TERMINUS ANTE QUEM CONSTRAINT OF PUEBLO OCCUPATION PERIODS
IN THE JEMEZ PROVINCE, NEW MEXICO

by

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**Abstract:**

Using dendroecological and archaeological methods and data we investigated the temporal dynamics of forest regeneration and fire history following depopulation of four large Pueblo IV period (1300-1600) villages on the Jemez Plateau, New Mexico. With tree rings we reconstructed the timing of reforestation on village footprints after depopulation – a novel approach to *terminus ante quem* dating of site occupation. Our tree-ring based forest age structure and fire history chronologies enabled us to reduce by 51 to 70 years the range of previous estimates of village depopulation dates derived primarily from terminal ceramic assemblages. One of the four village sites we investigated was depopulated in 1696, two were depopulated between 1625 and 1700 CE, while the fourth village was depopulated earlier (pre 1500), but the area was likely in continued use for agriculture or other seasonal purposes until the mid-1600s. Our results indicate that the Jemez were highly influential ecological agents. Forest structure and fire regime dynamics changed greatly after the departure of most people from these landscapes after circa 1650 CE. The *terminus ante quem* methods that we demonstrate in the Jemez Mountains have strong potential to constrain and refine low temporal resolution chronologies of human occupation at archaeological sites within other forested ecosystems of the Southwest and elsewhere.

**Introduction:**

*Background*

Humans have lived within fire-prone forest landscapes of the Southwestern United States for millennia. The Jemez Mountains of northern New Mexico are exemplary of a complex human-natural system where ancestral Pueblian people lived for hundreds of years. Throughout the region there are many archaeological and tree-ring records of human occupation, forest fire, and climate that extend well into the historic period (i.e., post 1541 CE). These materials provide an opportunity for in-depth investigation of human-forest-fire relationships (Elliott 1982; Swetnam et al. 1989; Allen et al. 2002, Kulischeck 2005;
Liebmann 2012). At least six large village sites (all with more than 500 rooms, at least two with more than 1,500 rooms) were occupied within or very near ponderosa pine forests, contemporary with initial Spanish contact in the late 16th century. The highest density of the ancestral Jemez population was focused on the Jemez Plateau, a roughly 400 square kilometer area in the southwestern part of the Jemez range (Figure 1). Populations were likely high enough during the early historic period (i.e., 1590s-1620s) to meet the modern definition of a “wildland urban interface” (WUI, i.e., the population density was more than 25 people/square kilometer, Radeloff et al. 2005; Kulischeck 2005; Liebmann et al. in preparation).

Forest areas of the Jemez region are now understood to be a fire-adapted landscape. Extensive tree-ring reconstructions from dozens of forest stands in the Jemez Mountains show that widespread surface fires occurred in ponderosa pine-dominant forests about once or twice per decade between 1650 and 1880 (Swetnam et al. 1989; Touchan et al. 1996; Allen et al. 2002; Falk et al. 2011). Given the human populations present during the Pueblo IV period (1300-1600 CE), humans were inevitably significant ecological agents. Extensive land use, such as timber and fuel wood harvesting, widespread agriculture, and hunting resulted in a strongly interrelated human-natural system (Kulischeck 2005; Elliott 1982, 1988). The arrival of Spanish soldiers and colonists in the late 16th century was followed closely by the congregation of natives around missions. This first began in 1598 with Fray Alonso de Lugo’s mission at Giusewa, in present-day Jemez Springs, New Mexico. Jemez population movements during this time led to abrupt changes in the ecology of this human-natural system.

Ecosystem resilience in the context of long-term, high density human occupations is a poorly understood, yet increasingly consequential issue in the context of climate change, population growth and forest management (Bowman et al. 2009, 2011; Falk et al. 2011; Allen et al. 2002). A combination of these processes has shifted many ecosystems in the Southwestern United States outside of their historical range of variability (Allen et al. 2002). This has created, among other things, dramatic changes in fire regimes, replacing high frequency low severity disturbance events with low frequency stand-replacement events (Covington 1997; Fulé et al. 1997; Allen et al. 2010; Stephens et al. 2005). The availability of
human and ecological records on the Jemez Plateau provides a unique opportunity to investigate an ecosystem that was likely pushed outside of its historical (or ‘natural’) range of variability during high human population density (from circa 1300 to 1690 CE) and then returned, for a time (circa 1690 to 1890 CE), to what is now considered a classically natural (i.e., no or relatively low influence of humans) Southwestern ponderosa pine ecosystem and fire regime. Our study approaches these problems utilizing a combination of long-term ecological and archaeological reconstructions from tree-rings. These data provide long-term perspectives that are essential for understanding the full range of variability in these systems, including the effects of both high and low intensities of human land uses. Our study provides evidence-based explanations of past and recent changes, and can help identify states of the system that were relatively more or less sustainable or resilient. This in turn informs necessary forest restoration efforts (Swetnam et al. 1999; Meador et al. 2014; Hessburg et al. 2014, Reynolds et al. 2013).

**Study Goals**

Our broadest goal in the study of this coupled human-natural system was to improve our understanding of long-term, human-forest-fire interactions by exploiting the unique geographical, ecological, and historical opportunity of the Jemez landscape. We were especially interested in examining how forests and fire regimes changed within and near large village sites in the context of intensive human occupation followed by depopulation. We focused our study on three main activities. First, it was necessary to determine dates of depopulation, and compare our results with independently produced tree-ring and ceramic dates – essentially determine where people were over time. Second, we attempted to characterize forest demography and fire history in proximity to villages before, during and after occupations of large villages on the Jemez Plateau. Last, we compared our forest age structure and fire reconstructions to climate data to evaluate interannual controls on fire occurrence and spread, as an alternative or additional variable explaining temporal and spatial fire history changes. Fundamentally, these research themes were designed to identify, and at least partially quantify, the extent of human influences on Jemez forest ecosystems and fire regimes. We aimed to evaluate and characterize the transition from what we refer to as an "ancient
WUI to a fire-forest ecosystem less influenced by human activities until the mid or late 19th century, when large numbers of livestock were introduced and active fire suppression began (Swetnam et al. 1989; Allen et al. 2002).

The Jemez Province and Chronological Limitations of the Region

One important objective of our study was to evaluate the chronology of mass depopulation for large Jemez villages, thereby allowing us to better characterize human-forest dynamics by comparing fire history before and after major human occupation of sampled sites and the landscape. By “depopulation” we mean the village rooms, built structures, and nearby areas were no longer occupied or utilized in more than a transient manner, i.e., there were much lower levels of human presence and utilization than previous to the Spanish enforced congregation (circa 1600 CE). That is, we use the term "depopulation" with implicit recognition that some degree of human presence and effects remained in these areas after these times. In some cases, village sites may have transformed from year-round occupation to strictly seasonal usage. For example, field house structures have been documented immediately adjacent to village structures, suggesting that construction occurred after depopulation of the primary village for agricultural activities (see Kulischeck 2005 for detailed descriptions and discussion of the field house phenomenon in the Jemez Mountains).

The geographic and cultural extent of Jemez peoples, commonly known as the Jemez Province, is largely defined by the distribution of Jemez Black-on-white pottery (Liebmann 2006). Liebmann (2006) writes “Jemez Black-on-white is often considered exceptional among northern Rio Grande ceramics due to its perceived homogeneity and lengthy temporal extent” (pp. 326, see also Kulischeck 2005). It is also notable that this particular ceramic tradition allows inference into social networks and behavior. Morley (2002) writes, “Jemez Black-on-white shows little or no standardized style,” suggesting, “a degree of agency exhibited by Jemez potters not typical of their Tewa neighbors” (Morley 2002, pp. 237; Liebmann 2006). Additionally, material culture present in this area has what several archaeologists have termed a “xenophobic” approach towards other Rio Grande technologies (Liebmann 2006, pp. 327; Morley 2002).
The distribution of this decorated ware is almost entirely centered on the Jemez Plateau landform (Liebmann 2006; Elliott 1982; Reiter 1938). Essentially, this means two things. First, viewing the Jemez community via a landscape scale case study is quite appropriate. Archaeological and ethnographic evidence suggests that social identity throughout the region was, in part, driven by an intrinsic set of cultural norms and can be approached as a cohesive unit of study (Liebmann 2006; Reiter 1938; Lambert 1981; Elliott 1991; Futrell 1998). Second, because of relatively few excavations and tree-ring based dating of Jemez ancestral village ruins, the chronology of occupations of most sites and population movements across the Jemez are based primarily on low temporal resolution ceramic-based interpretations. As a result, any temporal refinement via tree-ring sampling and analyses has high potential to greatly improve our understanding of Jemez chronology, and therefore our ability to characterize human-natural interactions.

Terminus ante quem Dating Applications in the Jemez Province

Assigning mass depopulation dates via *terminus ante quem* methods has yet to be explored or applied in extensive case studies in the Southwest. In this context, by *terminus ante quem* we mean the dendrochronological crossdating (sensu Douglass 1947; Stoke and Smiley 1968) of ring-width patterns in living or dead trees that are growing (or grew) within and immediately adjacent to Puebloan village ruins. This method has a lengthy history of application elsewhere. For example, the counting of tree rings in living trees growing within ruins to approximate tree ages, and hence minimum time since last occupation, was employed by Reverend Manessa Cutler in ancient Ohio mound structures in 1778. This approach of tree-ring counting to estimate minimum time since last occupation of dwellings in a ruined state was also described by Thomas Jefferson in 1799 (Silverberg 1986; Willey and Sabloff 1993). In our analysis we used dendrochronological crossdating of living and dead tree specimens rather than simple counting of the tree rings in living trees. We utilized the *terminus ante quem* method to evaluate and improve on site chronologies previously estimated by ceramic methods, and we then used our refined dating estimates to inform our ecological analyses. The tree-ring derived depopulation dates constrained
the temporal extent of occupations and enabled us to better characterize Pueblo IV period human impacts, including the effects of timber and fuel wood extraction on forested areas surrounding village structures, and immediate consequences to the fire-forest system.

We hypothesized that the history of intensive land use and the subsequent changes after the establishment of Spanish missions had profound and measurable effects on local forest and fire dynamics. Further, we expected that tree-ring reconstructions of tree establishment and fire frequency changes would show a lag time relating to the time required to transition from a human-natural system to a fire-forest system. In addition, fire extent and seasonality within the immediate and nearby surrounding areas of large village structures would show temporal and spatial changes corresponding with alterations in human presence and land use. We also hypothesized that fire, if present during sizeable occupations, would not generally be controlled primarily by climate effects on fuel moisture, connectivity, or ignitions by lightning. In particular, depletion of fuel amounts and disruption of fuel connectivity (continuity) via foot traffic, agriculture, and timber harvesting would have limited fire spread, and potentially even removed large spreading surface fires typical of the region from the measurable record. People may also have purposely burned portions of the landscape for various reasons (e.g., clearing agricultural fields of pine needles, weeds, grasses, and prior season's crop residues). Effectively, this would have increased ignitions, and could have influenced fire greatly during certain seasons when fires started by lightning are less frequent (see Allen 2002; Fule et al. 2011). Last, we expected fire after large scale depopulation will be driven by climatic factors, most importantly the availability of fine fuels (essential for fire spread) and drought. This study aimed to test these hypotheses by sampling living and dead trees and applying tree-ring analyses of forest age structures, fire histories, and climate within and near Jemez ancestral village sites.
Methods:

Study Area Description

The Jemez Plateau is part of a collapsed volcanic caldera west of Santa Fe, New Mexico at 35.8° N, 106.5° W (figure 1). A complex of mesas and canyons defines the plateau, much of which is covered by fire-adapted ponderosa pine forests. Northern Pueblo peoples lived on the plateau for more than 700 years, with populations in the Pueblo IV period (1300-1600 CE) estimated to be between 5,000 and 7,000 individuals (Kulischeck 2005; Liebmann et al. in preparation). Fray Zarate Salmerón claimed 6,556 baptisms at Giusewa in 1622 (Liebmann 2006; Kulischeck 2001, 2003; Liebmann et al. in preparation). During the Pueblo IV period (1300-1600CE), the Jemez occupied at least nine major multistory villages, with room counts as high as 1,850 (Kulischeck 2001, 2005, Elliott 1982). These villages are located mainly in ponderosa pine (Pinus ponderosa) forests and the ecotone between ponderosa and pinyon-juniper woodlands (Pinus edulis, Juniperus monosperma, Elliott 1982, 1986; Kulischeck 2005). It is generally thought that the villages were occupied mainly during the winter and that the Jemez population dispersed across the Jemez Plateau during the spring and summer months for agricultural production, occupying small, one to several room structures known as "field houses" (Kulischeck 2005). Field houses are remarkably common across the Jemez Mountains, with at least 3,483 documented in recent years (Liebmann 2006).

Again, tree-ring dates from architectural timbers are relatively rare in the Jemez Mountains, especially considering the abundance of archaeology covering the landscape. Lack of tree-ring dates from architectural timbers is generally due to the fact that few excavations have been completed or permitted in this area. In cases where villages were excavated (in the early 1930s), or beams were recovered from extant walls, roofs or rubble mound surfaces, the tree-ring dates show late prehistoric construction (e.g., 1560s-1570s CE at Unshagi and Nanishagi, with some earlier construction periods evident as well, i.e., 1300s-1500s, Reiter 1938, 1940; figure 1). A few early historic period dates have also been documented (e.g., 1611-1612 at Kwastiyukwa, 1610s-1620s at Giusewa, associated with the San Jose mission church
at Walatowa, and 1680s at Boletsakwa, a post-Pueblo Revolt refugee site Elliott 1982; Kulischeck 2005; Liebmann 2006).

Absence of tree-ring dates generally means occupation periods on the Jemez Plateau are defined via several ceramic traditions. The Jemez Province itself is considered regionally unique because of Jemez Black-on-white pottery, the limitations of which have been discussed previously (Liebmann 2006; Morley 2002). In addition, there are utility and trade ware traditions that correspond well to northern Rio Grande technologies. More specifically, corrugated wares were quite common, and imported glaze painted ceramics – likely traded north from the Zia region – were also present (Liebmann 2006). However, glazed trade wares existed in very low quantities (< 3 percent of total surface assemblage, around 1 percent datable rim sherds, Liebmann 2006). Glaze type dates are problematic because of their relatively low temporal resolution, generally corresponding to long blocks of time that are difficult to integrate with annual resolution tree-ring datasets (Habicht-Mauche et al. 2006). Further, ceramic type dates are difficult to acquire at many sites without implementation of invasive and destructive methods. This includes thousands of seasonally occupied field houses where decorated trade wares were not often used and assemblages tend to be deposited below ground (Kulischeck 2005). As a result, the uncertainty of Jemez site-level chronologies limited our ability to interpret human-natural and early Spanish-Jemez interactions.

Our study utilized extant remnant wood and living trees to define the earliest tree recruitment/establishment on village sites and their vicinity. There are two immediate benefits of these reconstructions. First, we could independently test the accuracy of ceramic dating of Jemez villages. Second, we increased the precision of terminal occupation dates by comparing tree establishment with the final glazed ceramics at each individual village. To elaborate, the most recent glazed ceramics present within villages occupied at the time of Spanish contact were generally Rio Grande Glaze F, a technology that spanned 1625-1700 (Habicht-Mauche et al. 2006). Given the presence of glaze F, we could infer that depopulation occurred sometime between 1625 and 1700. We tested this inference by dating the
establishment of the earliest trees on or nearby the village site. Our assumption was that tree establishment dates would likely follow by a small number of years (<10), or at most by one to two decades, depopulation of village sites. (We also tested this assumption with an example of a known occupation/depopulation case, i.e., Boletsakwa, a 1680 Pueblo Revolt refugee site, and tree establishment dating). Tree age reconstructions may therefore refine previously estimated occupation periods at individual village sites determined by late Rio Grande glazes.

We selected eight ancestral Jemez village sites for initial collections, and we prioritized a subset of four village sites for detailed study based on sample size, sample quality, ethnographic information and ceramic provenance. These included villages known as "Boletsakwa", "Kwastiyukwa," "Tovakwa" and “Wabakwa” (Laboratory of Anthropology numbers LA136, LA482, LA484 and LA478 respectively). Site names in the Jemez are inconsistent over the archaeological history of the region, but for the purposes of this paper we use these names, and the Laboratory of Anthropology site codes indicate the specific sites we are referring to. These sites are some of the largest and best documented village ruins in the Jemez Province, largely dated with northern Rio Grande ceramic chronologies (Elliott 1982, 1988).

We selected Boletsakwa (LA136) as special case for testing our assumptions, because it is exceptionally well dated due to a strong oral history, original Spanish documents, and tree-ring dates of architectural timbers from the ruins (Robinson et al. 1972; Liebmann 2006, 2012). This site provided the best opportunity for comparison between our tree-ring records and independently produced dates from documentary and architectural timber dates. Most importantly, Boletsakwa served as an initial validation of the *terminus ante quem* method we later applied to other Jemez sites. A cluster of architectural beam tree-ring dates indicate construction occurred in 1683. This was three years after the general uprising, known as the Pueblo Revolt of 1680, that led to the temporary expulsion of Spanish colonists and soldiers from the upper Rio Grande region. Boletsakwa was depopulated immediately preceding the reconquest of the province by Don Diego de Vargas, his Spanish soldiers, and Indian allies in the mid 1690’s (Liebmann 2006; Robinson et al. 1972; Kessel et al. 1995, 1998). Vargas noted specifically in his journals
that Boletsakwa room blocks “had been swept clean and nothing left in them,” and the site was “abandoned, apparently at the beginning of winter,” likely late 1693 or early 1694 (Kessel 1998, pp. 371). A small, multiethnic reoccupation, including Jemez people and other Puebloan refugees, also occurred in 1695 (Liebmann 2006).

Like other villages in the Jemez area constructed and occupied during this era (e.g., Astialakwa and Patokwa on Guadalupe Mesa, see Liebmann, 2006), Boletsakwa appears to have been constructed as a refuge and defensive site. It is located on a narrow, cliff-edged mesa top (2,207 meters elevation), overlooking the Paliza Canyon tributary to the Jemez River valley. Given the relatively recent history and exceptionally good chronology of Boletsakwa, we anticipated that a tree-establishment reconstruction would serve as a useful test of the terminus ante quem techniques and interpretations. That is, tree ages and fire history at Boletsakwa would provide a test of our basic assumptions about lag times between depopulation, tree establishment, and fire responses. Based on positive results in these analyses (discussed later) we applied our method to other large village sites in the Jemez with less well-established (or highly uncertain) dates of occupation and depopulation.

Our second site was Kwastiyukwa (LA482, also sometimes called the “Giant Footprint Ruin”). The site had an estimated at 1,250 rooms and is situated at 2,315 meters (7,595 feet) elevation, on the ecotone between pinyon-juniper woodland (Pinus edulis, Juniperus monosperma) and ponderosa pine forest (Pinus ponderosa). As with most of the large Jemez villages, Kwastiyukwa is on a gentle, south-sloping mesa top. The complex of ruin mounds, plazas and kiva depressions covers nearly a square kilometer. Based primarily upon ceramic assemblages, occupation has been dated between the 1300s and 1700 CE (Elliott 1982, 1986). Despite depopulation sometime in the 17th century, much of the site remains as extensive rubble mounds that are essentially treeless, in stark contrast to the surrounding pinyon-juniper and ponderosa pine forests. Occupation dates were previously derived from several ceramic types, including Jemez Black-on-white, corrugated utility wares and late Rio Grande glazewares (Elliott 1982, 1988; Habicht-Mauche et al. 2006).
A small room block at the north end of Kwastiyukwa appears to have been built and occupied later, with about a dozen large structural timbers, and a number of wood shards likely to have come from (reused) *vigas* lying on the rubble mound and within fallen room block walls. Tree-ring dates were collected here, with a single cutting date in 1611, and two more in 1612. Some additional noncutting date samples were dated to the early 1400s and 1500s (Robinson et al. 1972). The “barracks-like” (sensu Elliott 1988) appearance of this structure and the presence of the large *vigas* on the surface is anomalous within Jemez archaeology (Elliott 1982, 1986). It is possible that this portion of the ruin represents a relatively small reoccupation after the 1680 Pueblo revolt. Given the early nature of the tree ring dates, reoccupation and reuse of beams from older structures at the site (Robinson et al. 1972) seems the most likely explanation. However, this seemingly separate room block is very small (10-20 rooms), and refuge populations probably would not have produced the same ecological impacts as the primary Pueblo IV occupation. Alternatively, the barracks may have simply been the last occupied portion of the village, constructed in 1611 or 1612, and persisting sometime into the glaze F period (Elliott 1982; Personal comm. Liebmann 2013).

We selected Tovakwa (LA484, also known as Stable Mesa Ruin), based on characteristics similar to Kwastiyukwa. The village was possibly the largest in the Jemez Province, with an estimated three stories and 1,850 rooms (Elliott 1982). Located at 2,482 meters (8143 feet) elevation, Tovakwa sits on a south sloping mesa between aspect-dependent pinyon-juniper woodland and ponderosa pine forest. Ceramic evidence indicated the site was occupied over a span similar to Kwastiyukwa, i.e., from the 1300s to sometime before 1700 CE (Elliott 1982, 1986; Habicht-Mauche et al. 2006). Ceramics present included Jemez Black-on-white, Rio Grande glazes D, E and F, in addition to plain, smudged, and corrugated utility wares (Elliott 1982, 1986). This site may have served as an integrative center for the region, with the largest Jemez Province kiva (17.5 m./58 ft. in diameter) situated on a terrace adjacent to the site, in addition to five large plazas and 13 smaller kiva depressions (Elliott 1982).
Wabakwa (LA478) was the most poorly dated site included in this study. Ceramic chronologies placed the occupation between 1175 and 1500 CE based on corrugated and Jemez Black on White wares (Elliott 1982; Morley 2002; Liebmann in preparation). Wabakwa had about 1,400 rooms and was located at 2,341 meters elevation (7,680 feet). As with the other sites in this study, the village sat on the Ponderosa pine-Pinyon-Juniper ecotone. Several factors differentiated this site from Tovakwa and Kwastiyukwa. Primarily, ceramic evidence indicated that depopulation occurred much earlier. In addition, several fieldhouses were located directly on the footprint of the village, and in the immediate area. Wabakwa as a study site therefore gave us an opportunity to test the temporal boundaries of the *terminus ante quem* method, and also investigate the presence of what appeared to be an agricultural complex directly adjacent to the ruin.

*Field Collection and Dendrochronological Crossdating*

Surfaces of ruins and the surrounding areas were sampled completely for non-archaeological remnant wood (i.e., stumps, logs, and snags) in order to reconstruct the original, tree establishment chronology on and around the site that followed depopulation. We also sampled occasional old-appearing living trees that were growing in the area. In general, most living trees on or very near the ruins appeared to be relatively young (<200 years old) and were therefore unlikely to represent the first generation of trees that established in these areas following the generally known depopulation time period of the 1620s (or earlier) to the 1690s (i.e., about 400 to 300 years ago). Hence, our primary targets for sampling were ancient remnant tree-ring materials within and near the ruins. We expected that these were the original establishing trees on the site after depopulation. We removed cross sections from wood present on and within 120 meters of the site with a chainsaw. In order to get the most accurate establishment date, sections were taken at or near the root crown (Savage et al. 1996).

We also targeted alternative sources of remnant material in resource-limited environments, such as dry rocky slopes and cliffs very near the village sites. These are settings that tend to foster slow growing, dense wood, long-lived trees, and excellent preservation of remnant wood from ancient trees.
(Schulman 1954). For example, at Tovakwa, we also sampled a 1 kilometer transect along an adjacent cliff band bordering a steep canyon. Remnant wood here appeared ancient in nature. Our assumption was that the canyon and hill slope below the cliffs would have served as a likely pathway for fire during occupation periods because the difficult topography would have limited human alteration of fuel loads. Humans at the time would have likely collected wood primarily from areas farther away on the relatively flat mesa top instead of negotiating steep trails up the hill slope and narrow defiles through the cliffs.

We stabilized samples with wood glue and plywood. Each section was then polished with a belt sander using progressively finer grits until individual cells were clearly visible under a binocular microscope (Baisan and Swetnam 1990). In assigning each ring to a calendar year we used both visual and statistical dating methods (Stokes and Smiley 1968; Stokes 1996; Holmes 1994). Tree establishment dates were placed in ten-year bins to account for imprecision of these estimates. By “tree-establishment” we mean dates within 3 to 5 years of when tree seeds actually germinated. Determining exact germination dates of conifers is arduous and not always possible. More specifically, it requires dissecting and sampling exactly at the original root/shoot boundary at the height/depth on the bole in the soil where the seed began growing (Savage et al. 1996). We therefore sampled as close to the estimated root crown as possible. In cases where we sampled above the root crown we used an adjustment (added years) to account for number of years for the shoot to grow to the sample height. These adjustments were produced with growth rates derived from ponderosa pine in similar environments (i.e., about 5.9 centimeters per year for the first 1.37 meters of growth, see Puhlick et al. 2012; Margolis 2014). In cases where the pith, or center of the tree was not present, we estimated number of rings to center using concentric ring circles matching the width and curvature of the sample’s interior rings (Applequist 1958; Villaba and Veblen 1997). All samples that were successfully dated included, or were sampled close to the pith (discernable by the curvature of the interior rings). Therefore, our assigned establishment dates almost certainly had an error range within the ten year bins used for germination dates. Earliest dates of tree establishment were identified and a *terminus ante quem* depopulation date was subsequently assigned.
In addition to tree establishment we also noted the presence of fire injuries. These injuries are indicative of low severity surface fire, which likely postdated village depopulations. We assumed that spreading fires within or very near the villages capable of scarring standing trees would have been highly unlikely during occupation periods. That is because fuel wood gathering and the milling around of many people for decades and centuries would have left essentially no continuous fuels in the immediate area needed to carry spreading fires. Alternatively, if fire did somehow approach the village, it is logical that the Jemez would have protected their structures (i.e., wood-roofed homes and wooden ramadas, fences, and firewood piles, etc.) by suppressing wildfires. A few years to a decade or so after depopulation trees would have established within and around the village sites, along with grasses and shrubs, enabling spreading fires to occur. Therefore, the earliest fire scars present in the extant wood on ruin surfaces likely are the first fires occurring after mass depopulation and the recovery of continuous fuels on the site.

When possible, the season, or intra-ring position, of fire injuries was also noted (Figure 2). Fire injuries, or scars, occur when resident heat from fire kills part of the cambial tissue on the lower bole where cell division occurs, but does not kill the tree itself (Baisan and Swetnam 1990; Falk et al. 2011). Living tissue that is heat-killed is often protected from combustion by the bark, which eventually sloughs off the tree leaving the dead wood tissue exposed. The tree then begins growing over, or compartmentalizing the injury by adding new cellular growth from adjacent live cambium over the dead tissue. As a result, the date of the injury (fire) is determined by location of the injury within a dated tree ring. Furthermore, the intra-ring position, or season of injury, can also sometimes be identified (Dieterich and Swetnam 1984). The portion of cellular tissue killed through the bark stops dividing after it is killed by the fire. As the tree grows over the exposed tissue, it preserves the part of the ring where the fire occurred. Comparing this position to the phenology of ring growth allows us to estimate what part of the growing season (or dormant period) the injury occurred in. By convention, there are five intra-ring subdivisions that scars are located within: dormant, early wood, middle early wood, late early wood and late wood (Figure 2, Baisan and Swetnam 1990). An additional category of "unidentified" was assigned in
cases where it was not possible to confidently identify intra-ring position. This was usually due to very narrow rings, decay, charring or other obscuring characteristics of the ring/scar boundaries.

**Analyses**

Fire frequency at each site was analyzed using program FHX2 (Grissino-Mayer 2001). In addition, we used FHX2 to analyze fire scar seasonality and created site and landscape composites to investigate fire drivers and spatial extent. This was accomplished via minimum percent scarred and sample scarred “filters” applied across one or multiple sites (Swetnam and Baisan 1989; Kulakowski et al. 2003; Grissino-Mayer 1995, 1999). Compositing of fire scar data and then filtering (i.e., estimating fire frequency based on classes of estimated fire extent within sites) is useful for assessing relative extent of fires, with widespread fires assumed to be represented by high percentages of trees (>20) at a site recording the same fire date. It is possible to introduce various spatial biases with non-randomly distributed samples in space or time. However, these relativistic estimates of fire extent (e.g., fire intervals computed in percentage-scarred classes) have been shown to correlate very well with absolute area burned time series from independent documentary records in Southwestern ponderosa pine forests (Farris et al. 2010).

The most widespread fire dates within and among widely separated sites generally correlate well with inter-annual climate patterns (i.e., widespread fire years associated with dry seasons or years, e.g., Swetnam and Betancourt 1990; Swetnam 1993; Farris et al. 2010). For example, a fire present in multiple sites across an entire mountain range likely relates to climate, a regional phenomenon. Further, areas escaping these widespread events, or localized events within a region, are generally driven by localized factors, such as a village population removing nearby fuels or other microclimate or topographic influences (Swetnam and Betancourt 1990; Iniguez et al. 2008; Farris et al. 2012; Samuels and Betancourt 1982; Kohler 1992; Kohler et al. 2008). Essentially, we used this method to assess fire events across multiple spatial scales and ecosystem types (Swetnam 1993; Grissino-Mayer 1999). We filtered and composited 31 site-level fire chronologies across the Jemez and compared similarities and differences.
across the region (Figure 3). Each site was filtered to define a fire as a minimum of two trees injured within a given year. We then compared fire events at Boletsakwa, Kwastiyukwa, Tovakwa and Wabakwa to the regional compilation. This enabled us to identify synchronous and asynchronous fire patterns, which we generally inferred to be regional climate-driven events versus those controlled more by local, human factors, respectively.

Fire climate relationships were further explored using program Fire History Analysis and Exploration System (FHAES), which is based on programs FHX2 and EVENT (Grissino-Mayer 1995; Swetnam 1993). FHAES provides a Superposed Epoch Analysis (SEA) module. With SEA we compared fire history chronologies and Palmer Drought Severity Indices (PDSI), a tree-ring based reconstruction of wet and dry years (Cook et al. 1999; Swetnam 1993; Grissino-Mayer 1995; Holmes 1994). The SEA was produced by averaging annual climate reconstruction values surrounding a fire event. The program calculates average conditions during, prior to, and after event years, and also computes confidence intervals (significant dry or wet values were identified at p< 0.05 level) by means of a Monte Carlo simulation (Grissino-Mayer 2001).

Tree-ring based PDSI reconstructions are available across North America on a 2.5 degree grid, and in New Mexico these time series encompass the period from 800 to 2003 CE (Cook et al. 1999). For our objective of comparing local fire event chronologies to regional drought patterns, we averaged northern New Mexico PDSI time series from two grid points (119 and 133), and used this composite time series for assessing fire-climate patterns at each village. This ensured that the PDSI time series represented a widespread region, encompassing the entire northern half of New Mexico. We then generalized conditions during and surrounding fire events in four scenarios: (1) where a fire year was only present at a single site, (2) where all fire years present on village sites were included, regardless of commonalities between sites, (3) where a minimum of two villages experienced fire in the same year, and (4) where fire years were present during an occupation period. Further, we investigated limiting factors of fire spread, such as fuel and moisture, specifically by noting positive or negative averaged values within
the analysis window exceeding the 95% confidence intervals (i.e., significance levels of $p < 0.05$, Swetnam 1993; Swetnam and Baisan 1996). In the context of this study, SEA provided a basis for us to further characterize drivers of fire post-depopulation of large Jemez villages.

**Results and Discussion:**

*Forest Demography and Fire History at Village Sites*

We collected 65 samples at Boletsakwa, 44 of which were successfully crossdated. Undated sections generally had too few rings for confident crossdating, or were otherwise problematic. Only two trees were present during the occupation of the site (i.e., ages of about 5 and 14 years old) at the time of construction of the refugee village in 1680-1683 (Figure 4). These would have been very small saplings (<5cm) in the early 1680s. Two trees established between 1690 and 1699, eight trees from 1700 to 1709, and an additional five originated between 1710 and 1719 (Figures 4, 5 and 6). Our assigned *terminus ante quem* date for depopulation at Boletsakwa was therefore 1699 (1699 being the final year of the first ten year bin where trees established after the 1683 construction), which gives us a known error of four years.

This period of tree establishment immediately follows the known depopulation date of 1695. We interpret that this abrupt and clear tree establishment response as related to the depopulation of Boletsakwa. A likely mechanism of this response was the cessation of fuel wood gathering, ground disturbance, etc. following depopulation of this village in 1695. After multiple seasons of winter freezing and thawing, seasonal rains, and rodent activity, the hard-packed soil horizons within and around the villages would have loosened. Seeds from nearby mature trees would then have opportunities to disperse to the site, germinate and establish in the soils. Overall, we expected this process would not be immediate upon depopulation, but may have required several years to a decade or more. The results from Boletsakwa generally confirm this expectation, hence we considered this essentially a "validation" (i.e., an affirmative test) of our *terminus ante quem* approach, providing a basis for applying it to other cases where there were only ceramic-based estimates of site depopulation dates.
At Boletsakwa, we observed 42 fire scars, and 6 replicated fire events (minimum of 2 trees recording a fire scar in the same year, figures 2 and 4). The first replicated fire event occurred in 1742. A 47 year lag, therefore, was present between the last known occupation in 1695 and the 1742 fire. We interpret the cause of this multi-decadal lag in spreading fires on this site as a product of the time necessary for the buildup of sufficient surface and arboreal fuels to carry fire (i.e., grasses, pine needles and branches from nearby and recently established trees). During occupation (1683-1695) there would have been extensive and heavy collection of wood for construction timbers and fuels for necessary cooking and heating fires. Resource extraction such as this would have limited fire spread by eliminating or breaking up the continuity of the local fuel matrix.

Out of the 42 dated fire scars, we were able to assign an intra-ring position, or seasonal timing, to 20 scars (figure 2). Scars were formed predominantly during the dormant season (25%) and the early wood season (70%). That is, the dormant season scars occurred between the last formed latewood cells of the previous ring and the earlywood cells of the next ring. The early wood scars occurred at some location within the earlywood cells and prior to the latewood cells forming (Figure 2). Only a single scar was present within the latewood cells (5%). This intra-ring scar distribution generally coincides with the seasonal timing of pre-1900 fires in the greater American southwest (Swetnam and Baisan 1996, 2003), i.e., most fires likely occurred just prior to or during the major period of cambial growth in the spring and early summer (i.e., April to June). Weibull median fire intervals were calculated for individual trees (14.6 years), ten percent class (15.6 years) and twenty percent class (16.6 years). Fire years exceeding the twenty percent class, or widespread threshold, included 1742, 1756, 1764, 1773, and 1822.

We collected 62 samples at Kwastiyukwa, 34 of which were successfully crossdated. Undated sections, for the most part, had too few rings for reliable crossdating. Tree recruitment began between 1630 and 1639, with five trees establishing between 1630 and 1669 (figures 6 and 7). We therefore assigned a *terminus ante quem* date of 1639 to depopulation of Kwastiyukwa (figure 7, 1630 to 1639 is the first 10 year bin where trees established). The most recent ceramics present at Kwastiyukwa are Rio
Grande glaze F, and these are interpreted to date between 1625 and 1700 (Habicht-Mauche et al. 2006). Our tree establishment observations therefore shorten the dating window suggested by ceramics by about 60 years. Again, by our working definition of “depopulation” we interpret that post-occupation tree establishment reflects the end of intensive and continuous presence of relatively large numbers of people at the site, but other less intense presence of people and use of the site may have continued, or occurred episodically.

Within fire scarred sections collected from Kwastiyukwa we observed 70 fire injuries and 11 fire events, i.e., years with at least two fire scars present. The first replicated fire event occurred in 1685, 46 years after our assigned terminus ante quem date of depopulation. This is remarkably similar to the 47 year lag at Boletsakwa. We determined intra-ring positions of 37 scars. Most scars were dormant season (13.5%) and within the early wood (78.3%), with three instances of latewood injuries (8.1%). We used the fire scar observations to reconstruct median fire return intervals in three classes – individual scarred (15.0 years), >10 percent scarred (10.2 years) and >20 percent scarred (13.9 years). Event years exceeding the 20 percent class included 1685, 1767, 1773, 1789, 1801, 1806, 1810, 1829 and 1840.

Collections at Tovakwa included 30 trees from the ruin and immediate vicinity. Of these, 22 samples were successfully crossdated. Eight sections had too few rings to confidently crossdate. Tree recruitment at Tovakwa began in the 1640’s, with five trees establishing between 1640 and 1649. We therefore assigned a depopulation date of 1649 (1649 being the final year of the 10 year bin where trees first establish, see figures 6 and 7). This estimate shortens the ceramic dating window by 51 years.

We based the fire frequency analysis at this site on 46 injuries; 18 scars were assigned an intra-ring position (39 %). Seventeen scars occurred on the ring boundary or within the earlywood part of the ring (94%) with only 1 latewood scar present (6%). Eight replicated fire events occurred, the first in 1668 – following our estimated date of depopulation by 17 years. Scars occurred mainly in the earlywood portion of the ring, with three exceptions in the latewood tissue. As with LA136 and LA482, median fire return intervals were reconstructed in three classes – individual (24.1 years), >10 percent scarred (23.9
years), and >20 percent scarred (34.7 years). Fire years exceeding the 20 percent class included 1668, 1773, 1795, 1829, and 1840.

At Tovakwa we opportunistically collected an additional 27 samples along a one kilometer transect following a nearby canyon edge (starting approximately 180 meters from the village footprint). Of these sections, 13 samples were dated, the remaining sections were problematic because of missing rings and suppressions caused by injury, drought and otherwise extreme growing conditions. From these data we determined that some trees were present in these cliff-edge locations during occupation of Tovakwa in the 1500s and early 1600s, and that a number of surface fires burned on or around this area near the village. Scars (fires) occurred in 1502, 1594, 1607, 1623, 1645, 1647, and 1658, with five pre-1649 fires occurring during the likely occupation period. However no fire scars were present in more than a single tree, suggesting that these were not widespread fires. We found no evidence of trees establishing or fires occurring within the village footprint during the occupation period (before circa 1649).

Seasonality of fires in the cliff-edge and slope locations, however, does conform to our expectations of the natural fire season of the region, i.e. 100 percent of assigned intra ring positions (4 in total) occurred in the early wood part of the ring. Overall, we interpret the presence and survival of ancient trees in the cliff band area during occupation to the stunted and twisted nature of their boles, and relative inaccessibility, making them unsuitable for roof timbers. The fire scars on these trees may have been caused by surface fires spreading from the canyon and slopes below the cliffs. These fires may have been caused by lightning strikes on the exposed cliff edges or trees, or by people purposely or accidentally setting fires on the slopes below the cliffs.

We collected 50 samples at Wabakwa, 27 of which we were able to crossdate. Tree recruitment begins with a single tree in the 1550s, followed by a gap in the record until continuous establishment starts in the 1630s. Based on the single tree established in the 1550s, we assigned a 1559 terminus ante quem date. Ceramic evidence indicated that the village was depopulated, at the latest, in 1500. However, surface assemblages collected from nearby fieldhouses indicate that agriculture was taking place within
500 meters of Wabakwa between 1625 and 1700 CE (as determined by Rio Grande Glaze F, personal comm. Kulischeck 2015). These agricultural sites were likely related to the later village occupation at the nearby Seshukwa (1300-1700CE), and indicate changes in land use that may have limited ‘natural’ ecological processes from becoming dominant after the early Wabakwa depopulation (Elliott 1982).

Fire frequency analyses was based on 101 injuries and 19 fire events. In total, 55 injuries were assigned an intra-ring position (54.5%). The first replicated fire event occurred in 1676, following the terminus ante quem date by 126 years – a much longer lag time that any other site included here. Fire intervals were analyzed in the individual class (16 years), 10 percent scarred class (12 years), and the widespread, or 20 percent class (15.5 years). Widespread fire years included 1676, 1685, 1696, 1724, 1729, 1745, 1752, 1773, 1818, 1842, 1860, 1875, 1893, and 1898. Seasonality of fire injuries did not generally coincide with the greater Southwest at this site, with more late season injuries present than expected. There were 13 scars found on the ring boundary (23.6%), 8 in the early wood (14.5%), 7 in the middle early wood (12.7%), 20 in the late early wood (36.4%) and 7 in the latewood tissue (12.7%).

**Regional Comparisons of Fire and Superposed Epoch Analysis**

Fire events (2 trees recording a fire at a village) were compared to a regional composite of widespread fire (more than 25 percent of sites recording a fire, and for the period 1630 to 1920) comprising 31 Jemez fire histories (figures 2 and 10). In addition, fire regimes were compared between village sites (Table 1). We chose these comparisons to investigate both the inter-village and intra-regional similarities across landscapes and quantify local variation. At Boletsakwa, 2 of 6 replicated fire scars (33%) were also present in the regional composite, and 2 of 6 (33%) fires were present at Kwastiyukwa, Tovakwa or Wabakwa. Kwastiyukwa had 6 of 11 fires (55%) in common with the landscape composite, and 6 of 11 (55%) events in common with other village sites. At Tovakwa we observed 4 of 8 (50%) events present in the regional composite, with 6 of 8 fires observed at another village site. Wabakwa had 8 of 14 (57%) fires in common with the regional, and 4 of 14 (29%) with another village site. These similarities --both inter-village and intra-regional events -- suggest that inter-annual climate variation was a major driver of
fire occurrence, tending to synchronize fire activity (i.e., occurrence and spread) after the villages were depopulated.

More detailed aspects of the fire-climate relationships were explored in 4 scenarios using Superposed Epoch Analysis (SEA, figure 9). In each scenario different results were observed. The period of comparison for each iteration included the period when recruitment was occurring (i.e. the first to the last date of establishment). In iterations 1, 2 and 3, this was from 1550-1640 CE, and in the fourth SEA we used 1450-1640 CE. SEA 1 included all fires at all four sites (i.e. since all replicated events from the village fire histories were included; this means that at least one, and up to three sites were experiencing any given fire year), and showed a significantly wet year preceding a significantly dry fire year by 2 years (n = 28, p < 0.05). Scenario 2 was all fires when two or more sites experienced a fire and showed the same results, except the preceding wet year averaged a higher positive value (n = 8, p < 0.05). In the third SEA, where only a single site experienced a fire, a significant dry value was produced in the fire event year (n=20, p=0.05). These results largely coincide with expected patterns of ‘natural’ climate driven fire after circa 1639. Scenario 4 is perhaps the most interesting, where fire was occurring during occupation in the drainage adjacent to Tovakwa (i.e., prior to 1649 CE). No significant values were observed in this SEA, which indicates that climate was not necessarily the main driver of the recorded scars (n = 8, p > 0.05).

Conclusions:

Application and Limits of the Terminus ante quem method

Tree-ring based terminus ante quem dating can effectively constrain occupation periods defined by late Rio Grande glazewares. Boletsakwa is possibly the best dated ancestral village in Jemez archaeology. Here we observed strong seedling recruitment immediately after Vargas himself noted recent depopulation in the mid 1690s (Liebmann 2006). The strong surge of tree establishment in this context firmly illustrates the potential application of terminus ante quem dating via dendroecological sampling methods. Further, terminus ante quem dates assigned at Tovakwa and Kwastiyukwa fall within the
terminal glazeware period, and generally confirm the validity of the ceramic dating. Most importantly, however, tree establishment dates at our study sites significantly precedes the end of the glaze F period (1700). This indicates depopulation of these village sites occurred somewhere between 1630 and 1650 and significantly constrains occupation end dates. In addition, these dates suggest substantial quantities of Glaze F ceramics were in use at Jemez villages prior to 1650, in contrast to H.P. Mera’s original classification (1650-1700 CE, Mera 1935). Our method has verified existing, ceramic-based (and a few tree-ring construction timber-based) site dates, and greatly improved our understanding of ancestral Jemez movements. This non-invasive, non-destructive method of occupation end dates is an excellent resource in poorly dated settings, and there is good potential to apply it across the forested American Southwest.

We did not observe the same clear results at Wabakwa. Tree recruitment begins (with a single tree, 1550 CE) a minimum of 50 years after the terminal ceramic dating period. This is in contrast to Kwastiyukwa and Tovakwa, where we observed trees establishing within the terminal glaze period. There are at least two possible explanations for the longer lag time observed here. First, we may simply have reached the temporal limit of the terminus ante quem’s application at this particular location. Alternatively, land use at Wabakwa may have continued intensively after depopulation of the village proper, thus delaying transition from a human-natural to a fire-forest system.

Several factors support the latter of these explanations. Wabakwa is located quite close to Seshukwa, another village occupied through the Pueblo IV period. Ceramic evidence from two fieldhouses (LA 23672 and LA 24503) located very near to Wabakwa (<500 meters) indicate intensive agricultural production in the area through the mid-1600’s. Additional fieldhouses can be found even closer (at least 3 within 100 meters) and are likely contemporary with other fieldhouses in the area (Personal communication Kulischkeck 2015). In addition, depopulation at Wabakwa pre-dates the 1598 Spanish Mission at Giusewa, and local populations, therefore, did not experience pressure to centralize around churches. It is possible that populations were still strongly present in this area, and the longer than
expected lag time post-depopulation is in fact a *terminus ante quem* of continuing intensive land use. Abrupt tree establishment at Wabakwa, starting in the 1630s and 1640s, would also fall in line with this hypothesis. Meaning, after depopulation of the main village structure, agricultural production continued, in addition to the collection of fuel wood and anthropogenic segmentation of the landscape. Then, as with Tovakwa and Kwastiyukwa, the *congregación* efforts enforced by the Spanish in the early 17th century (discussed below) initiated a landscape shift from a human-natural to a fire-forest system.

Our *terminus ante quem* technique was corroborated by several ecological and historical factors. Primarily, we observed similar processes at three different geographical locations, corresponding to three distinct time periods. Further, all *terminus* dates fall near a known occupation end or within an independently determined ceramic dating period. In addition, recruitment occurred simultaneously with early Spanish missionization efforts. A small mission at Giusewa (San Jose de los Jemez) was established in 1598, followed by further construction of two additional churches in the early 1600s (Liebmann 2006; Kulischeck 2005). The arrival of Spaniards introduced policies of *reducción* and *congregación*, where natives were systematically and coercively centralized around missions. It is probable that the mountain dwelling Jemez were no exception to these policies during the early part of the 17th century, when local Spanish influence dramatically increased. Our *terminus ante quem* dates coincide quite well with this local history, suggesting mid-17th century depopulation/migration towards valley missions and the transition from a human-natural to a fire-forest system. Further, original Spanish estimates of populations decreased dramatically between 1621 and the mid 1600’s, indicating that other factors, such as disease or a Jemez exodus from the region, significantly reduced local populations (Kulischeck 2005).
The Jemez People as Agents of Disturbance

Inevitably, the Jemez people themselves were agents of ecological disturbance, and specifically, they altered fire and forest dynamics. As an analogy, the effects of high-severity fire on post-fire development of ponderosa pine forest structure may bear some similarity to forest dynamics in and around ancestral Jemez villages following depopulation. To elaborate, upper elevation forests tend to have fire intervals that are longer than lower elevation, drier forests (Fulé et al. 2003). In these settings, fires tend be mixed-severity, or high-severity, meaning that extended periods without fire results in resetting events where fire kills off many trees, thus opening up the forest canopy. Subsequently, the dynamics of competition change within the burn area, and shade-intolerant trees (such as ponderosa pine) can often re-establish in the openings in a short period of time (Heyerdahl et al. 2001, 2011; O’Connor et al. 2014). This dynamic, however, requires that canopy openings are relatively small and/or that some residual trees survive the disturbance event so that necessary seed sources are available. If canopy openings from disturbances are too large (100s to 1000s of ha.), forest regeneration may be very slow, or may not occur at all because seed sources and micro-site conditions (e.g., sufficient warmth are limiting). This is particularly the case for ponderosa pine forests, where seed production is erratic and seed dispersal limited to 150 meters or so (Haffey 2014).

Researchers have generally identified "cohorts" of post-disturbance establishing trees as cases when 5 or more trees from small plots (i.e., 0.1 ha, or the first 30 trees from plot center) originate within a 30 year period, and these trees were not preceded by earlier recruitment (Heyerdahl et al. 2001, 2011). This is an indicator that high-severity fire was present previous to the pulse of tree recruitment (Heyerdahl et al. 2011; Margolis et al. 2007; O’Conner et al. 2014). Tree establishment dates from Tovakwa exceed the requirements by this definition, with 10 trees establishing within a 30 year period. Samples at Kwastiyukwa and Boletsakwa also nearly meet the definition of a cohort. We observed 5 trees establishing within a 40 year period at Kwastiyukwa, in addition to 15 originating at Boletsakwa within 30 years (preceded only by two seedlings before the occupation). These observations leave no doubt that the Jemez people were agents of ecological disturbance and their effects on contemporary and subsequent
forest dynamics is observable in extant tree-ring materials. Of course, the analogy to severe fire is incomplete. In any case, it is highly evident that the participatory role of the Jemez people in forest ecology of the Jemez Plateau was profound.

Ecological Impacts of Jemez Populations

Strong periods of tree recruitment, followed shortly by the re-establishment of a high-frequency, low-severity fire regimes, appears to have occurred at different points in time and at different locations on the Jemez landscape. We are confident that these similarities through time and space are not coincidence, but in fact a processual transition from a primarily human-dominated system (prior to the mid 1600s) to a fire-forest system that was much less (but probably not entirely) affected by human activities, and much more controlled by non-human-related, vegetation/fuel and climate dynamics. There are several key inferences that can be made from this transition, specifically regarding forest structure and disturbance dynamics during major occupations. First, the Jemez likely had a tremendous extractive influence on wood resources in the area of their villages and for some distance away from villages. There were only two trees present during occupation at any of the sites (total n=128) sampled in within and immediately adjacent to the villages. We strongly doubt that this was strictly the result of a deteriorating natural record as we have often found ancient wood, and occasionally living trees, extending into the 1500s, 1400s and earlier in the Jemez and the greater Southwest.

Therefore, we propose that large-scale high density occupations significantly affected forest structure in the immediate area of village sites (i.e., <120 meters) by removing stems and woody fuels from the ground. Ancient anthropogenic deforestation has been reported in many studies across the greater southwest and depletion of local fuels has been suggested to have played major roles in the depopulation of many areas – Chaco and Mesa Verde to mention a few (Samuels and Betancourt 1982; Kohler 1992). Further, Jemez dominated culture was spread over the entire Jemez Plateau (around 450 square kilometers), with many contemporaneous occupations. It follows that the total product of
simultaneously occurring local human effects became a landscape-scale phenomenon – a direct consequence of population density and the cultural connectedness of the Jemez people.

The Jemez people altered fire-regimes. During established occupation periods at the three sites in this study there is no evidence of spreading fire on or in the immediate area (within at least 120 meters) of any site. At Boletsakwa, for example, it is likely that, due to its short occupation and relatively small population, this village was the least disturbed of the sites discussed here. Yet, despite an occupation of 12 years, there is no evidence of fire on the mesa top preceding or during occupation. The village was built by refugees after the Pueblo revolt of 1680, likely in a single effort to satisfy the needs of those present (Liebmann 2006). This village area, therefore, had a short but high density occupation period in the late 1600s that logically disturbed much of the immediate mesa top. The need for water, structural timbers, and fuel wood necessitated daily foot traffic that would have essentially created fuel breaks (trails), precluding widespread fires. Likewise, agricultural fields, seasonal field houses, and trails connecting these features would also have inhibited fire spread during portions of the year. In turn, this likely resulted in a suppression of widespread fire that was coincident to the human effects on the landscape, if not also a product of purposeful fire suppression. Meaning, the extractive influence humans applied to their environment resulted in a landscape without the necessary elements for spreading fire, specifically, continuous fuels. On the other hand, careless and purposeful ignitions of fire by the many people living and utilizing the landscape may have resulted in many ignitions above what would have occurred from lighting alone, especially during seasons when there is little convective storm activity and lower lightning occurrence. Again, however, the limiting fuel conditions (i.e., amounts, distributions and low connectivity) would likely have limited fires from spreading very extensively (Swetnam and Farella, in preparation).

Given Boletsakwa’s relatively short occupation and small spatial extent, the local impacts at the long-occupied villages of Tovakwa, Kwastiyukwa and Wabakwa must have been greater. The scale and temporal extent of occupations at these three villages dwarf that of Boletsakwa. Each covered over a
square kilometer, and comprised more than 1,000 rooms. Primary occupations at these sites spanned around 300 years (Elliottb1982, 1988; Kulisheck 2005). As with Boletakwa, there is no evidence of fire within 120 meters of these sites during established use periods. It is reasonable to assume that complete lack of evidence for fire resulted from a local suppression of spreading fire, either coincident to the density of occupation, or consistent with the human desire to protect one’s home and structures from destruction.

**Defining Natural in the Jemez Province**

Our tree age and fire history data and analyses suggest a need for broader perspectives about what is considered “the natural state” of the Jemez Province. More specifically, we need to consider that the Jemez landscape has functioned in multiple forms over the past 900 years. Modern characterization of fire in this region, for the most part, comes from tree-ring records dating between 1650 and 1880. This period of 230 years lies between large-scale removal and centralization of native groups by the Spanish, followed by Anglo-Americans, and the late 19th century introduction of widespread grazing which depleted fine fuels and limited spreading surface fire. The Jemez culture has been present in this landscape since the late 13th or early 14th century. Other large occupations existed as early as the 1100’s, and evidence of humans in the Jemez dates as far back as 2,990 ± 40 years before present (Liebmann 2006; Vierra et al. 2008). Preceding 1650, original Spanish documents note nine contemporaneous villages, with population estimates ranging from 1,860-30,000 individuals (Kulischeck 2001, 2005). More recent work on population estimates, derived from LiDAR-based data sets providing village ruin mound volumes calibrated to room numbers and population sizes, estimate a maximum population size at the time of Spanish contact at between 5,000 and 7,000 people (Liebmann et al. in preparation). These villages were estimated to have between 215 and 1,850 rooms. Thousands of smaller sites have also been documented across the Jemez Province. It is inevitable that some form of the processes we have observed at Boletsakwa, Tovakwa, Kwastiyukwa and Wabakwa were present at other sites in the Jemez Province.
The Jemez were and are social beings. In Pueblo IV they were spread across the Jemez Plateau, seasonally dispersing over large areas and interacting with one another both intra and inter village (Kulischeck 2005). Effects of Jemez populations could not have been constrained to an area as local as a village – the social nature of the Jemez and everyday necessities motivated a variety of activities on a landscape scale.

*Human-Natural as a Form of Natural*

Throughout this paper we have dealt with the Jemez landscape under the category human-natural. However, this concept seems especially problematic here. Dealing with a ‘human-natural’ system implies that humans are somehow separate from the system – in fact an implication that humans are not natural. Yet, on the Jemez Plateau, humans have clearly existed as a part of the system, removing fuels and, arguably, acting as fire would have in consuming those fuels. In turn, resource extraction seems to have maintained some amount of resilience in the disturbance-forest regime. This is a stark deviation from modern WUI’s in the western United States where fire-forest dynamics are moving farther and farther away from historical patterns with devastating results.

The results of modern, unhealthy, fires in ecosystems similar to the Jemez often have millennial scale legacies – resulting in soil loss and initiating ecosystem type changes in both species and disturbance regimes (Allen et al. 2002). Yet, in the Jemez, the ecosystem seems to have transitioned from human-dominated (pre 1650 CE) to relatively absent of humans (1650-1880 CE), without widespread evidence of subsequent severe disturbance. Given modern examples of high severity fire within altered fire regimes, this lack of evidence for high severity response to the Jemez exodus is intriguing. Most importantly it implies that some part of fire’s role on the landscape must have been fulfilled by humans. This cannot be said of the many modern examples of WUI’s. For example, the Las Conchas fire of 2011 burned 635 square kilometers, with destructive effects on soils, watersheds and forests (Tillery et al. 2012). The fire destroyed 112 structures, threatened the town of Los Alamos, and endangered nuclear infrastructure at the Los Alamos National Laboratory (Tillery et al. 2012). The severity of this fire was
most probably unprecedented, essentially ‘moon-scaping’ large swathes of land in the Jemez Mountains and leaving a legacy that will be visible for millennia.

Categorizing the Jemez as ‘human-natural’ is an incomplete distinction in our study area. More accurately, the Jemez people existed, in part, as a series of natural processes, directly participating in maintaining the ‘natural’ world’s controls. Human agency coincided, to a certain extent, with the nature of the system. This is not a challenge to the established idea of a fire-forest system (clearly a dominant disturbance regime in the Jemez from 1650-1880 CE), however, it is inevitable that there have been different kinds of normality within this system. High frequency, low severity fire regimes were a typical characteristic of ponderosa pine ecosystems. Yet, we cannot separate humans from animals – imply that we transcend the natural world. The Jemez were ecological agents, with measurable influence on their surroundings. Our assertion is that they themselves became necessary ecological players; that the mosaic of human movements, agriculture, and other resource extraction across the landscape in effect replaced part of fire’s function. The Jemez people were quintessentially natural.
Works Cited:


Applequist, Martin B. “A simple pith locator for use with off-center increment cores” *Journal of Forestry* 56.2, pp. 141. (1958)


Elliott, ML. *Pueblo at the Hot Place: Archaeological Excavations at Giusewa Pueblo and San Jose de los Jemez, Jemez State Monument, Jemez Springs, New Mexico*. MS Thesis, New Mexico State Monument, Santa Fe. (1991)


Elliott, ML. *Overview and Synthesis of the Archaeology of the Jemez Province, New Mexico*. Museum of New Mexico Office of Archaeological Studies, Archaeology Notes 51, Santa Fe. (1986)


Ferguson, T.J. in discussion with the author, May 2012


Haffey, Collin M. *Patterns and predictors of crown fire induced type conversion in dry conifer forests*. Diss. NORTHERN ARIZONA UNIVERSITY, 2014.


Kulisheck, J. in discussion with the author. June 2015


Liebmann, MJ. “Burn the Churches, Break up the Bells.’ The Archaeology of the Pueblo Revolt Revitalization Movement in New Mexico, AD 1680-1696.” (2006)


Liebmann, Mathew in discussion with the author. May 2013.


Mera, HP. *Ceramic Clues to the Prehistory of North Central New Mexico.* 1935. Print.


Robinson, William J., John W. Hannah and Bruce G. Harrill. *Tree-ring Dates from New Mexico, I, O, U: Central Rio Grande Area.* Laboratory of Tree-Ring Research, University of Arizona, Tucson. (1972)


Swetnam, TW, and CH Baisan. “Historical Fire Regime Patterns in the Southwestern United States Since AD 1700.” *2nd La Mesa Fire Symposium*. Rocky Mountain Research Station, 1996. 11–32.

Swetnam, TW et al. “Fire History of Rhyolite Canyon, Chiricahua National Monument.” Cooperative National Park Resources Studies Unit, School of Renewable Natural Resources, University of Arizona, 1989. 1-55


Figure 1: The Jemez Province. The grey area highlighted notes the approximate extent of Jemez Black on White pottery, generally considered unique to the Jemez people. Also noted (in circles) are Jemez Pueblo IV period (1300-1600CE) sites that have over 150 rooms. Note the central locations of the Giusewa Mission (established in 1598 and expanded upon in 1621) and Walatowa Mission (established 1621 or 1622).
Figure 2: Tree Anatomy/Intra-ring Position, and Fire Scars. (A) Cross sectional view of a tree with 9 divisions (adapted from LTRR image): (1) pith, corresponds to the date the tree established, (2) a full ring comprised of light, large celled earlywood, and dark, small, thick-walled latewood cells, (3) Ring-boundary, (4) early earlywood growth corresponding to early summer, (5) middle earlywood growth corresponding to early/mid-summer, (6), late early wood growth corresponding to mid/late summer, (7) latewood growth corresponding to late summer/early fall, (8) cambium where cells division occurs, (9) bark. (B) Sampled fire scar face, note the small charred ridges, each corresponding to a different fire. (C) Classic Southwest fire scarred cross section. The scars form generally when fire runs uphill, swirling hot gasses around the uphill side of the tree and igniting fuels, heating and killing the cambium through the bark. The bark later sluffs off, leaving dead wood exposed that, over repeated fire events, burns and is re-compartmentalized by live cambium, as with the multiple scars shown here.
Figure 3: 31 fire history chronologies across the greater Jemez region. Sites were composited across a large spatial scale to mitigate local factors, and emphasize regional climate influence on fire spread.
Figure 4: Occupation, tree recruitment and fire history at Boletsakwa. Vertical dotted lines indicate established occupation period.
Figure 5: Counts of tree establishment at all sites compared to Palmer Drought Severity Index (from Cook et al 1999, grid points 119 and 133). Negative values indicate below mean precipitation, and positive values show more moisture than average.
Figure 6: Tree recruitment at Boletsakwa, Kwastiyukwa and Wabakwa. Different symbols mark the establishment of trees within ten year bins.
Figure 7: Constraint of Glaze F ceramic dating with site recruitment dates. The grey box highlights the initial pulses of tree recruitment from Tovakwa (LA483) and Kwastiyukwa (LA482), from which we established terminus ante quem dates (dotted vertical dotted lines). Minimum depopulation dates are 1649 and 1639 at Tovakwa and Kwastiyukwa respectively.
Figure 8: Map of Tovakwa demography samples. Note the cluster (n=5) of recruitment dates starting in western part of the site and appearing to establish later in an easterly direction. The samples along the southern cliff edge show fire traveling along the drainage during occupation, with specific fire years noted in the white boxes. These fire dates contemporary with populations at Tovakwa indicate that fire did move through the adjacent drainage, and human impacts may have been partially limited to the easier terrain on flat mesa tops.
Table 1: Similarities between regional widespread fires (25 percent of actively recording sites experiencing a fire) and village fire chronologies (minimum 2 scars to establish a fire). The high percent similarity is a strong indication that climate is a major factor in these fire regimes.

<table>
<thead>
<tr>
<th>Site</th>
<th>Period of Overlap w/ Regional</th>
<th>Number Fires Events (Min 2 Scars)</th>
<th>Number of Fires in Common w/ Regional</th>
<th>Percent Similarity to Regional</th>
<th>Number Fires in Common with Other Villages</th>
<th>Percent Similarity to Villages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boletsakwa</td>
<td>1669-1902</td>
<td>6</td>
<td>2</td>
<td>0.33</td>
<td>2</td>
<td>0.33</td>
</tr>
<tr>
<td>Kwastiyukwa</td>
<td>1639-1967</td>
<td>11</td>
<td>6</td>
<td>0.55</td>
<td>6</td>
<td>0.55</td>
</tr>
<tr>
<td>Tovakwa</td>
<td>1649-1834</td>
<td>8</td>
<td>4</td>
<td>0.50</td>
<td>6</td>
<td>0.75</td>
</tr>
<tr>
<td>Wabakwa</td>
<td>1559-1990</td>
<td>14</td>
<td>8</td>
<td>0.57</td>
<td>4</td>
<td>0.29</td>
</tr>
</tbody>
</table>
Figure 3: Superposed epoch analysis in four separate scenarios. Wet years are indicated by positive PDSI values, and dry years by negative values. Significant values exceed the confidence interval (p=0.05) represented by the dotted horizontal lines. Period of analysis for 1, 2, and 3 is 1550-1920 CE, or the period when trees were establishing on the four sites. Period of analyses for 4 is 1450 to 1640, or the period when both humans and fire were present.
Figure 4: Regionally composited Jemez fire years. The composite at the bottom of the figure shows fire years that burned 25 percent of sites or more. Gray box after 1880 shows anthropogenic suppression of fire.