Timber procurement dynamics at the descendant Chacoan cultural center of Aztec Ruins, New Mexico

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Abstract

The second Chacoan capital at Aztec Ruins National Monument lies 85 km north of Chaco Canyon and includes four great houses, five enigmatic multi-walled structures, several road segments, and hundreds of other features. The extent to which this complex of monumental architecture required resource procurement from distant landscapes – a predominant feature of Chaco Canyon great houses – remains a mystery. We examine the origins of primary roof timbers for two Aztec great houses: the Chacoan-style Aztec West (1110-1120 CE) and the Mesa Verde-influenced Aztec East (ca. 1120-1260 CE). We compared the tree-ring growth patterns of 319 beams to tree-ring chronologies representing nine forested landscapes of the Colorado Plateau. Following the long-held assumption that most Aztec timbers were cut in the San Juan Mountains (25 km north) and floated down the Animas River, we were surprised to find that only 5% of beams came from this area, ruling it out as a major source of timbers. Instead, 45% of all Aztec beams and two-thirds of the beams from Aztec West – predominantly ponderosa pine – originated >100 km away in the Chuska Mountains. By contrast, over 60% of beams from Aztec East – predominantly junipers – originated in nearby woodlands along the San Juan River. Chuska-origin beams reflect the areas deep cultural significance to the Chaco Phenomenon. As Chaco Canyon waned, these beams helped to transfer power, knowledge, and spiritual practice to its new capital at Aztec. The mid-12th century shift to more local timber resources reflects a post-Chaco revitalization movement that spread across the Four Corners and centered on the architecture, material design, and ritual innovation of Mesa Verdean culture.

Introduction

The Chaco Phenomenon incorporated a regional system spanning over 50,000 km^2 of the Colorado Plateau in the southwestern US during the 10^{th}, 11^{th}, and 12^{th} centuries Common Era (CE). Its cultural and geographic center was in Chaco Canyon, where there is now one of the most densely concentrated arrays of monumental prehistoric structures in North America: the “great houses” of Chaco Canyon. Intensive archaeological investigations over the last century have revealed that the great houses required complex and dynamic resource procurement system for basic goods and materials (Cameron 2001; Benson et al. 2003; Grimstead et al. 2016; Mills et al. 1997), as well as some very distant trade for specific ritual items (Crown and Hurst 2009; Watson et al. 2015). This included hundreds of thousands of construction timbers (Dean and Warren 1983), which were sourced from forested mountain ranges over 75 km from Chaco Canyon (Betancourt et al. 1986; English et al. 2001; Reynolds et al. 2005; Guiterman et al. 2016). Where wood is locally unavailable, construction timbers comprise one of the most difficult and important materials to procure, requiring substantial human effort and organization (Windes and McKenna 2001). The dynamics of timber procurement are thus critical to investigate if we are to disentangle exchange networks, sociopolitical organization, religious motivations, and human-environmental interactions of prehistoric populations in the US Southwest.

Little is known about the timber procurement for great house structures outside of Chaco Canyon. Many of the >100 “outlier” structures (including great houses and great kivas) are situated in or near forested areas. The largest of these outliers is the present-day Aztec Ruins, located in central northern New Mexico along the Animas River, 85 km north of Chaco Canyon (Figure 1). Aztec includes four great houses, five enigmatic multi-walled structures, several road segments, and hundreds of other features (Brown et al. 2008; Glowacki 2015; Stein and McKenna 1988; Wharton et al. 2017). The great houses form the core of public architecture and appear to have been built sequentially; the entire community stretched for more than three kilometers along the Animas and its terraces (McKenna 1988; Cameron 2009; Turner 2019). Aztec became the center of political power after the decline of sites in Chaco Canyon in the 1120-1130s CE (Brown et al. 2008; Glowacki 2015; Reed 2008; Lekson 2015) and has been referred to as the second Chacoan capital (Lekson 1999). Van Dyke (2009) proposed that the configuration of the Aztec great houses West, East, and North may have been purposefully oriented to replicate the spatial relationship of Pueblo Bonito, Chetro Ketl, and Pueblo Alto in Chaco Canyon.

Archaeological investigations have been ongoing at Aztec for more than a century, beginning with excavations led by Earl Halstead Morris in 1916. Despite this long history and a sizable archaeological record, the Aztec great houses have received far less scientific attention than Chaco Canyon, leaving many unanswered questions regarding its connections to Chaco Culture, as well as the resource procurement, paleoenvironmental setting, and regional influences of Aztec itself. Here, we apply tree-ring sourcing methods recently established for the southwestern US (Guiterman et al. 2016) to assess the timber procurement dynamics of the East and West great houses at Aztec Ruins National Monument.

Figure 1. Panoramic view of Aztec West showing the C-Shaped great house and the reconstructed great kiva (right), Aztec Ruins National Monument. Photo by Rationalobserver, CC-BY-SA-4.0.

Aztec Ruins National Monument

Aztec Pueblo in north-central New Mexico was included in the UNESCO Chaco Culture World Heritage site designation in 1987, and falls under the jurisdiction of the US Department of Interior National Park Service as Aztec Ruins National Monument. The first excavations at Aztec Pueblo focused on Aztec West and Aztec East. These were conducted by Earl Morris from 1916 through 1927. Most of Morris's efforts were concentrated at Aztec West and only partial reports were published (Morris 1921, 1924a, 1924b, 1928), although the benefits of his careful excavations and particularly his collections of tree-ring samples are ongoing.

Morris obtained some of the first ever archaeological tree-ring specimens from Aztec West. In 1918, he sent six full cross-sections to the University of Arizona for Andrew Ellicott Douglass – the founder of modern dendrochronology – to examine. Douglass was able to cross-match the ring patterns, an initial demonstration of what would become the profound contribution of tree rings to archaeology. The following year, Douglass visited Aztec and had specialized tubular steel borers made that allowed Morris to extract 2.54 cm (one-inch) cores from intact roof beams without risking the structure (Figure 2; Douglass 1921). These specimens established a timeline for Aztec West, showing that its beams were cut after those obtained from Pueblo Bonito. Achieving calendar-dating for these and other prehistoric structures in the region would take another decade for Douglass and colleagues to "bridge the gap" between the floating archaeological tree-ring chronology and a modern chronology made of living trees and younger Pueblo structures (Douglass 1929).

The great houses of Aztec West and East have today yielded more tree-ring samples (>5,000) and more calendar dates (>1,200) than any other site in the southwestern US. Tree-ring samples have never been collected from Aztec North, and only three dates, all noncutting, have been derived from a few samples at Earl Morris Ruin. Until recently very little was known about Aztec North other than survey data and surface artifact analysis (Stein and McKenna 1988; Wharton et al. 2017). Turner's (2019) testing project at Aztec North has provided the first glimpse of the structural composition of this great house, but did not yield a single wood element for tree-ring dating or sourcing.

Aztec West is a C-shaped structure of approximately 450 rooms around a great kiva and two plazas, with as many as 28 blocked-in smaller kivas. Morris excavated much of the structure and adjacent areas. The tree-ring data indicate that Aztec West was built quite rapidly between 1110 and 1120 CE; a time when construction at great houses in Chaco Canyon was in rapid decline.

Much less research has been conducted at Aztec East. Only Morris' small-scale 1920s excavations and a few smaller projects contribute to our understanding of its architecture and cultural history. Based on a vast collection of *in situ* timbers cored by Thomas Windes of the National Park Service, we know that Aztec East was constructed over a long period, spanning the 1120s through the 1260s (Brown et al. 2008). The C-shaped great house is smaller than its neighbor to the west, including approximately 200-300 rooms. It contains at least five kivas, at least one of which is of "Mesa Verde style". The ceramic assemblage is dominated by Mesa Verde style pottery, such as Mesa Verde Black-on-White wares, but later polychome types, such as St John's Polychrome, are present as well (Reed 2017).

Morris hypothesized two separate occupations at Aztec: a Chacoan occupation (1110-1140 CE), mostly at Aztec West, and a later Mesa Verdean occupation (1200-1290 CE) at Aztec East that included some reoccupation of Aztec West. More recent research, however, shows a different and more complete story with a continuous occupation from 1070 through 1290. Ceramic dating shows that the earliest construction in the Aztec complex began no earlier than 1070, at Aztec North (Reed 2017; Turner 2019). Shortly after Aztec North was complete, stockpiling of materials and initial construction of Aztec West was underway probably in the late 1090s.

Turner's (2019) work also suggests that Aztec North was constructed by local builders with possible guidance from Chaco, but there is ample evidence to suggest that by 1100, Chacoan engineers and architects were part of a group who migrated to Aztec and focused their energies on building Aztec West (Brown et al. 2008). Immediately after the last stone was placed in Aztec West by 1120, construction began on Aztec East. Various lines of evidence demonstrate that although active use of Aztec North ceased between 1120 and 1140 CE, occupation of Aztec West and East was continuous until depopulation of the region by 1290.

Figure 2. Specimen H-53, a hand-drilled 2.54-cm (1-in) diameter ponderosa pine core collected by Earl Morris in 1919 from Aztec West. This core is among the first archaeological tree-ring specimens ever collected, and is currently housed in the collections of the Laboratory of Tree-Ring Research in Tucson, Arizona. The top photo shows the hand-hewn surface that Andrew Ellicott Douglass used to identify the ring pattern and provide tree-ring dates to Morris. The pinpricks mark decades of the early "relative dating" chronology, as he worked on this specimen before bridging the archaeological collections to modern trees in order to determine exact calendar dates. At bottom, a modern belt-sanded surface on the opposite side of the core reveals a clearer growth pattern for measurement and tree-ring width-based sourcing efforts. Pencil dots mark decades of calendar dating. This specimen dates 1061-1112 CE, and the beam was harvested in mid-summer from the Chuska Mountains.

Ceramic data suggest that occupation of Aztec West and East was continuous and the stylistic transitions from local Mancos, McElmo, and Mesa Verde Black-on-white types were continuous without a break (Reed 2017). Radiocarbon dating of corn cob specimens in association with pottery from a test unit in Aztec West corroborates the ceramic seriation (Reed 2017; Reed and Adams 2014). The tree-ring data support these finding and suggest a longer, slower construction period extending into the 13th century at Aztec East—generally termed a "post-Chacoan" occupation (Brown et al. 2008).

Construction materials for both Aztec West and East are generally assumed to be of local origins, given the position of Aztec in an extensive pinyon-juniper (*Pinus edulis*-*Juniperus* spp.) woodland and only about 25 km from the densely forested San Juan Mountains upstream along the Animas River. Some of the *Populus* from Aztec West were recently examined, showing the use of local cottonwood for many secondary beams but the inclusion of aspen trees shows that some wood was nonlocal, originating in the mountains (Tennessen et al. 2002). Excavations and surveys have revealed many distantly-sourced items from a variety of landscapes, including trachyte-tempered grayware pottery from the Chuska Mountains (Reed 2017), Narbona Pass chert from the central Chuska Mountains, and obsidian primarily from the Jemez Mountains (Turner 2019).

Materials and Methods

Tree-ring specimens from Aztec Ruins National Monument are housed in the collections of the Laboratory of Tree-Ring Research at the University of Arizona. The Aztec collection contain >5,000 specimens, of which 1,260 are precisely tree-ring (calendar) dated. From the dated collection, we selected specimens that have clear outside cutting dates and ≥30 rings, giving us a set of 699 beams to attempt tree-ring width based sourcing. We analyzed 329 (47%) beams, giving preference to those with a greater number of rings. Beams in our dataset encompass at least five species, including ponderosa pine (*Pinus ponderosa*), juniper (*Juniperus scopulorum*), Douglas-fir (*Pseudotsuga menziesii*), piñon (*Pinus edulis*), and a mix of spruce and fir (*Picea* and *Abies* species). We aimed for a representative dataset of each major structure. Some of the beams we measured, however, have archaeological provenances designated as "Unknown" or "Visitors Center", which we determined were predominantly obtained from West Ruin (Figure 3). We know from the documented history of excavations and preservation at Aztec that the visitor's center was roofed with some ponderosa pine beams salvaged from Aztec West.

To determine likely timber harvesting locations for each beam, we followed the methods of Guiterman et al. (2016). After verifying tree-ring dating visually and with skeleton plots, we measured the tree rings to the nearest 0.001 mm on a Velmex® system. These measurements were checked in the COFECHA computer program (Holmes 1983) to ensure data quality. Individual tree-growth time series were standardized with 50-year cubic smoothing splines in R using the dplR package (Cook and Peters 1981; Bunn 2008; R Core Team 2018). All series were correlated individually against a network of source-area chronologies from forest and woodland areas surrounding Aztec, NM (Table 1; Figure 4). To ensure coverage of the San Juan River valley, we added two new chronologies: the Beef Basin in southeastern Utah (Meko et al. 2007) and Mancos in southern Colorado (Stahle et al. 2015).

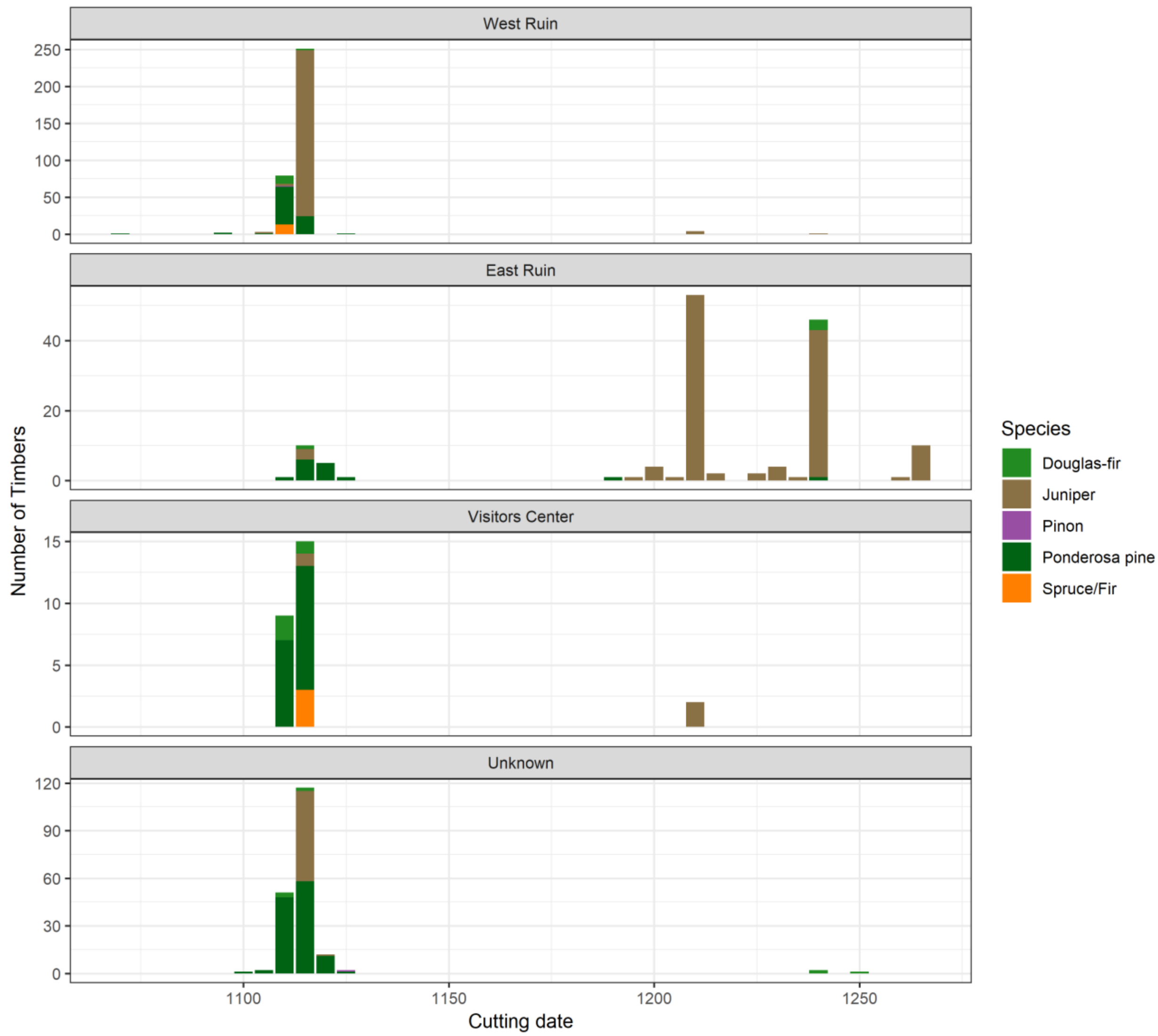

Figure 3. Timeline of cutting dates by architectural provenance, demonstrating that most "Unknown" and "Visitor's Center" samples came from Aztec West.

Table 1. Source-area chronologies representing forested areas of the San Juan Basin and greater San Juan River area

Location	Site code	Species	Date range	Latitude	Longitude	Elevation (m)	Reference
Beef Basin, UT	BFB	PSME	350-2005	37.96	-109.82	2000	Meko et al. 2007
Chuska Mtns	CHU	PIPO/PNN/JUN/DF	560-2010	36.08	-108.86	2650	Guiterman et al. 2016
Gobernador	GOB	PIPO	623-1989	36.73	-107.57	2230	Dean and Funkhouser
Mancos, CO	MAN	PSME	726-2011	37.27	-108.35	2245	Stahle et al. 2015
Mesa Verde	MVER	PSME	530-1989	37.22	-108.48	2263	Dean and Funkhouser
Mount Taylor	CEB	PIED	680-1986	35.55	-107.5	2072	Dean and Funkhouser
Northern Jemez Mtns	MEA	PP/PSME/PIST	644-2007	36.28	-106.63	2525	Guiterman et al. 2016 & Touchan et al. 2011
San Juan Mtns	DUR	PSME/PIED/PIPO/PIFL	-319-2009	37.42	-107.86	2213	Dean and Funkhouser; Bigio
Southern Jemez Mtns	JEM	PNN/PIPO	598-1971	35.67	-106.5	2011	Dean and Funkhouser
Zuni Mtns	CIB	PIED/PIPO/JUN/PSME	435-1971	35.33	-108.5	2072	Dean and Funkhouser

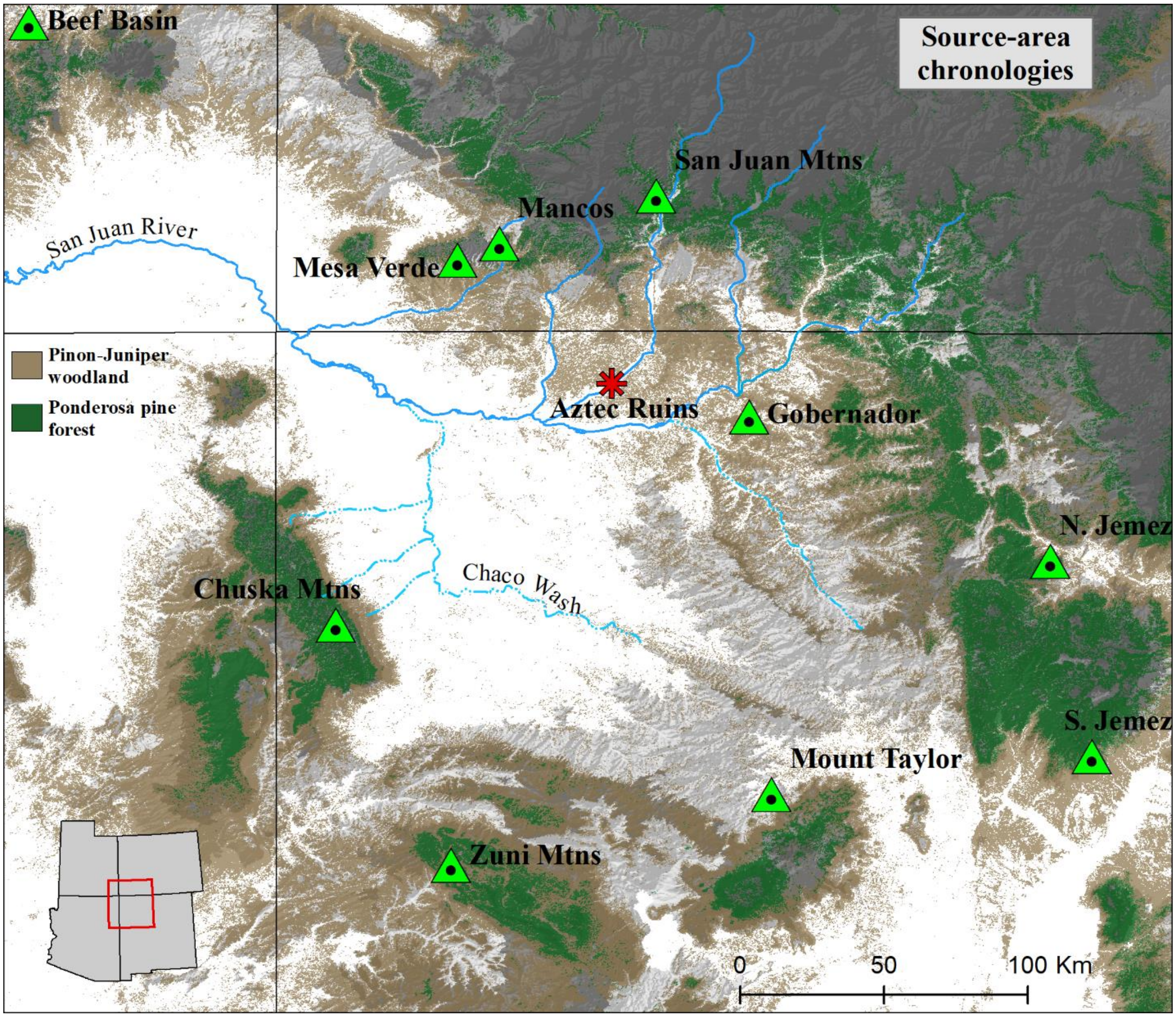

Figure 4. Distribution of source-area chronologies representing forested areas of the San Juan Basin and greater San Juan River.

Prior to conducting the correlation tests, we removed autocorrelation from each time series via autoregression modeling. Statistical significance of each Pearson's *r* correlation was determined via one-tailed *t* tests ($\alpha = 0.01$). Correlations were converted to *t*-values to aid in determining the strength of each correlation and comparing among them (Baillie and Pilcher 1973). Finally, we assigned the most probable source (growth origin) of each beam to the location with the highest significant *t*-value (Guiterman et al. 2016).

Results

We determined probable origins for 319 of the 329 beams, with cutting dates encompassing 1072 to 1263 CE. The majority of beams (45%) originated from the Chuska Mountains, more than 100 km southwest of Aztec (Figure 5). Local sources within the San Juan River valley also contributed a substantial number of beams, with 24% and 14% matching best to the Mesa Verde and Gobernador chronologies, respectively. The Mancos chronology near Mesa Verde adds an additional 7% of beams sourcing to the San Juan River valley. Given the broad distribution of piñon-juniper woodlands in the San Juan River valley (Figure 5), we interpret beams that source to these three chronologies as representing local cutting. Therefore, we found that 45% of beams were distantly sourced from the Chuska Mountains and 45% were locally sourced from the San Juan River valley. The San Juan Mountains, roughly 25 km north of Aztec and upstream on the Animas River contributed a total of 5% of beams.

Beams originating from the Chuska Mountains are primarily ponderosa pine. Seventy-one percent of the ponderosa pine we tested came from this distant landscape (Figure 6); the next highest source was the San Juan Mountains contributing 9% of ponderosa pine beams. Junipers were predominantly cut locally, with 64% of these beams originating from the San Juan River valley, but an additional 30% of junipers sourced to the Chuska Mountains (Figure 6).

Timber procurement patterns between Aztec West and Aztec East were strikingly different (Figure 7). Aztec West, largely constructed during the early 12th century from ponderosa pine beams, is composed of 64% Chuska-origin timbers. Aztec East, by contrast, was constructed during the later 12th and 13th centuries from local, San Juan River valley juniper (80% of the assemblage). These differences also highlight a change in timber origins through time (Figure 8).

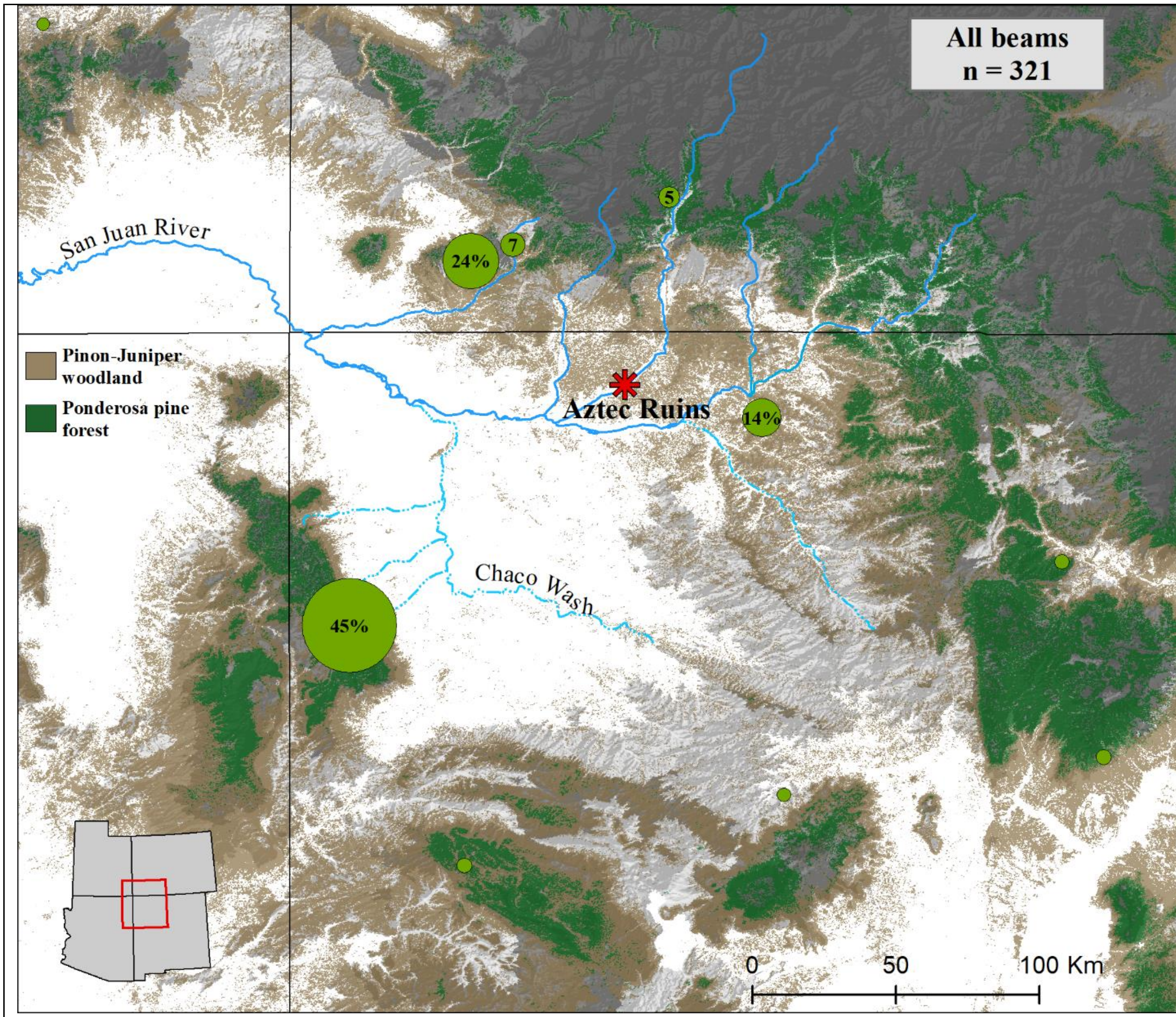

Figure 5. Regional sources for Aztec Pueblo construction timbers.

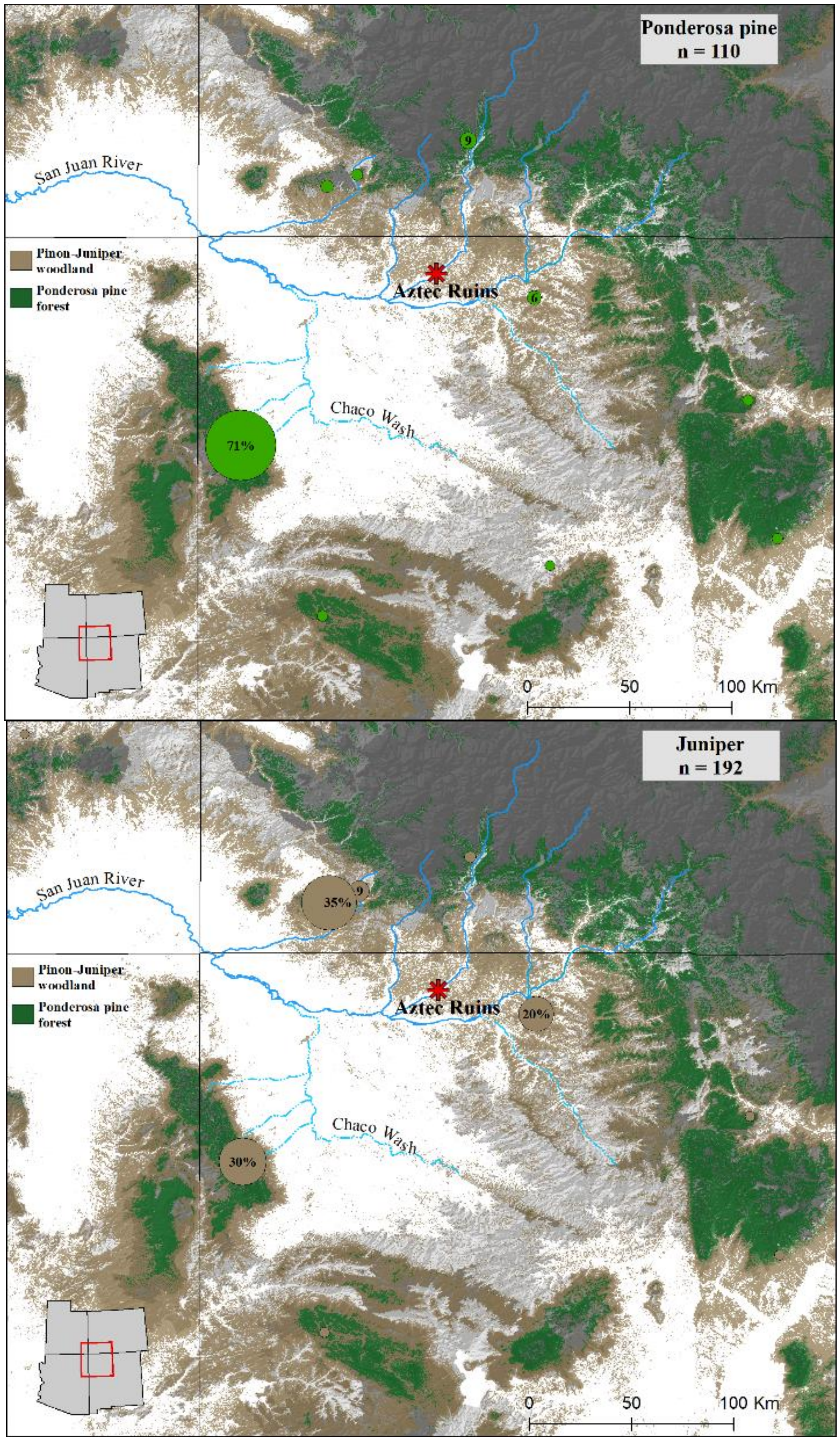

Figure 6. Sourcing results for ponderosa pine beams (top) and juniper beams (bottom).

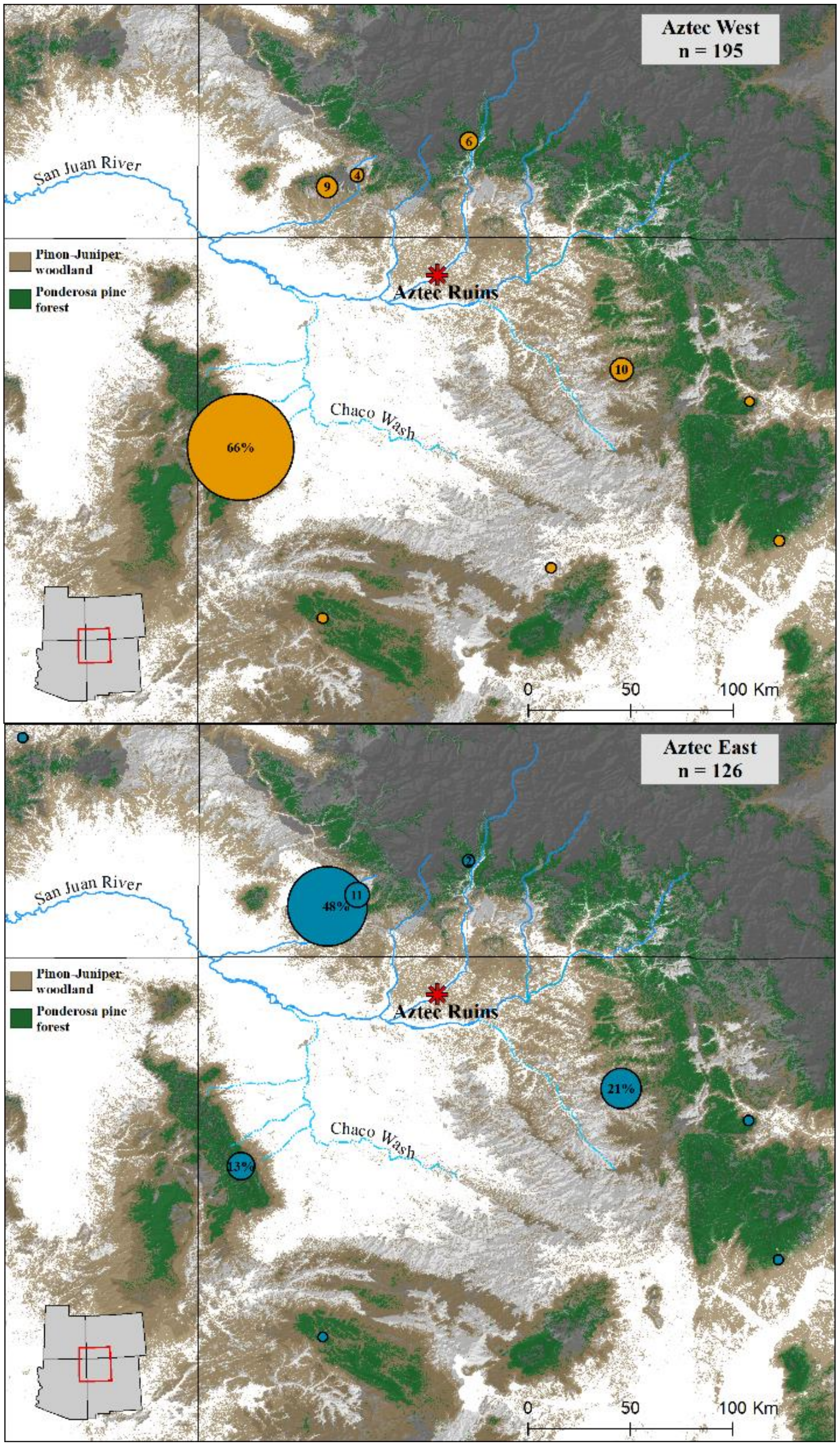

Figure 7. Sourcing results for the structures of Aztec West (top) and Aztec East (bottom).

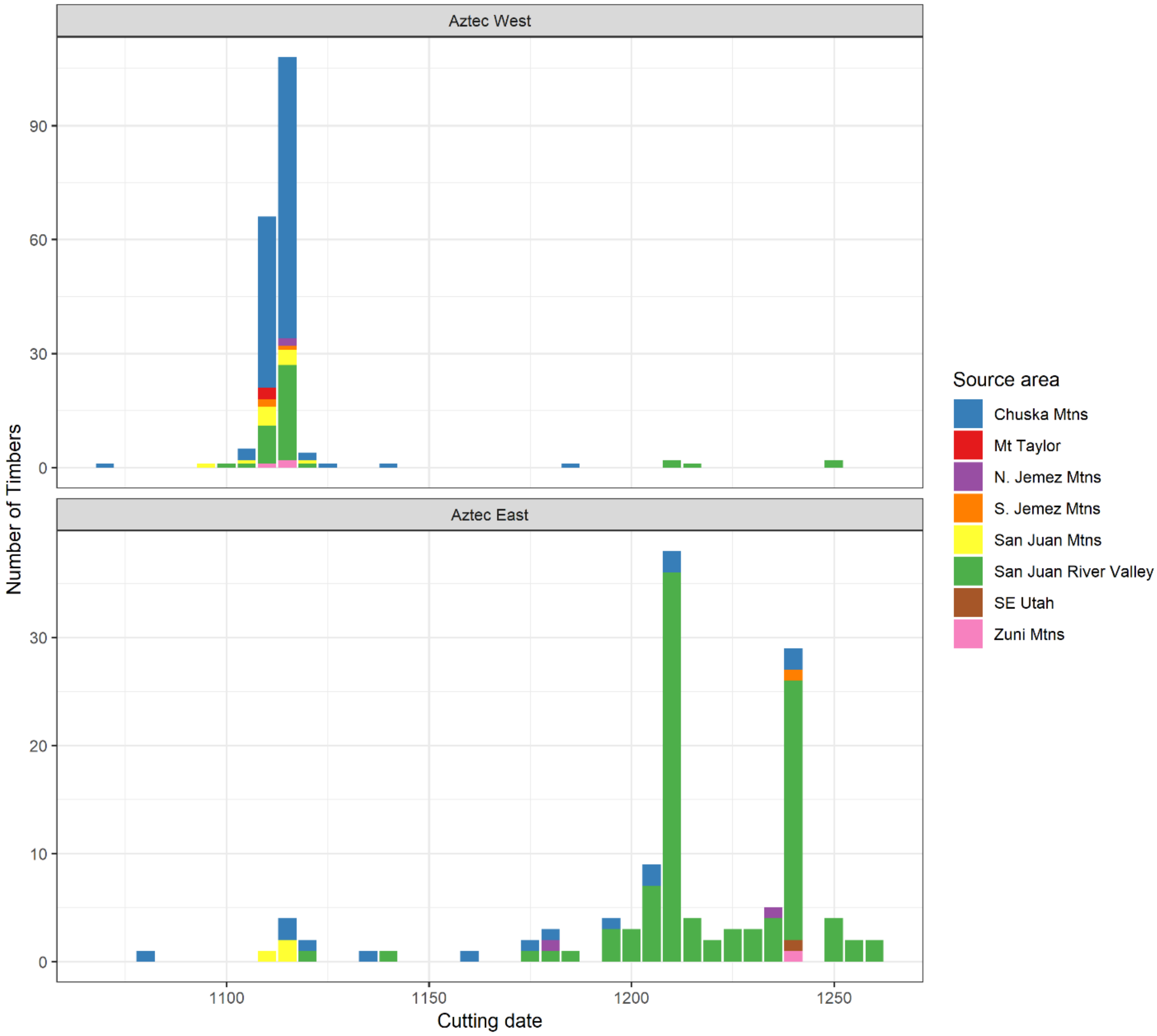

Figure 8. Timeline of timber origins for Aztec West and Aztec East structures.

Discussion

Our findings reinforce the idea that large Ancestral Puebloan communities during the Chaco Phenomenon employed complex and dynamic socioecological and economic systems for the procurement of basic, labor-intensive construction materials. At Aztec, we found multiple probable sources for construction timbers, with changing patterns between species, structures, and time periods. The majority of beams for Aztec West, a Chacoan-style great house, came from the Chuska Mountains, just as did the majority of beams used in Pueblo Bonito, Chetro Ketl and other important great houses in Chaco Canyon (Guiterman et al. 2016). By contrast, the majority of beams for Aztec East, a Mesa Verdean-style great house, came from local juniper woodlands, reflecting the pattern of wood use and probable procurement for Mesa Verde cliff structures.

Despite the proximity of Aztec to the forested areas of the San Juan Mountains, and potential procurement strategy of floating logs down the Animas River, few beams came from this area. The ponderosa pine and other conifers that were likely procured from the San Juan Mountains may have accompanied aspen, but aspen is plentiful in the Chuska Mountains, and is often found growing in mixed stands with ponderosa pine (Guiterman, personal observation). Based on beam procurement of only 5% of 329 specimens sourcing to the San Juan Mountains, we rule out the idea that most beams came from the nearby range. It may be that floating beams down river in a temperamental semi-arid climate that can easily lead to highly variable river flows, makes such an effort more arduous and unpredictable than archaeologists have assumed. Our view is that cultural factors and the reference point of origin were likely more important in the procurement of construction timbers than proximity or ease of transport.

As many researchers have proposed, great house construction within Chaco Canyon was orchestrated with very specific parameters regarding the types of materials used, the level of craftsmanship employed, and the configuration and orientation of structural components (Lekson 1984, 1999). These monumental structures were built with precision and a clear purpose to create a built landscape of great meaning. Timber origins of ponderosa pines at Aztec West supports the idea that the late Bonito Phase Chacoan system had extraordinarily close ties to the Chuska Mountains (Guiterman et al. 2016). This mountain chain lying directly to the west of Chaco Canyon was not only a source of timber but also provided a source of unique and high quality pink chert (Narbona Pass chert) and a shiny green volcanic rock (trachyte) used to temper pottery made in the Chuska Valley. The Chuska area was important for food production and meat procurement for Chaco (Grimstead and Benson 2015; Benson et al. 2003; Grimstead et al. 2016), though these archaeological records have not been tested at Aztec. At canyon-area Chaco great houses, major resource procurement efforts from the Chuska Mountains began circa 1020 CE and continued through the 1110s when construction largely ended (Guiterman et al. 2016). During the late 11th and early-12th centuries, the Chuska Mountains were the predominant area for construction and utilitarian goods at canyon sites. As construction efforts ebbed in Chaco Canyon, they peaked at Aztec West.

There are many reasons why the builders of Aztec West might have used ponderosa pines from the Chuska Mountains. These beams might have simply been the best available near large populations areas (i.e. the Chuska Valley) and as such were carried to Aztec West just as they were carried and distributed to nearly a dozen structures in Chaco Canyon. It is also possible that timbers used at Aztec West were not transported directly from the Chuska Mountains to Aztec Pueblo, a distance of ~100 km. We are unaware of any Chacoan Road that leads directly from the Chuskas to the Aztec area. The beams could have arrived at Chaco Canyon at the tail-end of the late 11th – 12th century construction effort, and were then brought north via the Great North Road (Lekson et al. 1988) to support new construction efforts at Aztec West in the 1110s. Finally and probably most likely, these beams, or at least their place of origin, might have held a spiritual meaning for Chacoans that was required to transfer to Aztec the cultural significance of a descendant Chacoan cultural center. Although we do not know the origin of structural beams from Aztec North – the first great house built by local folks in the Aztec complex – the great house built by Chacoan engineers (Aztec West) clearly contains a significant amount of beams from the Chuska Mountains. Thus, it would seem that in order to create the sacred space required by Chacoan builders at Aztec, beams from the Chuska Mountains may have provided a reference to a sacred point on the natural landscape as well as a possible reference back to Chaco Canyon itself.

In contrast to the overwhelming amount of wood beams from the Chuska Mountains in Aztec West, the trend at Aztec East is much different. By the time most of the construction at Aztec East was underway, the use of beams from the Chuska Mountains had probably lost its importance. As discussed by Brown et al. (2008), construction of Aztec East continued throughout the late 1100s and into the 1200s, beyond the collapse of the Chaco System at roughly 1140. Many have hypothesized that the Chaco collapse was spurred or accelerated by the severe and long-lasting 12th century megadrought (1130-1150; Woodhouse et al. 2010). Some have raised the question of whether the drought had large-scale ecological effects in the Chuska Mountains that disrupted the Chacoan system (Lekson and Cameron 1995; Betancourt and Guiterman 2016), and others suggest Chacoan leaders lost much of their sacred authority as agricultural production declined amid the drought. Construction efforts at Aztec nearly ceased during this period (Figure 8), reflective of broader socioecological effects of the mid-12th century drought and collapse at Chaco.

The late 12th century marks a transition from the Chuska-centric Chacoan System to local San Juan Area, Mesa Verde architecture, styles, and materials. This shift is evident in differences of masonry styles and room designs between Aztec East and West (Brown and Paddock 2011; Brown et al. 2008). It shows in the sharp decline of trachyte-tempered pottery present in ceramic assemblages from Aztec by the middle 1100s (Reed 2017). The shift of timber origins away from the Chuska Mountains and to local woodlands of the San Juan area underscores that this transition was deeply embedded in socioecological aspects of Aztec Pueblo. Our findings support the idea that the Chuskan influence on the Ancestral Puebloan societies ebbed during the mid-12th century and that the transition led to the dominance of the Mesa Verdean system that lasted for the next century.

Conclusions

Dynamic timber procurement strategies that include multiple tree species and harvesting locations that change with time, characterize the great houses of Chaco Canyon and Aztec Ruins. The two main structures at Aztec represent a transition in cultural foci, with wood use and origins that mirror the Chaco to Mesa Verdean transition. The points of origin for these societies – Chaco to the southwest in the Chuska Mountains, Mesa Verde to the west along the San Juan River – show the path that timbers followed during the three-hundred year course of construction at Aztec.

Cultural transitions likely incurred major social turmoil. In this case, it also reflects a revitalization movement across the Four Corners Region in the late 1100s after the collapse of Chaco's influence (Glowacki 2015). As Chaco's so-called second capital, the religious leaders at Aztec put great effort into revitalizing what was left of the Chaco power structure, which included continued construction at Aztec East and ritual innovation evident in construction of five multi-walled structures at Aztec, the highest concentration of these special structures in the region. The reach of this transition is evident in architecture, wood use, and timber procurement. How these changes are reflected in the large available archaeological record for Aztec Ruins is yet to be fully realized.

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References

Baillie, M. G. L., and J. R. Pilcher

1973 A simple crossdating program for tree-ring research. *Tree-Ring Bulletin* 33:7–14.

Benson, Larry, Linda Cordell, Kirk Vincent, Howard Taylor, John Stein, G Lang Farmer, and Kiyoto Futa

2003 Ancient maize from Chacoan great houses: where was it grown? *Proceedings of the National Academy of Sciences of the United States of America* 100(22):13111–5. DOI:10.1073/pnas.2135068100.

Betancourt, Julio L., Jeffrey S. Dean, and Herbert M Hull

1986 Prehistoric long-distance transport of construction beams, Chaco Canyon, New Mexico. *American Antiquity* 51(2):370–375.

Betancourt, Julio L., and Christopher H Guiterman

2016 Revisiting human-environment interactions in Chaco Canyon and the American Southwest. *Past Global Change Magazine* 24(2):64–65. DOI:10.22498/pages.24.2.64.

Brown, Gray M., Cheryl I. Paddock

2011 Chacoan and Vernacular Architecture at Aztec Ruins: Putting Chaco in its Place. *Kiva* 77(2):203-224.

Brown, Gary M., Thomas C. Windes, and Peter J. McKenna

2008 Animas Anamnesis: Aztec Ruins, or Anasazi Capital? In *Chaco's Northern Prodigies, Salmon, Aztec, and the Ascendency of the Middle San Juan Region after AD 1100*, edited by Paul F. Reed, pp. 231–50.

Bunn, Andrew G.

2008 A dendrochronology program library in R (dplR). *Dendrochronologia* 26:115–124. DOI:10.1016/j.dendro.2008.01.002.

Cameron, Catherine M.

2001 Pink Chert, Projectile Points, and the Chacoan Regional System. *American Antiquity* 66(1):70–101. DOI:10.1126/science.332.6028.417.

2009 Chaco and Post-Chaco in the Northern San Juan Region. *Chaco and After in the Northern San Juan: Excavations at the Bluff Great House*:18.

Cook, Edward R., and Kenneth Peters

1981 The smoothing spline: A new approach to standardizing forest interior tree-ring width series for dendroclimatic studies. *Tree-Ring Bulletin* 41:45–53.

Crown, Patricia L., and W. Jeffrey Hurst

2009 Evidence of cacao use in the Prehispanic American Southwest. *Proceedings of the*

National Academy of Sciences of the United States of America 106(7):2110–3. DOI:10.1073/pnas.0812817106.

Dean, Jeffrey S., and Richard L. Warren
1983 Dendrochronology. In *The Architecture and Dendrochronology of Chetro Ketl, Chaco Canyon, New Mexico*, edited by Steven H. Lekson, pp. 105–240. U.S. Department of the Interior National Park Service, Albuquerque, New Mexico.

Douglass, Andrew E.
1921 Dating our Prehistoric Ruins. *Natural History: The Journal of the American Museum* 21(1):27–30.
1929 The secret of the Southwest solved by talkative tree rings. *National Geographic*(56):736–770.

Van Dyke, Ruth M.
2009 Chaco reloaded: Discursive social memory on the post-Chacoan landscape. *Journal of Social Archaeology* 9(2):220–248. DOI:10.1177/1469605309104137.

English, Nathan B., Julio L. Betancourt, Jeffrey S. Dean, and Jay Quade
2001 Strontium isotopes reveal distant sources of architectural timber in Chaco Canyon, New Mexico. *Proceedings of the National Academy of Sciences* 98(21):11891–11896.

Glowacki, Donna M.
2015 *Living and Leaving: A Social History of Regional Depopulation in Thirteenth Century Mesa Verde*. The University of Arizona Press.

Grimstead, Deanna N., and Larry V Benson
2015 Another possible source of archeological maize found in Chaco Canyon, NM: The Tohatchi Flats area, NM, USA(December). DOI:10.13140/RG.2.1.1089.9046.

Grimstead, Deanna N, Jay Quade, and Mary C Stiner
2016 Isotopic Evidence for Long-Distance Mammal Procurement, Chaco Canyon, New Mexico, USA. *Geoarchaeology*.

Guiterman, Christopher H., Thomas W. Swetnam, and Jeffrey S. Dean
2016 Eleventh-century shift in timber procurement areas for the great houses of Chaco Canyon. *Proceedings of the National Academy of Sciences* 113(5):1186–1190. DOI:10.1073/pnas.1514272112.

Holmes, Richard L.
1983 Computer-assisted quality control in tree-ring dating and measurement. *Tree-Ring Bulletin* 43(1):69–78.

Lekson, S.H., and C.M. Cameron
1995 The abandonment of Chaco Canyon, the Mesa Verde migrations, and the reorganization of the Pueblo world. *Journal of Anthropological Archaeology* 14(2):184–202.

Lekson, Stephen H., Thomas C. Windes, John R. Stein, W. Judge, and James
1988 The Chaco Canyon community. *Scientific American* 259(1):100–109.

Lekson, Stephen H.
1984 *Great Pueblo Architecture of Chaco Canyon*. Publications in Archeology 18B, Chaco Canyon Studies. National Park Service, Albuquerque, New Mexico.
1999 *The Chaco meridian: Centers of political power in the ancient Southwest*. Rowman Altamira.
2015 *The Chaco meridian: one thousand years of political and religious power in the ancient Southwest*. Rowman & Littlefield.

McKenna, Peter J
1988 Late Bonito Phase Developments at the Aztec Ruins, New Mexico. In *53rd annual meeting of the Society for American Archaeology, Phoenix*.

Meko, David M., Connie A. Woodhouse, Christopher A. Baisan, Troy Knight, Jeffrey J. Lukas, Malcolm K. Hughes, and Matthew W. Salzer
2007 Medieval drought in the upper Colorado River Basin. *Geophysical Research Letters* 34(10):1–5. DOI:10.1029/2007GL029988.

Mills, Barbara J., Andrea J. Carpenter, and William Grimm
1997 Sourcing Chuskan ceramic production: Petrographic and experimental analyses. *The Kiva* 62(3):261–282.

Morris, Earl H.
1921 *The House of the Great Kiva at the Aztec Ruin*. *Anthropological Papers*. Vol. 26.
1924a *Burials in the Aztec Ruin*. *Anthropological Papers*. Vol. 26.
1924b *The Aztec Ruin Annex*. *Anthropological Papers*. Vol. 26.
1928 *Notes on Excavations in the Aztec Ruin*. *Anthropological Papers*. Vol. 26.

R Core Team
2018 R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Reed, Lori Stephens
2017 Ceramic Artifacts. In *Prehistoric Puebloan Community in the Animas River Valley: The Aztec Ruins National Monument Archeological Inventory*, edited by Jeffery T. Wharton, Lori Stephens Reed, and Aron J. Adams. National Park Service, Aztec Ruins National Monument, Aztec, New Mexico.

Reed, Lori Stephens and Aron J. Adams
2014 Closing the Gap at Aztec Ruins: Refining the Dating Sequence Using Corn and Pottery. Final report submitted to Western National Parks Association in fullfillment of WNPA Grant 13-01, Tucson, Arizona. On file at Aztec Ruins National Monument, Aztec, New Mexico.

Reed, Paul F
2008 *Chaco's Northern Prodigies: Salmon, Aztec, and the Ascendancy of the Middle San Juan Region After AD 1100*. University of Utah Press.

Reynolds, Amanda C., Julio L. Betancourt, Jay Quade, P. Jonathan Patchett, Jeffrey S. Dean, and John Stein
2005 87Sr/86Sr sourcing of ponderosa pine used in Anasazi great house construction at Chaco Canyon, New Mexico. *Journal of Archaeological Science* 32(7):1061–1075.

Stahle, D.W., J.R. Edmondson, J.N. Burns, D.K. Stahle, E. Kvamme, C. Lequesne, and M.D. Therrell
2015 Bridging the Gap With Subfossil Douglas-Fir At Mesa Verde, Colorado. *Tree-Ring Research* 71(2):53–66. DOI:10.3959/1536-1098-71.2.53.

Stein, John R, and Peter J McKenna
1988 *An Archeological Reconnaissance of a Late Bonito Phase Occupation near Aztec Ruins National Monument, New Mexico*. Division of Anthropology, Branch of Cultural Resources Management, Southwest~….

Tennessen, David, Robert A. Blanchette, and Thomas C. Windes
2002 Differentiating Aspen and Cottonwood in Prehistoric Wood from Chacoan Great House Ruins. *Journal of Archaeological Science* 29(5):521–527. DOI:10.1006/jasc.2001.0746.

Turner, Michelle I
2019 Becoming Chacoan: The Archaeology of the Aztec North Great House. Doctoral Thesis. State University of New York at Binghamton.

Watson, Adam S., Stephen Plog, Brendan J. Culleton, Patricia A. Gilman, Steven A. LeBlanc, Peter M. Whiteley, Santiago Claramunt, and Douglas J. Kennett
2015 Early procurement of scarlet macaws and the emergence of social complexity in Chaco Canyon, NM. *Proceedings of the National Academy of Sciences*:201509825. DOI:10.1073/pnas.1509825112.

Wharton, Jeffery T., Lori Stephens Reed, and Aron J. Adams
2017 *Prehistoric Puebloan Community in the Animas River Valley: The Aztec Ruins National Monument Archeological Inventory*.

Windes, Thomas C., and Peter J. McKenna
2001 Going against the grain: Wood production in Chacoan society. *American Antiquity* 66(1):119–140.

Woodhouse, Connie A, David M Meko, Glen M MacDonald, Dave W Stahle, and Edward R Cook
2010 A 1,200-year perspective of 21st century drought in southwestern North America. *Proceedings of the National Academy of Sciences of the United States of America* 107(50):21283–8. DOI:10.1073/pnas.0911197107.