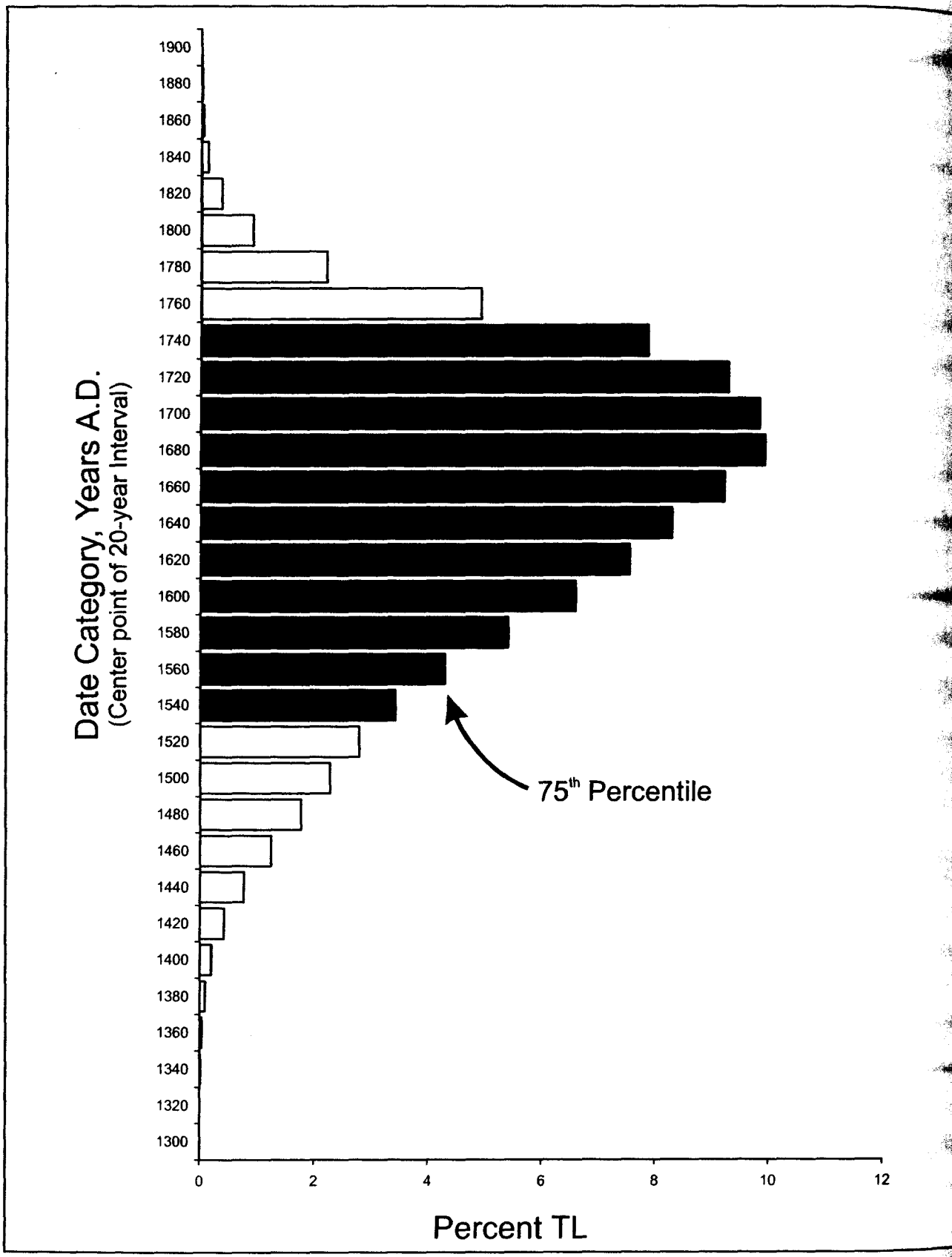

Figure 164. Graphical analysis of aggregated TL dates.

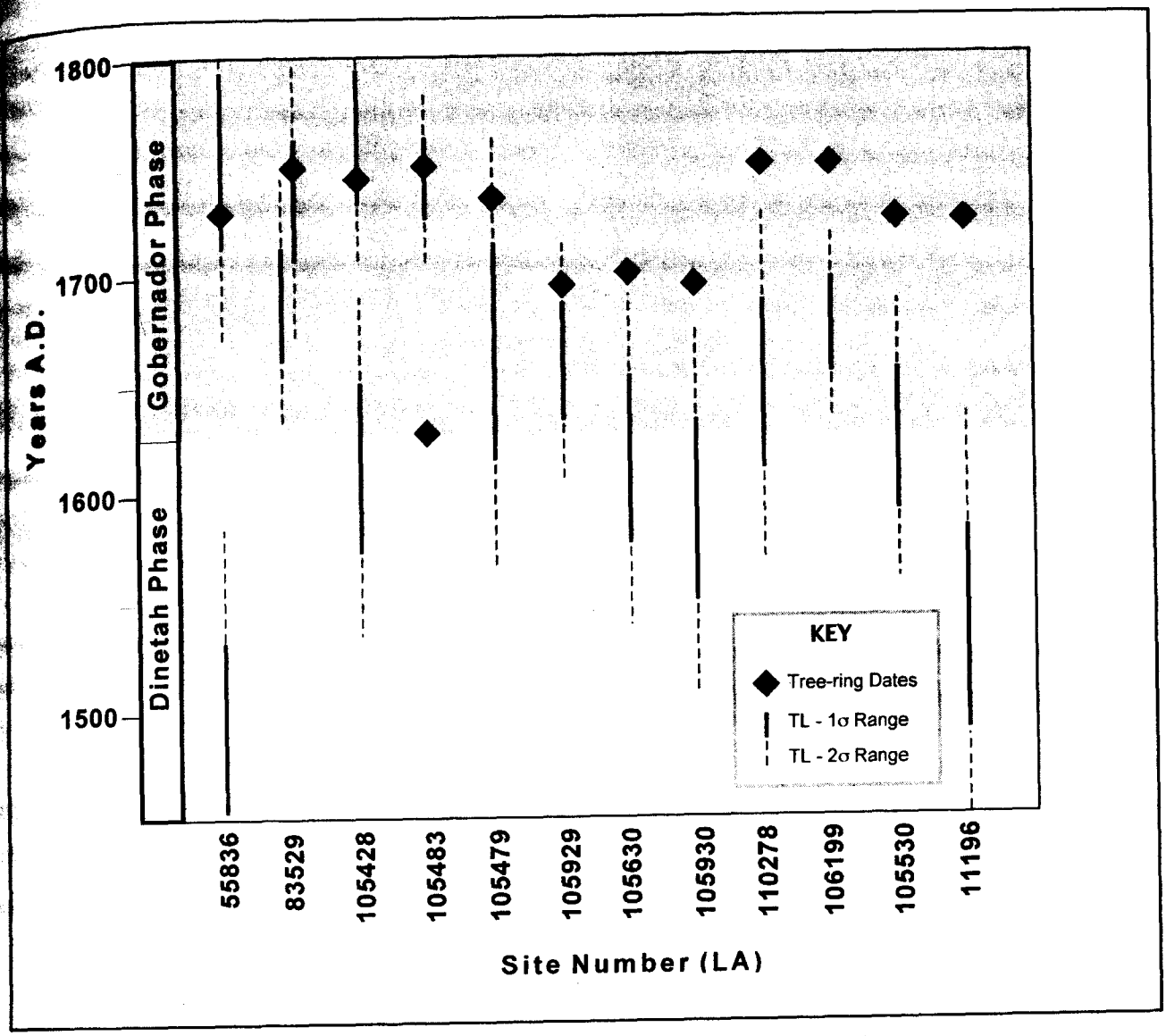

Figure 165. Direct comparison of tree-ring and TL dating correspondence.

the probability of direct correspondence with target dates. Thus, imprecision may provide accurate results because the larger date range offers a greater opportunity to hit the target date. Conversely, better precision produces a narrower range that is statistically less likely to hit the target, but when these do correspond, the highest standard of precision and accuracy is achieved.

Earlier we characterized, as unacceptably imprecise, the 400-year date range often provided by radiocarbon results in the protohistoric period. TL results should improve on that level of precision and show correspondence with the tree-ring target dates to be a viable alternative to radiocarbon dating. TL dates for all samples produced two-standard-deviation ranges that varied from 76 years to 264 years with a mean range of 145 years. Consequently, the precision of the TL results shows considerable improvement compared to typical radiocarbon results for the period.

Correspondence between the TL range and tree-ring date is indicated by 6 of 15 TL dates (see Figure 165). In these cases the correspondence between the target tree-ring date and TL-dated event is unequivocal, but it might be instructive to consider the character of these samples. The sample materials consisted of four Gobernador Polychrome sherds, one Dinetah Gray sherd, and one piece of sandstone. The sandstone sample demonstrates the poorest precision, indicated by the broadest date range of

all TL samples and this likely factored into its correspondence with the associated tree-ring date. Nonetheless, it is encouraging that the sandstone sample provided accurate results, given the potential problem of insufficient heating. In the group of ceramic sherd samples it is apparent that Gobernador Polychrome provided more correspondent dates than Dinetah Gray samples. This suggests that the accuracy of TL results may vary with ceramic type and raises the issue of the relationship between dating and sample character, which is explored later in the ceramic comparison.

Bridging arguments are necessary to evaluate the nine TL dates that did not directly correspond to tree-ring dates. Probably the most common reason for the lack of correspondence is the inequality of the events dated by the two techniques. This phenomenon can be evaluated by closer inspection of sites with multiple TL dates where both correspondence and lack of correspondence occur. Three sites, LA 55836, LA 83529, and LA 105428 meet this condition.

Two ceramic sherds from LA 55836 (Romine Canyon ruin) were dated by the TL method. A sample of Gobernador Polychrome provided a date range in the A.D. 1700s that corresponded well with the tree-ring estimate for the site. The noncorrespondent date in the late A.D. 1400s was measured from a fragment of Jemez Black-on-white (UW 251). This ceramic type is known to have been widely traded in the Southwest, but originated from production centers in the Jemez area, located about 100 km south-southeast of the Dinétah (Harlow 1973). Production of Jemez Black-on-white cross dates with the tree-ring record between A.D. 1300 and A.D. 1700 (Breternitz 1966). The painted designs of this decorated ware may have been favored by the Navajo for heirloom pieces (Cleveland et al. 1999; Langenfeld 1999). Moreover, Jemez Black-on-white is quite sturdily built and individual pieces could have a use life of considerable duration. This combination of attributes suggests that the early TL date for the Jemez Black-on-white sherd may be attributed to the old pot effect.

The situation at LA 105428 is similar to that just addressed for Romine Canyon ruin. The later, correspondent date is derived from a piece of Gobernador Polychrome, but the earlier date is from a fragment of untyped Rio Grande matte paint polychrome pottery. In this case, however, the early date is unexpected, because production of this pottery does not begin until ca. A.D. 1650 in the Rio Grande area (Harlow 1973). The most recent extreme of the TL date range is A.D. 1690, which does correspond with the earliest production of this pottery. Consequently, at two degrees of freedom the TL date could accurately date the production of this pottery. This result is still about 50 years older than the tree-ring target date, thus the relationship between site and dated event is best regarded as due to the old pot effect.

Two TL dates from LA 83529 (Morris Site 1) show some overlap at one standard deviation and considerable overlap when the range is broadened to two standard deviations. The statistical similarity of TL ranges suggests that the same or similarly aged events are dated; however, only one of these dates showed correspondence with the tree-ring date. The character of the occupation at Morris Site 1 must be considered in building the bridging argument for the noncorrespondent date. Morris Site 1 is a large and complex site that consists of numerous features, including a sweat lodge, hearths, and possible residential structures (Brown 1993). The accretion of features suggests some duration of the occupation and noncutting tree-ring dates prior to A.D. 1749 might represent earlier use of the site. Therefore, it is possible that the Morris Site 1 pueblito represents one of the last structures built at the site. In this case the bridging argument relies on physical data from the site, consideration of other tree-ring dates, and statistical similarity between multiple TL results, which combined, imply that both TL dates are accurate.

There is little independent data that can be brought to bear on the six remaining TL dates that do not correspond with the target tree-ring dates. In most cases the difference between the TL range and tree-ring date is 30 years or less. Inequality of dating events may be argued for the LA 11196 results. This site, like Morris Site 1, is extensive and contains a large and varied feature assemblage, which may be indicative of a lengthy occupation or perhaps multiple occupational components. The other five noncorrespondent TL dates may also be the product of dated event inequality, but this cannot be resolved by closer examination of site data or tree-ring dates. Tree-ring dates at these sites tend to be cutting dates or clusters of dates indicating good confidence in a narrow range of possible dates for the target event.

Comparison of sample types indicates that four of the six noncorrespondent samples are either Dinetah Gray or sandstone, and two samples are Gobernador Polychrome. This is a virtual mirror image of the distribution of sample types correspondent with tree-ring results, and may indicate some loss of accuracy for TL dates derived from Dinetah Gray.

In summary, 6 of 15 TL samples unequivocally correspond to tree-ring dates from same site contexts. Bridging arguments are invoked to convincingly explain apparent discrepancies between dating and target events in 3 of the 9 remaining cases. Consequently, in 9 of 15 cases the correspondence between the dating techniques is knowable and often quite good. That leaves 6 sites where there is insufficient data to build convincing bridging arguments, but inequality of dating events is the prime suspect for the date discrepancies. Even so, the differences between the TL ranges and target dates are relatively small.

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The precision and accuracy of the TL dates appear to be related, in part, to the type and character of the sample. On average the TL mean dates occurred within 79 years of corresponding tree-ring dates. Three of four TL mean dates that departed from tree-ring dates by greater than 100 years were assayed from sandstone or trade ware pottery samples that may reflect old heating events. In contrast, the average departure of the TL mean for locally made ceramics, Dinetah Gray and Gobernador Polychrome, is only 54 years. Moreover, Gobernador Polychrome samples appear to be more reliable than Dinetah Gray, because the average departure from tree-ring dates is 44 years. The figure for Dinetah Gray is 71 years. Better accuracy for TL dates derived from Gobernador Polychrome may be due to the relatively narrow time frame, about 135 years, in which this pottery was produced. Dinetah Gray was produced for 350 years or more. Gobernador Polychrome, therefore, may have the potential for producing dates with better accuracy due to its shorter period of production. The accuracy of sandstone samples for dating may suffer from a lack of consistent heating due to multiple heating events, which may affect the ability to isolate the TL signal that relates to the event of interest. When sufficiently heated, the resultant dates from sandstone demonstrate dating resolution similar to Dinetah Gray samples. Finally, trade ware pottery produced outside of the Dinétah area may be unreliable, because production of these types was not closely linked with local site use. Therefore, better dating accuracy is associated with locally produced pottery.

Aggregate Comparison

The direct comparison shows that the TL dates are generally in the same range as tree-ring dates, but it is apparent that significant discrepancies can occur. In some cases the discrepancies can be explained if the respective events being dated are also shown to be separated in time—inequality of dating events. On a project-wide scale these differences might average out and provide an accurate representation of the time of occupation. This requires grouping TL and tree-ring dates into two data series and comparing the two on the same time scale. The construction of each data series was treated differently to accommodate the differences in the way dates are reported.

The aggregated tree-ring and TL results are compared by overlaying the previously generated histograms (Figure 10), so the fit can be evaluated visually. The distribution of individual tree-ring dates is displayed as a series of vertical lines, but to facilitate the comparison the TL distribution is indicated by a series of points connected by lines. These points actually represent histogram values for each [illegible]

In the early Navajo period the correspondence of the TL mode with the strongest tree-ring mode is impressive. Both distributions support a significant early Navajo occupation between A.D. 1690 and A.D. 1750. The tree-ring data indicate the terminus of the early Navajo occupation after A.D. 1750. The TL distribution indicates the terminus in the A.D. 1740 interval (A.D. 1730-1749), just short of the A.D. 1750 boundary in the A.D. 1760 interval. The comparison indicates a great deal of correspondence between the TL and tree-ring results in this time frame.

The skewness of the TL curve prior to the A.D. 1680 interval appears to be responsible for a lack of fit in the early part of the occupation. In order to replicate the tree-ring results, another mode should be evident in the TL distribution in the A.D. 1620 interval. Such a mode is not indicated; however, a slight change in the slope of the TL distribution is evident after the A.D. 1620 interval. This slight flattening of the curve indicates fewer summed TL results in the A.D. 1640 interval and may represent the only evidence in the TL curve for an earlier occupation.

Thermoluminescence and Archaeological Dating

Good correspondence between the tree-ring and TL results of the Morris Site 1 project indicates that the TL technique produces reliable dates for the protohistoric time frame. This demonstration of reliability suggests that in archaeological contexts where TL is the only viable dating technique, the results may be regarded with a measure of confidence for aging cultural events of interest. Reliance wholly on a single dating technique should be avoided, because individual dating methods tend to be internally consistent. The best test of dating reliability in archaeological site contexts is correlation of results from several techniques, as indicated by the comparison reported here. It is worthwhile to consider TL dating in comparison with other dating techniques commonly used in the Southwest. In this regard, radiocarbon and ceramic cross-dating techniques are often used to age early Navajo sites because suitable dating materials are common at such sites. Moreover, both radiocarbon and ceramics are dependent upon heating events that could be cross dated by the TL technique, thus potentially reducing the problem of disparity due to the inequality of dated events.

TL and Radiocarbon

The archaeological debate concerning the time of Athabascan arrival in the Southwest has called into question the accuracy of a number of very early radiocarbon dates from Navajo sites in the La Plata valley of New Mexico

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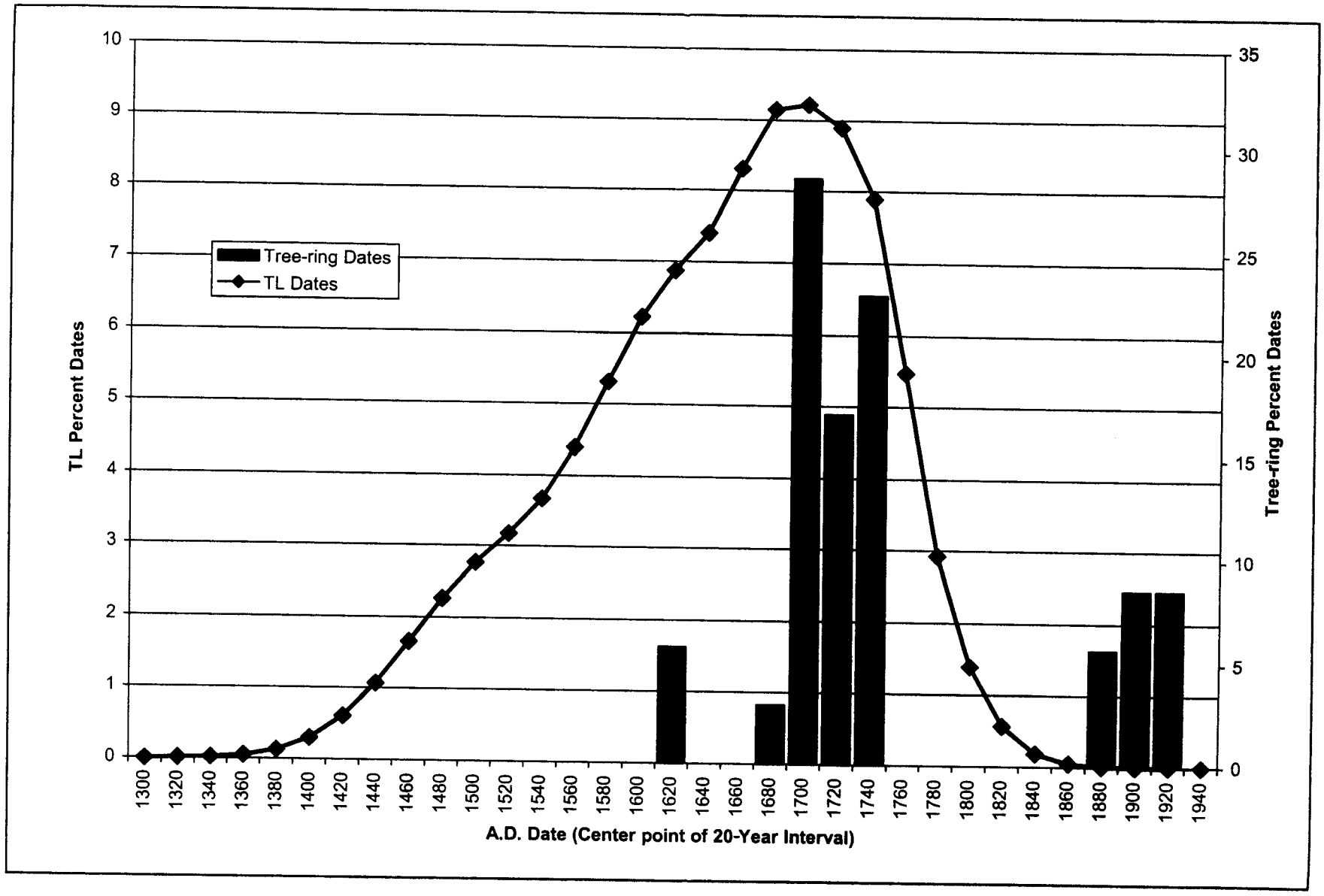

Figure 166. Tree-ring and TL graphics compared.

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Brown 1990, 1996; Fetterman 1996; Reed and Horn 1990). In most cases other dating techniques including dendrochronology and TL were used, but lack of dating correspondence from different methods caused researchers to invalidate dates returned by one method or another. The good correspondence between TL and tree-ring dates, as demonstrated herein, suggests that the disparity may be related to inaccuracy and imprecision of radiocarbon dates.

Hogan (1989) addressed the issue of untenably early radiocarbon dates by a statistical methodology that showed most errors were accounted for in the two-standard-deviation error range. He concluded that in most cases the more recent portion of the range tended to be most accurate. Reed and Horn (1990) found that the radiocarbon technique produced dates about two centuries older than TL dates from the same sites. They argued that the radiocarbon dates pushed the Navajo occupation in the La Plata valley back to the middle A.D. 1400s and rejected the seventeenth-century TL dates. In this case, Reed and Horn (1990) placed more confidence in the tried-and-true radiocarbon technique. Brown (1990) developed a model to correct for the old wood effect that he felt was inherent to the radiocarbon samples from Navajo sites in the La Plata valley. The old wood correction moved the radiocarbon dates forward by 100 to 200 years, thereby indicating much better correspondence with TL results (Brown 1996; Brown and Hancock 1992). Fetterman (1996) took a slightly different approach to the radiocarbon problem. He compared tree-ring dates with radiocarbon dates derived from both wood and annual plant samples. The comparison indicated that radiocarbon dates consistently overestimated the age of sites given by tree-ring analysis. Moreover, radiocarbon dates on annuals consistently produced better correspondence with tree-ring dates, likely because the old wood effect is negated. He argued that though the dates from annuals performed better, the support for comparable tree-ring dates was only at the extremes of the error ranges.

The Morris Site 1 dating study reported here indicates that TL results correlate well with tree-ring dates in early Navajo contexts. Moreover, TL dates are often accurate within the one-standard-deviation error range, which represents a significant improvement over the precision typical of calibrated radiocarbon dates. This suggests that disparity between radiocarbon dates and other dating methods (particularly tree-ring and TL) is likely due to unknown error in radiocarbon assays. Consequently, the Morris Site 1 information supports the conclusions of Brown (1990, 1996), Brown and Hancock (1992), Fetterman (1996), and Hogan (1989) that suggest that radiocarbon assays consistently overestimate the age of relatively recent Navajo occupations in northwestern New Mexico. The causes of this error are undetermined, but could be related to unrecognized technical problems with the assay of recent materials or potential environmental causes peculiar to the northwestern New Mexico region. Whatever the cause, the better performance of TL dating, as shown here, suggests the technique should be used more frequently for dating relatively recent occupations.

TL and Ceramics

The negative skew of the TL distribution is likely due to a few unusually early dates, possibly the result of the old pot effect. Only five of the reported mean TL dates occur prior to A.D. 1600. Three of these dates have error intervals that do not extend into the A.D. 1600s and are likely candidates for the old pot effect. One of the dates, obtained from a sandstone sample, is considered anomalous, because the old pot effect is not applicable. The other two dates, both in the A.D. 1400s, were obtained from Dinetah Gray (UW237b) and Jemez Black-on-white (UW251) sherds. Fifteenth- century dates for Dinetah Gray are quite rare and often based on disputed radiocarbon dates reported for Navajo sites in the La Plata valley (Brown and Hancock 1992; Reed and Horn 1990). The early result could be attributed to the old pot effect, but it was argued earlier that the expectation of a short-term use life for Dinetah Gray makes this explanation unlikely. Consequently, the early date is unsupported and considered anomalous.

The Jemez Black-on-white sample (UW251), however, appears to be an ideal candidate for the old pot effect. This ceramic type is known to have been widely traded, but originating from production centers in the Jemez area, located about 100 km south-southeast of the Dinétah area (Harlow 1973). Production of Jemez Black-on-white cross dates with the tree-ring record between A.D. 1300 and A.D. 1700 (Breternitz 1966). Jemez Black-on-white is a decorated ware that is quite sturdily built. This combination of attributes may have made this pottery favored for heirloom pieces. Consequently, the seemingly early date for the Jemez Black-on-white sherd may be attributed to the old pot effect.

The old pot effect raises the issue of the relationship between pottery production and TL dates obtained from sherds. If TL dates are dependent upon thermal signals from ceramic firing events, then the TL distribution plotted for a number of ceramic samples should approximate the production period estimated for specific pottery types. This proposition can be addressed by evaluating the TL date distribution for the most commonly dated ceramic types in this sample, Dinetah Gray and Gobernador Polychrome.

Brugge (1981) describes the production period for Dinetah Gray between ca. A.D. 1700 and A.D. 1800. Recently, however, it has been securely dated by tree rings to A.D.

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1541 (Hancock 1997), and it is likely that the technology is even older. The terminal date suggested by Brugge has not been challenged, consequently, the production period for Dinetah Gray is estimated to be the mid-A.D. 1500s to ca. A.D. 1800.

Gobernador Polychrome is best dated from ca. A.D. 1640 to A.D. 1765. The beginning date is indicated by data from the Frances Mesa project and Morris Site 1 project (Langenfeld 1999; Wilshusen et al. 2000; also see chapter 8), and supported by other researchers (Marshall 1995; Reed and Reed 1996). The terminus of Gobernador Polychrome production is circa A.D. 1765.

To evaluate the TL dating distribution for individual pottery types, the ^{14}C program (Kintigh 1994) was used to produce separate histograms for dated Dinetah Gray and Gobernador Polychrome sherds (Figures 167 and 168).

The Gobernador Polychrome distribution is shifted to more recent times and is a strong contributor to the primary A.D. 1700 mode in the date distribution of all ceramics. Gobernador Polychrome exhibits generally a single mode, with perhaps some finer detail. The seventy-fifth percentile, A.D. 1640 to A.D.1780, fits remarkably well with the expected dates of A.D. 1640 to A.D.1765 for this ceramic type. The distribution of Dinetah Gray dates shows a much broader range from the A.D.1520s to the A.D.1740s (seventy-fifth percentile) and is bimodal, one mode corresponding with that of Gobernador Polychrome and the other largely responsible for the pre-A.D. 1600 dates in the overall distribution. This distribution again fits well with the expected dates for this ceramic type. Moreover, deconvoluting the overall TL distribution by ceramic types successfully reproduces the bimodality evident in the tree-ring dates and indicates at least two early Navajo occupations of the project area.

The agreement with known age distributions for these ceramics suggests that TL can be very reliable for dating ceramic production periods and may serve as an independent test for current ceramic cross-dating sequences. Moreover, TL dating may be useful for expanding ceramic cross dating to pottery types that are not currently keyed by reliable tree-ring dates. For dating occupations at individual sites, reliability may be compromised to some degree by production periods that extend longer than the site duration—the old pot effect. Pottery types that had short periods of production will likely return more reliable TL dates than pottery with long periods of production.

Conclusions

The evaluation of tree-ring and TL correspondence indicates generally good agreement between results returned by the two techniques. In the direct comparison of dates from the same site context, 6 of 15 (40 percent) TL samples corresponded with tree-ring dates. Bridging arguments provided logical explanations for lack of dating correspondence for three other samples. Finally, another six TL samples were found to be noncorrespondent compared to tree-ring dates. Given that dating-event disparity is usually present when comparing the results of two techniques (Dean 1978), the level of correspondence evident in the tree-ring and TL comparison is quite good.

Aggregating the dates from multiple sites effectively averages the temporal differences between individual events and produces impressive correspondence in dating results. Close correspondence in both the modes and the overall distributions is apparent and may indicate the growth, fluctuations, peak occupation, and abandonment of the Morris Site 1 project area during the early Navajo period.

TL dating consistently outperforms radiocarbon dating in both precision and accuracy for the protohistoric period, as is apparent when comparing the results here with those of Smiley and Ahlstrom (1997) and Fetterman (1996). TL dating and tree-ring dating are best viewed as complementary techniques, each providing slightly different temporal information relative to the target event. Where tree-ring dates are available, they can also serve as a valuable independent check on the TL dates, which are inherently less precise. The TL technique is complementary, because it has wider applicability for sample materials, like ceramic sherds and burned rock that are more abundant in archaeological contexts than the well-preserved wood necessary for tree-ring dating. Aggregated TL data appear to provide excellent correspondence with tree-ring results, and should be used with confidence where tree-ring dates are not available. Bridging arguments may be necessary to account for variability in ceramic production duration and the old pot effect. Nonetheless, an aggregate of TL dates from a single site would significantly improve reliability of individual site dating.

The direct TL dating of sherds may have implications for the Southwest's most commonly applied relative dating technique, ceramic cross dating, because it provides an accurate temporal profile of ceramic production. This may be used to calibrate ceramic cross dating in the absence of tree-ring dates. Finally, the suitability of TL dating for

Date Category, Years A.D.

Fig

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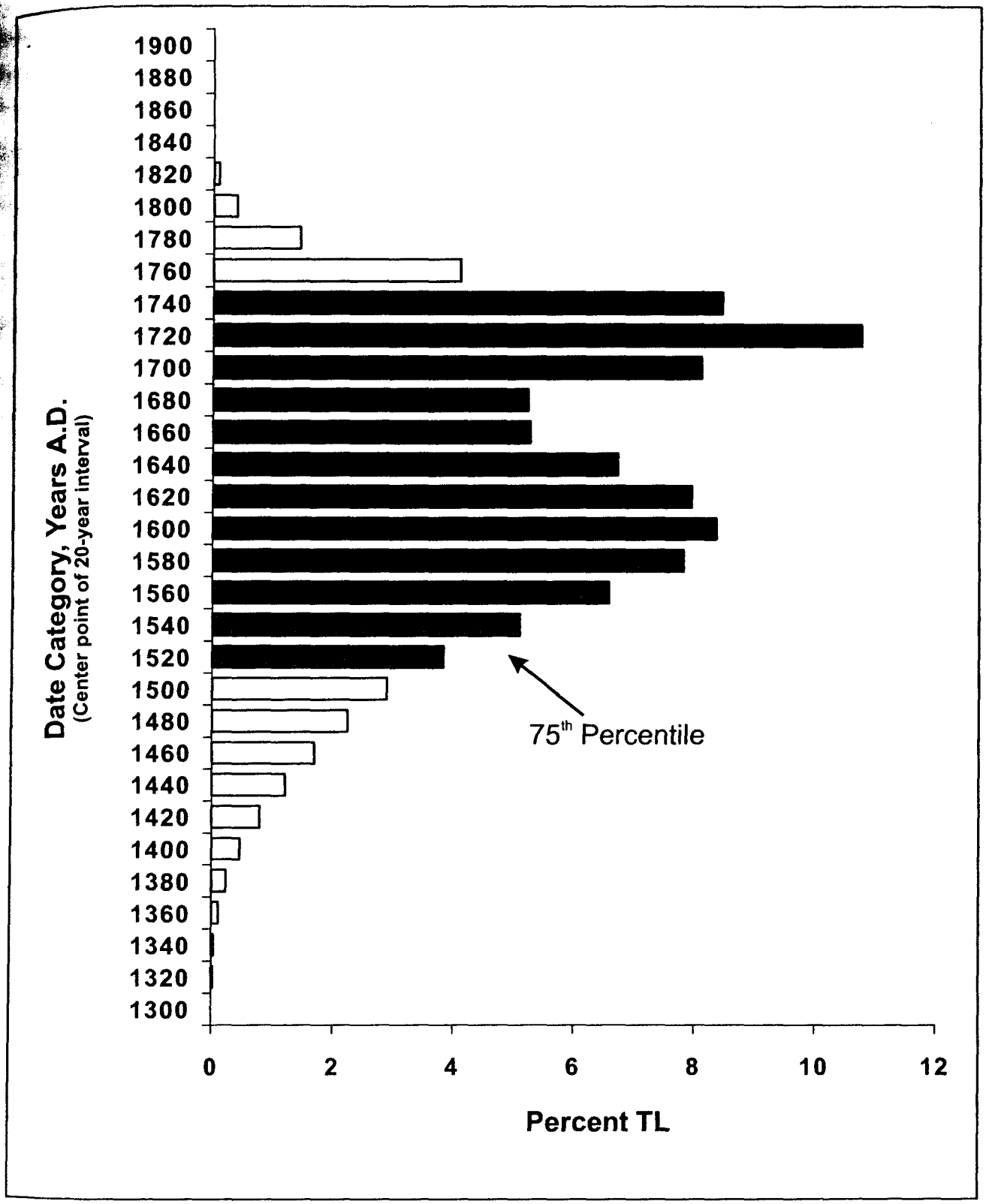

Figure 167. Graphical analysis of TL date profile for Dinetah Gray.

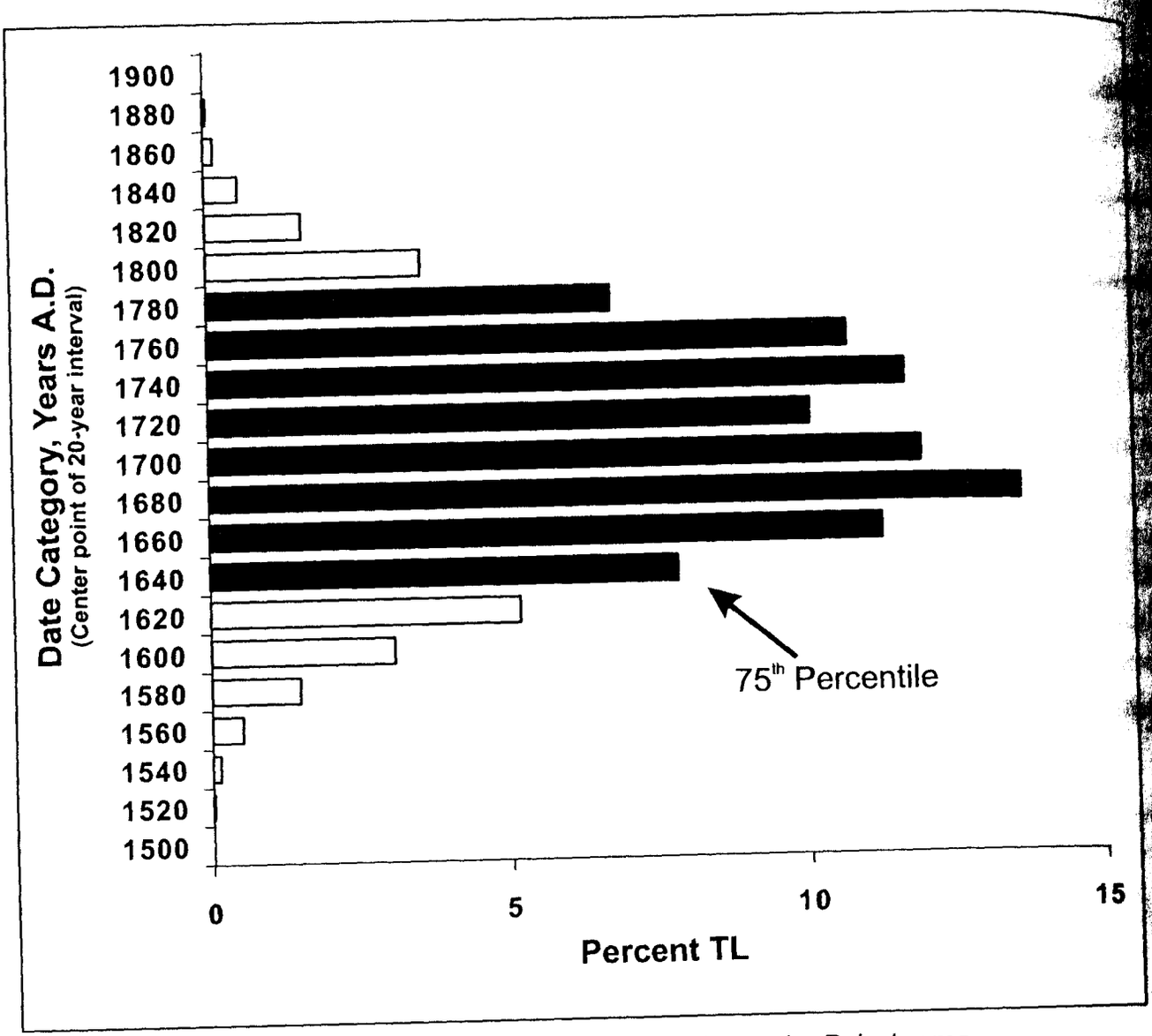

Figure 168. Graphical analysis of TL date profile for Gobernador Polychrome.

common archaeological materials and effectiveness for dating surface artifacts make it a good choice for large archaeological inventories like the Morris Site 1 project.

In the research design it was suggested that dating calibration could be a beneficial result of the tree-ring and TL comparison. Unfortunately, problems of dating disparity and inequality of dated events prevented a demonstration of consistent and measurable differences that would permit the construction of a calibration scheme. However, the application of both techniques provides powerful tools for evaluating target dates for archaeological sites. The construction of bridging arguments is critical for resolving disparity issues when multiple dates are obtained from the same site context. This logical process considers context, sample integrity, cultural, technical, and other factors to obtain reasonable confidence in dating results. Yet the highest confidence is achieved when there is agreement in dating results produced by different techniques. In this study such correspondence occurred with sufficient frequency to indicate that TL dating may be employed independently with good confidence.

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