IN-FIELD OBSIDIAN XRF ANALYSIS OF SITES IN THE LION MOUNTAIN AREA AND GALLINAS MOUNTAINS OF WEST CENTRAL NEW MEXICO

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ABSTRACT

The Gallinas Mountains of west central New Mexico were home to a diverse and thriving population of agriculturalists between ca. AD 850-1450. Recent and ongoing research as part of the Lion Mountain Archaeology Project (LMAP) has allowed for in-field, non-destructive analysis of surface obsidian artifact assemblages via portable handheld energy dispersive X-ray fluorescence spectrometry(ED-XRF). Influenced by the principles of preservation archaeology and the archaeological repository curation crisis, the LMAP has sought to design and conduct field research to gather the most data with the least amount of impact to archaeological sites. Non-destructive in-field analysis via portable handheld ED-XRF subscribes to these goals while also providing answers to significant questions about human behavior. Collected data show that within the study area variable patterns of obsidian source utilization and procurement strategy existed both through time and between contemporaneous populations. These results are indicative of a complex and shifting system of exchange and social interaction between the residents of the Gallinas Mountains and those of the surrounding regions during the Ancestral Puebloan occupation of the area.

INTRODUCTION

Obsidian provenance studies have been used worldwide to explore procurement strategies, exchange networks, inter-group interaction, and even cultural identity (Carter et al. 2013; Doelman et al. 2008; Ferguson et al. 2016; Goebel et al. 2008; Goring-Morris and Cohen 2022; Kim and Chang 2021; Shackley 2005). The advent of portable handheld energy dispersive X-ray fluorescence spectrometry (ED-XRF) has allowed for the non-destructive analysis of obsidian in museum settings, the capability to analyze large numbers of specimens in a short period of time, and the means to conduct in-field analysis (Frahm 2014; Frahm et al. 2014; Tykot 2021). Given the long-standing and on-going curation crisis prevalent amongst archaeological repositories (Bawaya 2007; Friberg and Huvila 2019; Kersel 2015; Lyons et al. 2006; Marquardt et al. 1982), in-field analysis is particularly important for researchers attempting to conduct a no-collection research strategy at newly discovered sites or sites without curated collections. Given the rising costs and decreasing amount of space for curating collections, in-field analysis has become standard practice for most federal land agencies in the United States and elsewhere (Lyons et al. 2006).

The American Southwest is one of the best locales in which to conduct obsidian provenance studies (Shackley 2005). The material's highly desirable tool making qualities coupled with the relative abundance of sources within the region led to its widespread utilization and distribution. The present study focusing on sites in the Gallinas Mountains of west central New Mexico shows that variable patterns of obsidian source utilization and procurement strategy existed both through time and between contemporaneous populations inhabiting the study area. These patterns are indicative of a complex and shifting system of exchange and social interaction between the residents of the Gallinas Mountains and those of the surrounding regions.

The Gallinas Mountains are situated within a transition zone between three classically defined archaeological culture areas: the Cibola region to the northwest, the Mogollon Highlands to the southwest, and the Rio Abajo to the east (Eckert and Huntley 2022; Lekson 1996). Despite extensive research in surrounding regions, prior research in the Gallinas Mountains has been limited in scope and focused mostly on the Gallinas Springs site (add GS citations). New and ongoing research in the area as part of the Lion Mountain Archaeology Project (LMAP) (Eckert and Huntley 2022) has sought to better understand the cultural developments of this region.

Expanding upon the recent intensive pedestrian archaeological surveys and of the LMAP, the present study explores how agricultural-period settlements of the Gallinas Mountains were connected with surrounding regions through networks of exchange and social interaction. Focusing on Ancestral Puebloan sites dating between ca. AD 850-1450, this study examines these topics during a time period that saw radical shifts in the way people lived and interacted with the world around them (Adler 1996; Lekson 2006). These shifts included substantial changes in settlement patterns, architecture, economic strategy, ritual organization, and social interaction (Eckert and Huntley 2022).

In order to approach the topics of procurement, exchange, interaction, and identity, this study utilized non-destructive, in-field analysis of surface assemblages via portable handheld ED-XRF in order to determine geologic source of obsidian artifacts at a sample of agricultural-period sites in the Gallinas Mountains. Guided by the principles of preservation archaeology (Doelle 2012) and the archaeological curation crisis, the LMAP has sought to design and conduct field research to gather the most data with the least amount of impact to archaeological sites. Non-destructive in-field analysis via portable handheld ED-XRF subscribes to these goals while providing answers to important questions about human behavior.

BACKGROUND

The Gallinas Mountains and the Lion Mountain Area

The Gallinas Mountains (Figure 1) are located in west central New Mexico in western Socorro County near the present-day village of Magdalena. The majority of sites in this study lie along the western edge of the Gallinas Mountains where they meet the Plains of San Augustin. This area is referred to as the Lion Mountain Area due to its proximity to Lion Mountain, a prominent peak which makes up the far western edge of the Gallinas Mountain range. Historically, this area lies within or near traditional cultural areas for at least five present-day Native American tribes: the Zuni (Ferguson and Hart 1985; 56-57), the Acoma (Marshall and Marshall 2008; White 1943), the Piro (Marshall and Walt 1984), the Puertecito Navajo Band (Marshall and Marshall 2008) and the Chiricahua Apache (Marshall and Marshall 2008).

Primarily contained within the Magdalena Ranger District of the Cibola National Forest, the Gallinas Mountains range is situated along the northeastern margins of the Plains of San Augustin, a massive Pleistocene lakebed. To the west it connects with the Datil Mountains effectively forming an east-west trending arc across the northern end of the plains. Elevations range from around 2,134 meters (7,000 ft) along the edges of the plains up to 2,597 meters (8,522 ft) at the highest point. Terrain along the margins of the Gallinas Mountains can generally be described as level and open, interspersed with low ridges and hills. As one moves further into the interior, ridges gradually increase in height and grades become somewhat steeper, although level areas are still common. A number of shallow arroyos and canyons created by ephemeral streams cut through the more rugged interior of the Gallinas. The local environment can be described as semiarid to semihumid and occupies the Transitional Ecozone. Pinyon-juniper woodland is dominant at the lower elevations and ponderosa pine forest at the higher with pockets of interspersed grassland throughout. While no permanent waterways are present, a number of springs can be found on the landscape.

<FIGURE 1 ABOUT HERE>

The Lion Mountain Archaeology Project

Relative to many areas of the American Southwest, the Gallinas Mountains have received little archaeological attention. The area effectively lies within a transitionary zone between three classically defined and more extensively researched culture areas, the Cibola region to the northwest, the Mogollon Highlands to the southwest, and the Rio Abajo region (or Lower Rio Grande Valley) to the east (Eckert and Huntley 2022; Schaefer 2020). While archaeological investigations in the Gallinas Mountains span back to the early 1900s, most of this research has been limited in scope.

Early academic work in the area (Danson 1957; Mera 1935; Winkler and Davis 1961) in conjunction with research conducted by the Cibola National Forest (Cartledge 1998, 2000; Cartledge and Benedict 1999; Des Planques 2000; Tainter 1979) and private contractors (Marshall and Marshall 2008) focused primarily on Ancestral Puebloan occupations and identified two prominent yet distinct cultural groups (Lekson 1996). The first group, defined as the inhabitants of the Lion Mountain Site Complex (Cartledge 1998, 2000; Cartledge and Benedict 1999; Eckert and Huntley 2022; Marshall and Marshall 2008), consisted of a large population exhibiting an earlier dispersed and later aggregated settlement pattern along the western edge of the Gallinas Mountains; these residents produced a mineral painted ceramic tradition consisting of primarily Cibola White Wares and White Mountain Redwares dating to ca. AD 1000-1300.

The second group, argued to be an immigrant population potentially originating from the Mesa Verde region, consists of a population centered primarily at a single large nucleated Pueblo (Gallinas Springs Pueblo) and a number of associated sites within the interior of the Gallinas Mountains; these residents produced a carbon painted ceramic tradition consisting of Magdalena Black-on-white dating to ca. AD 1240-1300 (Basham 2011; Danson 1957; Ferguson et al. 2016; Huntley and Eckert 2020; Lincoln 2007; Mera 1935; Winkler and Davis 1961). Despite living within a few kilometers of each other and having been occupied at the same time, the Lion Mountain Community and Gallinas Springs Pueblo exhibit drastic differences in settlement pattern, site layout, architectural style, and ceramic technology. Understanding the nature of and interplay between these two cultural manifestations, as well as how they interacted with the surrounding regions, is essential to understanding the late cultural development of the Gallinas Mountains.

LMAP investigations have focused on gaining a better understanding of the cultural developments taking place in the Gallinas Mountains during ca. AD 850-1450. Since its inception in 2016, the LMAP has focused on systematic pedestrian survey of the Lion Mountain area within the Cibola National Forest; recording previously undocumented sites as well as producing updated information on those previously identified. Of particular focus thus far has been an examination of the Lion Mountain Community (Eckert and Huntley 2022). Ultimately, our goals include discovering the true extent of various occupations, exploring patterns of social and ritual organization, and determining how communities of people interacted with their neighbors at both the local and regional scale.

LMAP research has made it clear that the Ancestral Puebloan residents of the Gallinas Mountains exhibited a mix of traits commonly associated with the three surrounding cultural regions. One difficulty encountered has been the different period and phase names used by archaeologists working in these different cultural regions. To address this issue, a series of general eras have been employed which rely on broad similarities in settlement/subsistence patterns (Eckert and Huntley 2022). These five eras (Table 1) are the Preagricultural Foragers (ca. 10,500 BC – AD 200), Early Agriculturalists (ca. AD 200 – 1000), Dispersed Agriculturalists (ca. AD 1000 – 1175), Aggregated Agriculturalists (ca. AD 1175 – 1300), and Nucleated Agriculturalists (post – AD 1300). In addition, tentative date ranges have been established for over 100 sites from the LMAP area using a combination of mean ceramic dating and frequencies of diagnostic surface ceramic sherds from established chronologies in surrounding regions (Eckert and Huntley 2022). The sites discussed in the current work rely on this chronology.

<TABLE 1 ABOUT HERE>

The obsidian provenance work undertaken in this present study aims to help address some of the core questions posed by the Lion Mountain Area Project as well as additional ones regarding procurement strategy. The primary goal is to produce a better understanding of the patterns of obsidian source use by the people who lived in the Gallinas Mountains during the Early Agriculturalists through Nucleated Agriculturalists eras. Understanding which sources were utilized by which groups and how those utilization patterns changed through time will ultimately provide a narrow but precise understanding of resource procurement strategy, as well as an indication of inter-regional interaction.

Obsidian Studies and the American Southwest

The American Southwest is a phenomenal locale for conducting obsidian provenance studies due to the large number of sources spread over a wide geographic area. Over 40 distinct high-quality sources exist within Arizona, New Mexico, Chihuahua, and Sonora. Shackley (2005; 2019) divides obsidian sources in the Southwest into five regions based on source clusters. The Northern Arizona region includes those sources belonging to the San Francisco (including Government Mountain, RS Hill, Sitgraves Mountain) and Mt Floyd Volcanic Fields (including Presley Wash, Partridge Creek, and Black Tank). The West and Central Arizona region includes such sources as Superior, Vulture, Topaz Basin, Sand Tanks, Bull and Burro Creeks, and Tank and South Sauceda Mountains. The Eastern Arizona/Western New Mexico region includes the sources of the Mule Creek group, as well as the Cow Canyon, Gwynn Canyon, Red Hill, Antelope Wells, and McDaniel Tank sources. The Northern New Mexico region includes the sources of the Jemez Mountains, Mt Taylor, and No Agua Peak groups. The Northwest Mexico region includes a large number of sources including Los Vidrios, Agua Fria, Los Jagüeyes, and Sierra Fresnal sources.

Due to its highly desirable tool making qualities, as well as its relatively wide availability in the region, obsidian was an important and heavily utilized lithic raw material to the people living in the American Southwest. Projectile points, knives, blades and other cutting tools made of obsidian would have been valued in a utilitarian sense for their superior sharpness and ease of flaking relative to those made of other materials such as basalt, chalcedony, or chert. From a more non-practical standpoint, some degree of aesthetic, symbolic, and/or ceremonial value is known to have been placed on obsidian or items made from the material by certain groups (Durán 1971 [1588]; Griffin 1969; Hunt 2015; Ponomarenko 2003; Shackley 2005; Taube 1991). While there exists variation in the proportion that obsidian makes up any given Southwestern site's lithic assemblage, it is generally present in some amount. This ubiquity has allowed archaeologists working in the region to use obsidian provenance data to address questions of human behavior to great effect (e.g., Arakawa et al. 2011; Duff et al. 2012; Ferguson et al. 2016; Hughes 2015; Kocer and Ferguson 2017; Mitchell and Shackley 1995; Taliaferro et al. 2010; VanPool et al. 2013).

Obsidian's superb tool making qualities and its limited availability in most areas made it a valuable commodity amongst prehistoric peoples (Glascock et al. 1998). Material was obtained in one of two ways; through direct or indirect (i.e., exchange [Shackley 2005]) procurement. Direct procurement was an option to those either living in close proximity to the natural distribution area for a given source (including secondary deposits) or those traveling to or through said area. However, direct procurement was not always an option; or at least not an economically or socially sensible one. This was especially true for more sedentary groups living further away from a resource's natural distribution area (Eerkens et al. 2008) or when social or political boundaries prevented direct access. In such cases it seems that indirect procurement of materials through networks of exchange was the more feasible option. Networks of exchange between those who had direct access to this raw material and those who did not developed in many areas.

Exchange networks were often linked to a complex variety of social, ideological, and political factors (Ponomarenko 2003). Social interaction through the exchange of goods can be classified as a form of relational connection. Relational connections forged by exchange (whether frequently exercised or not) may provide the basis for the development of a variety of other kinds of social relationships (Peeples 2018). Alternatively, some preexisting relational connection could give rise to exchange in the first place. Whatever the case, indirect access to a given resource (in this case obsidian sources) was ultimately dictated be the degree of relational connectivity between those who had direct access and those who did not. Relational connections are typically dynamic things, prone to change over time and space (Peeples 2018). Analysis of source use can serve as an indicator of distant social connections independent from other commonly utilized lines of evidence such as ceramic typology and architecture.

METHODS

Provenance Studies and Portable XRF

While the bulk of the elemental composition is roughly similar for all obsidian (i.e., major elements), significant differences in the proportions of trace (<1%) elements are typically present between sources. These differences are crucial in defining and subsequently differentiating between sources (Glascock et al. 1998). Trace elements commonly used in the source identification of obsidian artifacts via XRF include rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb).

Elemental composition of obsidian source material and artifacts may be established via a number of developed methods. Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), neutron activation analysis (NAA), and X-ray fluorescence (XRF) are perhaps the most widely used in modern archaeometric obsidian compositional studies. Each of these methods have their own merits and shortcomings, and in practice, no one method is ideal for every situation. Considerations when selecting the analytical method best suited to a given scenario may include analytical accuracy and precision, data comparability, effect on the sample, size of the artifacts, ease of use, speed, cost, portability, and access to instrumentation (Ferguson et al. 2014; Glascock et al. 1998; Shackley 2005).

In this study, permitting constraints restricted studies to non-destructive in-field analyses only. Of the three most widely used methods in obsidian geochemical studies, XRF is the only one which offers both a non-destructive means as well as portable options (commonly referred to as pXRF). Permit constraints aside, pXRF analysis, when conducted properly and calibrated using a set of known standards, is a more than adequate method for determining the elemental composition of obsidian artifacts in most cases (Ferguson 2012; Frahm 2013; Speakman and Shackley 2013) and particularly for the American Southwest. In addition, the ethical aspects of non-destructive analytical methods such as pXRF and non-intrusive studies in general, especially to the modern preservation minded archaeologist, should be acknowledged.

Data Collection, Calibration, and Source Assignment

This study made an attempt to produce a site sample representative of the Ancestral occupations of the Gallinas Mountains/Lion Mountain area spanning the Early Agriculturalists, Dispersed Agriculturalists, Aggregated Agriculturalists, and Nucleated Agriculturalists eras. For the ten sites ultimately included in this study, an intensive 100% surface area survey was undertaken. All observed obsidian was flagged and analyzed on site using portable handheld energy dispersive X-ray fluorescence spectrometry (ED-XRF). Given the attempt to produce as comprehensive a sample of obsidian surface artifacts as possible, we recognize the potential for some of the debitage to have been derived from the same core or objective piece.

Spectra were gathered using a Bruker Tracer 5i XRF spectrometer. The instrument was operated under the following settings: voltage: 50 kV, current: 35 µA, filter: Cu100-Ti25-Al300, collimator: 3mm, assay time: 20 seconds. An attempt was made with every artifact to produce the most precise and accurate readings by 1) analyzing only interior surfaces (i.e., avoiding surfaces with remaining cortex), 2) using clean surfaces free of foreign debris (such as clinging soil) 3) using the flattest surface available, and 4) scanning the thickest portion of the artifact. Artifacts were classified as either formal tools (i.e., unifaces, bifaces, and projectile points) or debitage and informal tools (i.e., unmodified nodules, cores, angular debris, and flakes). Following data collection, all artifacts were returned to their original found context.

Following in-field data collection, artifact trace element concentrations were calculated using a matrix-specific calibration Bruker S1Cal Process software. A calibration developed by the University of Missouri Research Reactor's (MURR) Archaeometry Laboratory (Glascock and Ferguson 2012) based on precise and accurate elemental measurements of 37 different obsidian source standards was used. Data for this calibration was produced by a combination of laser ablation and mass digestions inductively coupled plasma mass spectrometry (LA- ICP-MS and MD-ICP-MS), neutron activation analysis (NAA), and X-ray fluorescence (XRF) from both MURR and other labs. Sources were selected to cover a broad range (high through low values) of trace element concentrations as well as to account for inter-element interactions. This calibration was developed specifically for application to obsidian data gathered using XRF (Glascock and Ferguson 2012). Processing the gathered XRF spectra through this calibration file produced elemental composition estimates for the samples in the form of parts per million (ppm). Compositional data were retained for one minor (Fe) and six trace elements (Mn, Rb, Sr, Y, Zr, and Nb). All elemental data are available in Schaefer (2020).

Artifact samples were compared to established source group reference samples for 32 discrete Southwestern obsidian sources. Artifact samples were assigned to a given source based on similarity in elemental composition. The list of obsidian sources includes the vast majority of known high quality obsidian sources utilized in the region's core (i.e., Arizona, New Mexico, and Northern Mexico). Geologic source reference samples were compiled by and are housed in the MURR Archaeometry Lab for use in provenance studies. Source material was analyzed using the same instrument, operated under the same settings, and calibrated using the same calibration file as that used for the artifact sample.

Compositional data (elemental ppm) for sampled artifacts and source groups were imported into GUASS; a statistical software package developed specifically for use with multi-variate datasets. Artifact samples and source groups were projected in 2-D elemental scatterplots using the data for primarily five trace elements (Rb, Sr, Y, Zr, and Nb). Elemental compositions (ppm and elemental ratios) of artifact samples were visually compared to that of source material standards. Dissimilar sources were gradually eliminated until only the most compositionally similar source remained. If reasonably similar in composition, the artifact was then assigned to that source. In most cases, confident assignment to a specific known source was achieved.

RESULTS AND DISCUSSION

Assemblages of surface obsidian artifacts (n=500) were analyzed from ten sites as part of this study. They include two sites from the late Early Agriculturalists/early Dispersed Agriculturalists era transition (LA61489 Artifact Concentration #2 and LA193028), one site from the Dispersed Agriculturalists era (LA125085 - Bobcat Pueblo), one site from the late Dispersed Agriculturalists/early Aggregated Agriculturalists era transition (LA189382), five sites from the Aggregated Agriculturalists era (LA121885 - the Nicoll Site, LA121884, LA121883, LA189381, and LA1178 - Gallinas Springs Pueblo which dates to this era but exhibits a nucleated settlement pattern), and one site from the late Aggregated Agriculturalists/early Nucleated Agriculturalists era (LA1180). These ten sites span the late Early Agriculturalists through early Nucleated Agriculturalists eras and provide a sample representative of spanning nearly six centuries of occupation (ca. AD 850-1450). Provenance data from obsidian artifacts (n=58) excavated at LA285 - Goat Springs Pueblo (Eckert and Huntley 2014; Eckert and Huntley, in prep.), a large Nucleated Agriculturalists era pueblo occupied ca. 1325-1680 and located roughly 28 km East of Lion Mountain, has been included here for discussion purposes.

General Patterns of Source Utilization

In total, 12 known chemically distinct sources were identified among the Gallinas Mountains sites and Goat Springs Pueblo (Table 2). These include the Grants Ridge and Horace Mesa sources of the Mount Taylor source group, the McDaniel Tank Source, the Rabbit Mountain (Obsidian Ridge or Cerro Toledo Rhyolite), Cerro del Medio (Valles Rhyolite), Polvadera Peak (El Rechuelos Rhyolite), Paliza Canyon (Bearhead Rhyolite), and Bear Springs Peak (Canovas Canyon Rhyolite) sources of the Jemez Mountains source group, the Antelope Creek source of the Mule Creek source group, the Cow Canyon and Superior sources, and the Government Mountain source of the San Francisco Peaks source group. Overall, only 0.9% (5 out of 558) of the samples were not able to be assigned to a known Southwestern geochemical source. It is possible these samples originate from a source outside of the Southwest or from an unknown geochemistry within the region itself. Alternatively, surface contamination or analytical error may be to blame.

<TABLE 2 ABOUT HERE>

Two sources/source groups were found to make up the majority of every individual site assemblage; the Mount Taylor source group (including both Grants Ridge and Horace Mesa) and the McDaniel Tank source. Mount Taylor was the most commonly encountered overall (53.23%) with McDaniel Tank second (34.59%). These two sources/source groups are the closest primary sources of material to the study area geographically speaking. While McDaniel Tank is relatively local with primary deposits occurring about 28 km SE of Lion Mountain (Figure 2), Mount Taylor (the next closest source to the study area at about 113 km to the NNW) is most likely the superior source of raw material. While both sources produce obsidian of excellent quality in regards to their knappability (the degree to which a given lithic raw material can be predictably and/or easily reduced via the process of flaked stone reduction), Mount Taylor is far more abundant and occurs in much larger nodules at its primary deposits. Mount Taylor was extensively utilized and distributed throughout north central/central New Mexico and can be considered a “major” source by Southwest standards (Shackley 2005). By comparison, McDaniel Tank is a relatively minor Southwestern source and is not commonly encountered in archaeological assemblages very far from its primary depositional range (LeTourneau et al. 2010). This is most likely a result of the very small size of available nodules (rarely above 3cm in diameter).

Although Jemez obsidian only made up 9.50% of the total assemblage, some amount of material was encountered at nearly every site (typically ranking third in abundance behind Mount Taylor and McDaniel Tank). The Jemez source group includes several high-quality glass sources that were heavily accessed by and widely distributed amongst people living in New Mexico and beyond (Shackley 2005; Baugh and Nelson 1987). Geographically speaking, the primary deposits are somewhat distant from the study area at approximately 185-230 km to the NNE (depending on the specific source). However, the desirable attributes of this raw material source group (one of the best sources for volcanic glass in the American Southwest in terms of abundance, nodule size, and knappability) undoubtedly led to its appearance in the sample. The possibility that some of the Jemez material may have been procured from secondary deposits in the Rio Grande alluvium (Church 2000; Shackley 2021) only shortens the geographic distance. The Rio Grande valley itself lies only about 48-56 km to the east of the study area. However, due to the presence of material from Cerro del Medio, which is not known to be present in secondary deposits within the Rio Grande alluvium, at least some proportion of Jemez obsidian must have been obtained from primary deposits within or very near the caldera.

<FIGURE 2 ABOUT HERE>

Several additional sources were identified within the overall sample in a more minor capacity. Most common among these was the Antelope Creek source of the Mule Creek source group. Antelope Creek was only encountered at two sites (making up 1.25% of all analyzed material). Primary deposits are located a similar distance from the study area to that of Jemez (around 180 km to the SW). Mule Creek material exhibits superb knappability and is commonly encountered at sites in west central/southwestern New Mexico and east central Arizona. In addition to Mule Creek, a single sample of material from the Cow Canyon source, located approximately 195 km to the SW, was encountered. Cow Canyon obsidian appears in many assemblages in east central Arizona and west central New Mexico, although it is commonly overshadowed by Mule Creek (Shackley 2005; Shackley 2019).

A single sample each of material from the geographically distant Superior source of south central and Government Mountain source of north central Arizona were identified. Primary source deposits for Superior are located approximately 355 km to the WSW and Government Mountain 420 km to the WNW. Both of these sources are superb sources of volcanic glass and were extensively utilized and distributed by various peoples in the Southwest, although their primary distribution ranges were mostly in Arizona. Despite this, Government Mountain has been previously identified in assemblages as far east as Socorro (Shackley 2005). The presence of these two sources indicates that the Ancestral Puebloan residents of the Gallinas Mountains were at least peripheral participants in a far-reaching social network.

Artifact Class and Source Material

Examinations of artifact class suggest that the sources identified within the collective sample were not necessarily all utilized or accessed in quite the same manner. Overall, a significantly higher proportion of formal tools (unifaces, bifaces, and projectile points) than debitage and informal tools (unmodified nodules, cores, angular debris, and flakes) was identified in two of the more geographically distant sources/source groups exhibiting larger sample sizes (Table 3). Material from the Jemez source group exhibited 20.93% formal tools (with Cerro del Medio specifically exhibiting the highest proportion of any single source at 57.14%) while material from Antelope Creek of the Mule Creek group exhibited 28.57% formal tools. The proportions of formal tools amongst these two sources/source groups were well above the average proportion for the sample as a whole (7.97%). This suggests that material from Jemez and Mule Creek primarily entered the study area not as unmodified or lightly reduced nodules, but as more or less finished tools. If the material had entered the area in a relatively raw or unfinished state, it is expected that artifacts representative of the entire production sequence (i.e., flakes, debris, cores, and unworked pieces) would be more common (Medchill and Loendorf 2021; VanPool et al. 2013). In other words, much of the initial reduction of the material from the more geographically distant sources seems to have occurred elsewhere.

<TABLE 3 ABOUT HERE>

The Mount Taylor source group was found to have a significantly lower proportion of formal tools (at 5.10%) when compared to other sources (Table 3). This could potentially be due to a collection bias towards smaller artifacts for the Mount Taylor group. Specifically, surface visibility issues resulted in much of the sample from Gallinas Springs Pueblo being gathered from anthill contexts. This assemblage was also the single largest contributor of Mount Taylor material to the collective sample. However, anthill contexts did not necessarily prohibit the discovery and analysis of small puebloan arrow points, and other sites without this visibility issue also exhibited a lower proportion of formal tools made from Mount Taylor. Additionally, a significant difference was found in the proportion of formal tools to debitage and informal tools between the two Mt Taylor sources. Grants Ridge only exhibited about 1.75% formal tools, while Horace Mesa had 7.80% (close to the average proportion for all sources overall at 7.97%). If the size bias had affected the proportion of formal tools within Grants Ridge, it should have affected Horace Mesa as well.

The significantly smaller proportion of formal tools within the Mount Taylor group (and more specifically Grants Ridge) might instead be explained by the physical characteristics of that source. In comparison to the largely aphyric Horace Mesa, Grants Ridge exhibits a more vitrophyric matrix. Phenocryst inclusions can hamper the production of small bifaces. Thus, Grants Ridge simply may not have been used to make formal tools to the extent of Horace Mesa. Shackley (2005) argues that Horace Mesa was the preferred source throughout northeastern Arizona and northwestern New Mexico from the Archaic to Pueblo III period. If Grants Ridge was less preferred in the manufacture of formal tools when compared to Horace Mesa, why does material from these two sources appear in somewhat equal proportions within the study area? It is quite possible that these two sources filled slightly different roles as is known to occur with some flaked stone raw material types (Andrefsky 1995). While the production of small bifacially flaked knives and projectile points could have been reserved primarily for material from Horace Mesa, Grants Ridge obsidian could have been used in the production of more expedient flake tools.

Variation through Time

Through the analysis of the individual site assemblages included in this study it is evident that a number of major changes in obsidian source utilization and procurement strategy occurred in the Gallinas Mountains over time (Figure 3). The late Early Agriculturalists to early Nucleated Agriculturalists era (ca. AD 850-1450) was a dynamic time in Southwestern prehistory, one which saw major shifts in social and ritual organization, economic strategy, and demographics. We argue that the dynamic nature of this period is reflected in the shifting patterns of obsidian source utilization identified in this study.

<FIGURE 3 ABOUT HERE>

During the late Early Agriculturalist and Dispersed Agriculturalists eras (ca. AD 850-1175), Mount Taylor is the primary obsidian source utilized among residents of the Gallinas Mountains (making up about two-thirds of overall source use). The remaining part of the assemblages is made up of a combination of material from the McDaniel Tank and Jemez sources. The late Early Agriculturalists era sees the utilization of Jemez sources at its peak both in terms of volume and variety. The LA61489 assemblage had the highest observed proportions of Jemez material and LA193028 exhibited samples from two of the more minor Jemez sources, Paliza Canyon and Bear Springs Peak. Combined, this reliance on Mount Taylor and Jemez sources indicates the presence of strong social connections with northern populations.

These connections make sense, as during this era many of the residents of the areas to the north and west of the Gallinas Mountains were participants in the Chacoan Interaction Sphere. Despite debate over its exact nature, most scholars agree that that some degree of shared social and ritual organization, architectural and ceramic traditions, as well as networks of exchange and interaction linked those participating in this system (Cordell and McBrinn 2012; Kantner and Kintigh 2006; Lekson et al 2006; Sebastian 2006). Bobcat Pueblo (LA125085), identified as a Chacoan great house (Eckert and Huntley 2022), exhibits compelling evidence that the residents of the study area were participating in this system as well. While use of Mount Taylor remains relatively constant though most of the Early Agriculturalists and Dispersed Agriculturalists eras, there is a gradual observable decrease in the use of Jemez coupled with an inverse rise in the use of McDaniel Tank.

Beginning in the late Dispersed Agriculturalists/early Aggregated Agriculturalists era however, we see a more drastic shift emerge. Utilization of Mount Taylor obsidian declines substantially with an inverse rise in the exploitation of the relatively local McDaniel Tank source. With the further development of the Lion Mountain Community during the Aggregated Agriculturalists era, this pattern becomes much more pronounced to the point where McDaniel Tank has become the primary source utilized at the majority of sites. This conspicuous drop in the utilization of northern sources and a shift to more local material during the late Dispersed Agriculturalists to Early Aggregated Agriculturalists era could be explained by a disintegration of exchange ties to the north and/or a greater focus on local networks of exchange and interaction.

The Chaco Interaction Sphere began to contract in the early 1100s and appears to have been largely defunct by ca. AD 1150 (Reed and Brown 2018). The exact causes and nature of this decline remain a matter of debate (Ingram 2017; Judge and Cordell 2006; LeBlanc 1999; Lekson 2008; Lekson and Cameron 1995; Varien 2018). However, it is generally agreed upon that the following period was one of major social and ritual reorganization for many of the areas once encompassed in the Chacoan system (Cordell 1996). Obsidian evidence shows a drop in the importation of northern material beginning somewhere between the abandonment of Bobcat Pueblo (ca. 1145) and the initial occupation of LA189382 (ca. 1165). Following the collapse of the Chacoan system (ca. AD 1150), networks of exchange and interaction between the people living in the Gallinas Mountains and those living to the north towards Mt Taylor and Chaco could have broken down or at least fallen under significant stress. Northern material may not have been as accessible as it once was. Alternatively, the shift to the utilization of the relatively local McDaniel Tank and away from Mount Taylor could have been caused by a conscious disassociation with the north on the part of the people living in the Lion Mountain Community.

With the beginning of the Nucleated Agriculturalists era (ca. AD 1300) we see a shift back to source utilization patterns similar to those of earlier periods. Utilization of McDaniel Tank obsidian drops to levels similar to that of the Early Agriculturalists era. Mount Taylor once again dominates the assemblages. Jemez sources see a slight increase in utilization as well. This return to the use of northern sources was likely stimulated by the emergence of new or strengthened connections to growing population centers in the Zuni, Acoma, and Laguna areas as well as in the Rio Grande Valley. The Nucleated Agriculturalists era is one of substantial demographic upheaval and settlement reorganization, but it is also an era of expanding exchange networks (Adams and Duff 2004; LeBlanc 1989). It appears as though the residents of the Gallinas Mountains were linked into this expanding network of exchange and interaction.

Evidence for relational connections manifests in the presence of Zuni Glaze Ware sherds found at some of the latest sites in the study area (Huntley and Eckert 2020; Marshall and Walt 1984). These wares are known to have been produced at several locales including but not limited to the Zuni, Acoma, Upper Little Colorado River, and Techado areas (Huntley 2008). Zuni Glaze Wares found in Rio Grande Valley contexts are thought to indicate close contact and extended interactions between Western and Eastern Pueblo groups (Habicht-Mauche and Eckert 2021; Herhahn 2006). Mt Taylor was likely the most important source of obsidian for populations living in the Zuni, Acoma, and Laguna areas (Blake 1999; Hunt 2015; Schachner 2012) and Jemez for those in the Rio Grande Valley (Arakawa et al. 2011). Sustained relational connections between these population centers and the inhabitants of the Gallinas Mountains would have likely resulted in the importation of these sources.

The appearance of Government Mountain is most likely tied to a similar vector. During this same era, populations further west were consolidating around the Hopi Mesas (Adams 1996). Government Mountain was the preferred source of obsidian for those living along the eastern slopes of the San Francisco Mountains (Silva 2006). Interactions between population centers at the Hopi Mesas and in the Zuni region brought the material further east into western New Mexico (Schachner 2012).

During the Nucleated Agriculturalists era, we also see a marked uptrend in the volume and variety of southwestern sources being imported. Antelope Creek is actually the second most abundant source material at LA1180, surpassing both McDaniel Tank and Jemez. Additionally, material from the Cow Canyon and Superior sources appear for the first time. The increase in use of Antelope Creek obsidian and the introduction of new sources may be related to changes occurring in the Mogollon region to the southwest of the study area. By the beginning of this era (ca. AD 1300), much of the Mogollon Highlands appears to have been depopulated (Martin 1979). It has been theorized that some of its former residents traveled north and settled in the Zuni region (Gregory 2007), while others traveled east and settled in the Rio Abajo region (Cordell and McBrinn 2012).

Antelope Creek was the most widely utilized source in the Mogollon Highlands and Cow Canyon, while typically overshadowed by the Mule Creek sources, was widely utilized as well (Taliaferro et al. 2010). Immigrants from this area would have brought with them the knowledge of and/or material from these two sources. Maintenance of social connections post- migration could have played a role in procurement as well. Increased relational connections between the residents of the Zuni and/or Rio Abajo regions and those of the Gallinas Mountains could have then brought the material into the study area. Alternatively, based on the connections evident between the Mogollon region and the study area (Cartledge 2000; Cartledge and Benedict 1999; DeHaven and Turner 2016; Huntley and Eckert 2020; Marshall and Marshall 2008) it is conceivable that some emigrants from the south could have found their way directly into the Gallinas Mountains. Material from the Superior source could have entered via a similar route.

Variation across Cultural Boundaries

Obsidian source utilization was found to not only differ through time, but also across perceived social boundaries between contemporaneous cultural groups residing in the Gallinas Mountains. The advent of the Aggregated Agriculturalists era (ca. AD 1175 - 1300) witnessed the fluorescence of the Lion Mountain Community (Eckert and Huntley 2022). The Lion Mountain Community during this era is characterized by an aggregated settlement pattern consisting of a complex of discrete residential single-story roomblocks averaging 10-20 rooms. These roomblocks are centered around a smaller number of ceremonial sites including the bi-wall Nicoll site (LA121885). Residents chose to build this community on a relatively open landscape along the far western edge of the Gallinas where they meet the Plains of San Augustin. Architecture associated with these sites is primarily of unshaped rhyolite and basalt cobble masonry, while decorated pottery assemblages consist primarily of mineral-painted Cibola White Wares and White Mountain Redwares (Cartledge 2000; Cartledge and Benedict 1999; Eckert and Huntley 2022; Huntley and Eckert 2020; Marshall and Marshall 2008). The Lion Mountain Community appears to have developed out of a local tradition stretching back to the Early Agriculturalists era.

Standing in stark contrast to the Lion Mountain Community were the residents of Gallinas Springs Pueblo. Occupied from ca. AD 1240-1300, this massive multistory 300-500 room nucleated pueblo is situated in the more rugged interior of the Gallinas Mountains approximately 6 km due east of the core Lion Mountain site complex. The site exhibits a bimodal layout, bisected by Gallinas Canyon, a large dry arroyo. Architecture is a combination of both unshaped rhyolite and basalt cobble masonry and shaped tabular sandstone masonry. The inhabitants subscribed to a carbon-painted whiteware ceramic tradition consisting primarily of Magdalena Black-on-white. Due to a list of shared material culture and settlement patterns, its contrast with the perceived local traditions, and its sudden appearance in the AD 1200s at a time in which mass migrations out of the Four Corners area were occurring (Cordell 2012; Lekson 2008; Wilshusen and Glowacki 2017), numerous researchers have argued that the inhabitants of this unique site consisted of a population of immigrants from the Mesa Verde region (Basham 2011; Danson 1957; Ferguson et al. 2016; Lincoln 2007; Mera 1935; Winkler and Davis 1961).

Despite living within a short walk of each other and having been occupied at the same time, the Lion Mountain Community and Gallinas Springs Pueblo exhibit stark differences in settlement pattern, site layout, architectural style, and ceramic technology. As part of this study, obsidian samples were analyzed and compared from Gallinas Springs Pueblo (LA1178) and contemporaneous sites of the Lion Mountain Community (LA121885 [the Nicoll Site], LA121884, LA121883, and LA189381). Analysis showed that significant differences are present in the patterns of obsidian source utilization between these two communities. McDaniel Tank was by far the preferred material among residents of the Lion Mountain Community during the 1200s. On average these sites exhibited 71.63% McDaniel Tank and 21.78% Mount Taylor. The inverse was true for residents of Gallinas Springs Pueblo, with material from Mount Taylor (82.93%) vastly outnumbering McDaniel Tank (8.94%). The drastically different patterns of obsidian source utilization which exist between the Lion Mountain Community and Gallinas Springs Pueblo complement the other differences observed in material culture and serves to reinforce the notion that these sites were occupied by different social groups.

If Gallinas Springs Pueblo was in fact founded by immigrants from the Four Corners area, the conspicuous reliance on Mount Taylor as their primary source of obsidian makes sense. The residents of the Mesa Verde region were well aware of Mt Taylor, consistently utilizing it as a major source of obsidian throughout the occupational history of the area (Arakawa et al. 2011). From a geographic perspective, any emigrants leaving the Mesa Verde region and heading south directly towards the Gallinas Mountains would have passed very near Mount Taylor itself. Theoretically, material could have been acquired from this known landmark along the way. Additionally, the Mesa Verde Region was not depopulated all at once (Arakawa et al. 2011; Cordell 2012; Lekson 2008; Varien 2010; Wilshusen and Glowacki 2017), nor does Gallinas Springs Pueblo appear to have been built in a single event (Lincoln 2007). A stream of new arrivals filtering into the growing Gallinas Springs Pueblo could have supplied a continued flow of Mount Taylor obsidian. Social connections with residents of the Mt Taylor area or resource gathering trips back to the source on the part of the Gallinas Springs Pueblo residents could have brought in additional material. Additionally, it is entirely possible if the residents of this community were in fact newcomers to the area, that they simply were not very familiar with the local and relatively minor McDaniel Tank source and thus chose to procure most of their material from the closest known "major" source.

CONCLUSIONS

This study set forth with the goal of producing a broad scale picture of the obsidian source use patterns and procurement strategies of the people who lived in the Gallinas Mountains of west central New Mexico during ca. AD 850-1450, more specifically the late Early Agriculturalists through early Nucleated Agriculturalists eras. The Gallinas Mountains are a relatively under-researched area in comparison to many other regions of the Southwest. Despite this, ongoing research under the Lion Mountain Area Project shows that this area was home to a large and thriving population during this time period. This research has sought to better understand how these people fit within the broader social landscape of the surrounding regions. This includes investigating a variety of questions pertaining to social identity, social interaction, and networks of exchange. The present study utilized patterns of obsidian source use and procurement strategy in an effort to help answer some of these questions.

This research analyzed the obsidian artifact assemblages of ten sites in the Gallinas Mountains area. These sites were selected to represent the range of cultural and temporal variation present during the Ancestral Puebloan occupations of this area. The surface obsidian artifact assemblages from these ten sites were analyzed in-field in a non-destructive manner using portable handheld energy dispersive X-ray fluorescence spectrometry (ED-XRF). In total, 500 obsidian artifacts were analyzed as part of this study. Provence data from an additional 58 obsidian artifacts recovered from excavations at an additional nearby site, LA285 - Goat Springs Pueblo, were included for discussion purposes. Of this large sample, only 0.9% were unable to be confidently assigned to a known southwestern geochemical source.

This study shows the power of in-field obsidian analysis to help inform on changes in obsidian procurement across space and through time while simultaneously exemplifying how such research can be achieved in a manner that lessens the burden on archaeological repositories and impacts to archaeological sites. The patterns identified in this study showcase the diverse obsidian source utilization and procurement strategies of the residents of the Gallinas Mountains area during the Ancestral Pueblo period. These observations offer an important glimpse into the networks of exchange, interaction, and identity of those who lived in this area during a dynamic period of Southwestern prehistory. Research into the cultural developments of the Gallinas Mountains is relatively new territory. As research in the area continues with the Lion Mountain Archaeology Project, new insights into the patterns observed here may be offered. Until those results come to light, we can know that the ways in which the people who inhabited the Gallinas Mountains chose to interact with the surrounding regions were surely as complex as that of the other areas of the American Southwest.

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Figure 1. Map of study area showing sampled sites and significant topographic features.

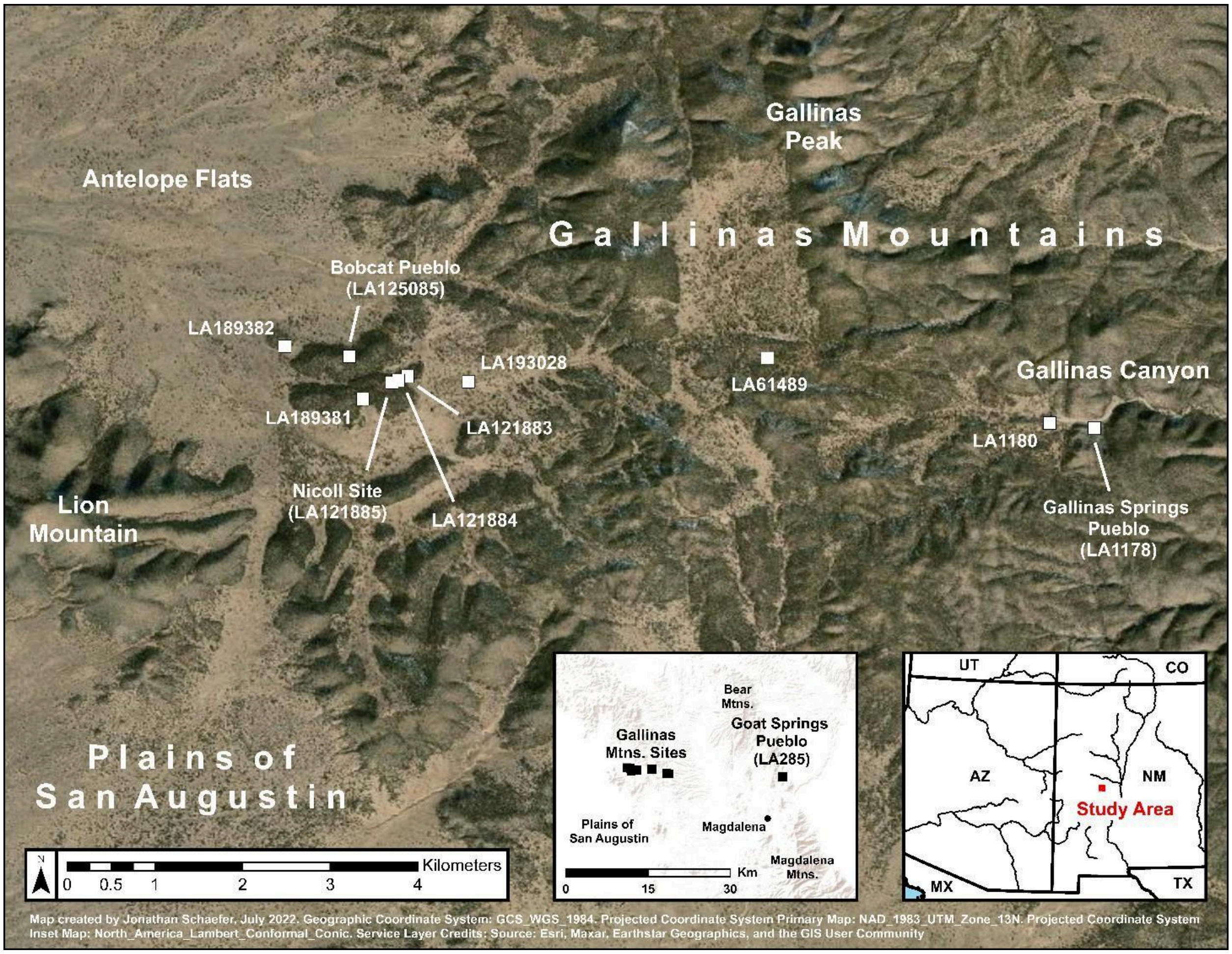
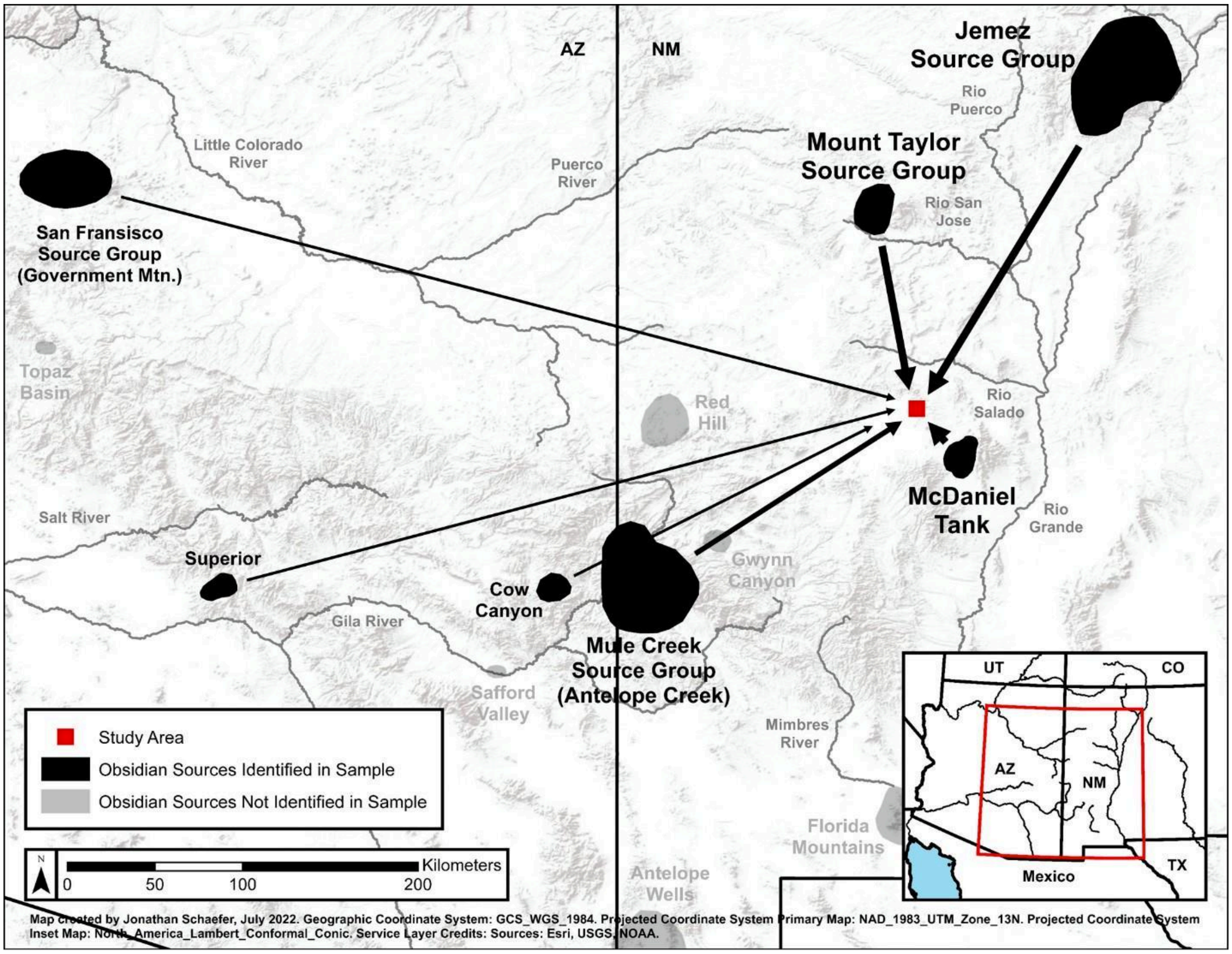


Figure 2. Obsidian sources identified in study area site assemblages.



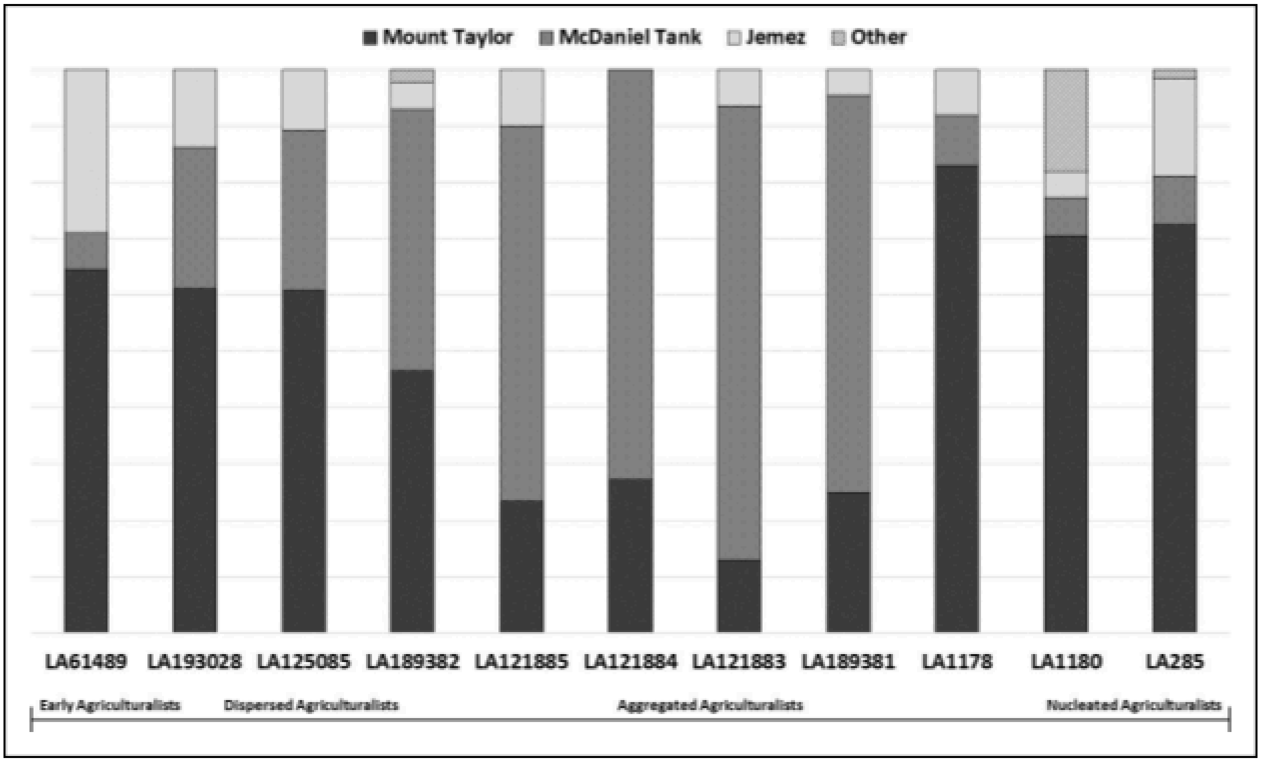


Figure 3. Change in obsidian source use through time (supplemental data from LA285 - Goat Springs Pueblo included). Sites arranged in approximate chronological order.

Table 1. Generalized eras and neighboring culture area Phases/Periods discussed in this paper (after Eckert and Huntley 2022).

Time range	Era	Rio Abajo Phases	Cibola Periods	Mogollon Phases	General Characteristics
post-AD 1300	Nucleated Agriculturalists	Ancestral Piro ca. AD 1300-1450	Pueblo IV ca. AD 1300-1540	Cliff ca. AD 1300-1450	Rio Abajo and Cibola regions dominated by large, nucleated villages; Mogollon region witnesses decline in population early in the 1300s
ca. AD 1175-1300	Aggregated Agriculturalists	Late Elmendorf ca. AD 1200-1300	Pueblo III ca. AD 1175-1275	Tularosa ca. AD 1150-1250	Larger pueblos and fewer sites when compared to earlier eras probably the result of population consolidation and aggregation
ca. AD 1000-1175	Dispersed Agriculturists	Early Elmendorf ca. AD 1000-1200	Pueblo II ca. AD 900-1175	Reserve ca. AD 1000-1200	Various types of architectural styles and site configurations, however residential sites tend to be relatively small and dispersed across the landscape
ca. AD 200-1000	Early Agriculturists	Tajo ca. AD 800-1000 San Marcial ca. AD 300-800	Pueblo I ca. AD 700-900 Basketmaker III ca. AD 500-700	Pithouse ca. AD 200-1000	Increased reliance on horticulture, introduction of pottery, introduction of the bow-and-arrow, onset of long-term storage, maintenance of long-distance exchange networks, and construction of social ceremonial rooms
ca. 10,500 BC-AD 200	Preagricultural Foragers		Archaic Paleoindian		Mobile foragers; archaeological sites most commonly identified through diagnostic lithic artifacts

Table 2. Obsidian source provenance of surface artifacts from sites in the Gallinas Mountains (supplemental data from LA285 - Goat Springs Pueblo included).

Site	Era	Date Range	Grants Ridge	Horace Mesa	McDaniel Tank	Rabbit Mountain	Cerro del Medio	Polvadera Peak	Paliza Canyon	Bear Springs Peak	Antelope Creek	Cow Canyon	Superior	Gov.	Unas.	Total
LA61489 (AC#2)	late Early Ag. to early	AD 840 - 1010	10	10	2	8	1									31
LA193028	late Early Ag. to early	AD 965 - 1050	1	21	9	2		1	1	1					1	37
LA125085	Dispersed Ag.	AD 1095 - 1145	4	13	8	2	1									28
LA189382	late Dispersed Ag. to	AD 1165 - 1205	11	9	20		2				1					43
LA121885	Aggregated Ag.	AD 1180 - 1245	7	7	40	5		1							3	63
LA121884	Aggregated Ag.	AD 1205 - 1265		3	8											11
LA121883	Aggregated Ag.	AD 1205 - 1270	2	2	25	1	1									31
LA189381	Aggregated Ag.	AD 1230 - 1290	10	12	62	4									1	89
LA1178	Aggregated Ag.	AD 1240 - 1300	57	45	11	10										123
LA1180	late Aggregated Ag.	AD 1275 - 1450	12	19	3		2				6		1	1		44
LA285	Nucleated Ag.	AD 1325 - 1680	22	20	5	5	4	1				1				58
Total			**136**	**161**	**193**	**37**	**11**	**3**	**1**	**1**	**7**	**1**	**1**	**1**	**5**	**558**

Mount Taylor **Jemez**

Mountain

Dispersed Ag.

Dispersed Ag.

(Bobcat Pueblo)

early Aggregated Ag

(Nicoll Site)

(Gallinas Springs Pueblo)

to early Nucleated Ag.

(Goat Springs Pueblo)

Table 3. Frequency of formal tools as compared to debitage and informal tools among identified sources (data from LA285 - Goat Springs Pueblo unavailable).

Source	**Formal Tools**	**Debitage and Informal Tools**	**Total**
Mount Taylor Group	13	242	255
(Grants Ridge)	*(2)*	*(112)*	*(114)*
(Horace Mesa)	*(11)*	*(130)*	*(141)*
McDaniel Tank	15	173	188
Jemez Group	9	34	43
(Rabbit Mountain)	*(5)*	*(27)*	*(32)*
(Cerro del Medio)	*(3)*	*(4)*	*(7)*
(Polvadera Peak)	*(1)*	*(1)*	*(2)*
(Paliza Canyon)	*(0)*	*(1)*	*(1)*
(Bear Springs Peak)	*(0)*	*(1)*	*(1)*
Antelope Creek	2	5	7
Superior	0	1	1
Government Mountain	0	1	1
Unassigned	1	4	5
Total	**40**	**460**	**500**