Obsidian Procurement in the Gallinas Mountains of West Central New Mexico

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by
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The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

Obsidian Procurement in the Gallinas Mountains
of West Central New Mexico

presented by Jonathan Schaefer, a candidate for the degree of Master of Arts, and hereby certify that, in their opinion, it is worthy of acceptance.

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Abstract

The Gallinas Mountains of west central New Mexico are a relatively understudied area within the greater American Southwest. The area effectively lies within a transitionary zone between three classically defined 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. New projects in the Gallinas Mountains area have sought to better understand how its extensive Pueblo period occupations interacted with the surrounding regions. The following research uses in-field X-ray fluorescence to analyze the surface obsidian assemblages of ten late Pithouse and Pueblo period sites in the Gallinas Mountains in order to determine source use and ultimately provide a narrow but precise indication of procurement strategy and inter-regional interaction.

Results show that residents of the area utilized a variety of obsidian sources through time. Chief among these were Mount Taylor and McDaniel Tank, with Jemez also being somewhat common. Mule Creek along with several other sources were utilized in a more minor capacity. Residents of the area during the late Pithouse, early Pueblo, and late Pueblo periods showed a preference for northern source material, especially Mount Taylor, while middle Pueblo period sites (with the exception of the possible Mesa Verde migrant community of Gallinas Springs Pueblo) showed quite the opposite, with assemblages dominated by material from the relatively local McDaniel Tank source. The variable obsidian source use patterns and procurement strategies observed through time and across cultural boundaries are indicative of a complex and shifting system of exchange and interaction between the residents of the Gallinas Mountains area and those of the surrounding regions.

Chapter 1: Introduction

Compared to many parts of the American Southwest, the Gallinas Mountains of west central New Mexico are a relatively unresearched area. While archaeological investigations in the area span back to the early 1900s, most have been limited in scope. Unlike the Mimbres Valley with its captivating Black-on-white pottery, Chaco Canyon with its monumental Great Houses, or the Salt and Gila River Basins with their extensive irrigation networks and ball courts, no comprehensive cultural-historical overview has been developed for this locality to date. Despite this, past survey work in the area has made it abundantly clear that the Gallinas Mountains were home to a large and thriving population during the Pithouse and Pueblo periods.

The people who called the Gallinas Mountains home lived through a dynamic period in Southwestern prehistory, one which saw drastic shifts in the way people lived and interacted with the world around them. Changes in architecture, subsistence, ideology, exchange, and social interaction permeated the Pithouse and Pueblo periods. The Gallinas Mountains are located within a transitional zone between several classically defined culture areas. These include 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. Unsurprisingly, research has shown that the people of the Gallinas Mountains incorporated various aspects of each of these surrounding areas.

Recent investigations in the Gallinas Mountains under the banner of the Lion Mountain Archaeology Project (led by Drs. Suzanne Eckert of the University of Arizona and Deborah Huntley of Tetra Tech, Inc.) has sought to better understand how the people who called this area home fit within the broader social landscape of the Pueblo period. This includes examining how the occupants interacted with their neighbors in the surrounding regions via social connections and networks of exchange.

The provenancing of obsidian artifacts from archaeological sites has a long history of successful application to questions of human behavior. Obsidian provenancing studies provide archaeologists a narrow but precise indication of procurement strategies, exchange networks, inter-group interaction, and even cultural identity. The American Southwest is one of the best locales for these kinds of studies. Here the relative abundance of obsidian sources coupled with the material's highly desirable attributes in regards to the manufacture of stone tools led to widespread utilization and distribution.

This study aims to capture a broad scale picture of the obsidian source use patterns for the Gallinas Mountains area during the late Pithouse/early Pueblo through late Pueblo periods. An attempt was made to produce a sample representative of the full range of cultural and temporal variation present in this area during this dynamic time period. Extending upon the previous and ongoing research in this area, the present study attempts to help answer the question of how the occupants of the Gallinas Mountains during the Pithouse and Pueblo periods were connected with the surrounding regions through networks of exchange and social interaction.

The following background chapter begins with a geographical and environmental overview of the study area. Relevant information pertaining to the previous research which has been conducted in the area, including that of the ongoing Lion Mountain Archaeology Project, is then presented. Next, a brief introduction into the geology of obsidian and its use is presented, as well as the principles of provenancing studies and how they can help archaeologists answer questions about procurement, exchange, and interaction. A discussion of the various analytical methods utilized in the chemical characterization of obsidian is given and why portable handheld electron dispersive X-ray fluorescence spectrometry (ED-XRF) was the ideal choice for this particular study.

In Chapter 3, the methods used to carry out this research are presented. I discuss how potential sites were selected for inclusion in this study. As previously stated, an attempt was made to produce a site sample representative of the full range of cultural and temporal variation present in the study area for the late Pithouse/early Pueblo through late Pueblo periods. For the ten sites ultimately included in this study, a 100% surface area survey was undertaken. All observed obsidian was analyzed using portable handheld ED-XRF. All artifacts were returned to their original context following analysis. The elemental chemistry of each artifact was then compared to that of known Southwestern obsidian sources in order to assign provenance.

In Chapter 4, I present the results of this research. Each of the chemically distinct raw material sources which appeared in the collective sample are identified. A brief description of each source is provided in addition to relevant statistics pertaining to their frequency and how they were utilized (in terms of artifact type). I then present the results of a series of statistical tests intended to identify if any significant differences exist among the sources in regards to how they were utilized. Next, each of the sites analyzed in this study (as well as an additional comparative assemblage) are discussed. A brief description is given for every site, as well as relevant statistics pertaining to source material frequency. I go on to provide the results of a second series of statistical tests intended to ascertain whether or not any significant differences exist between the source frequencies observed at individual sites.

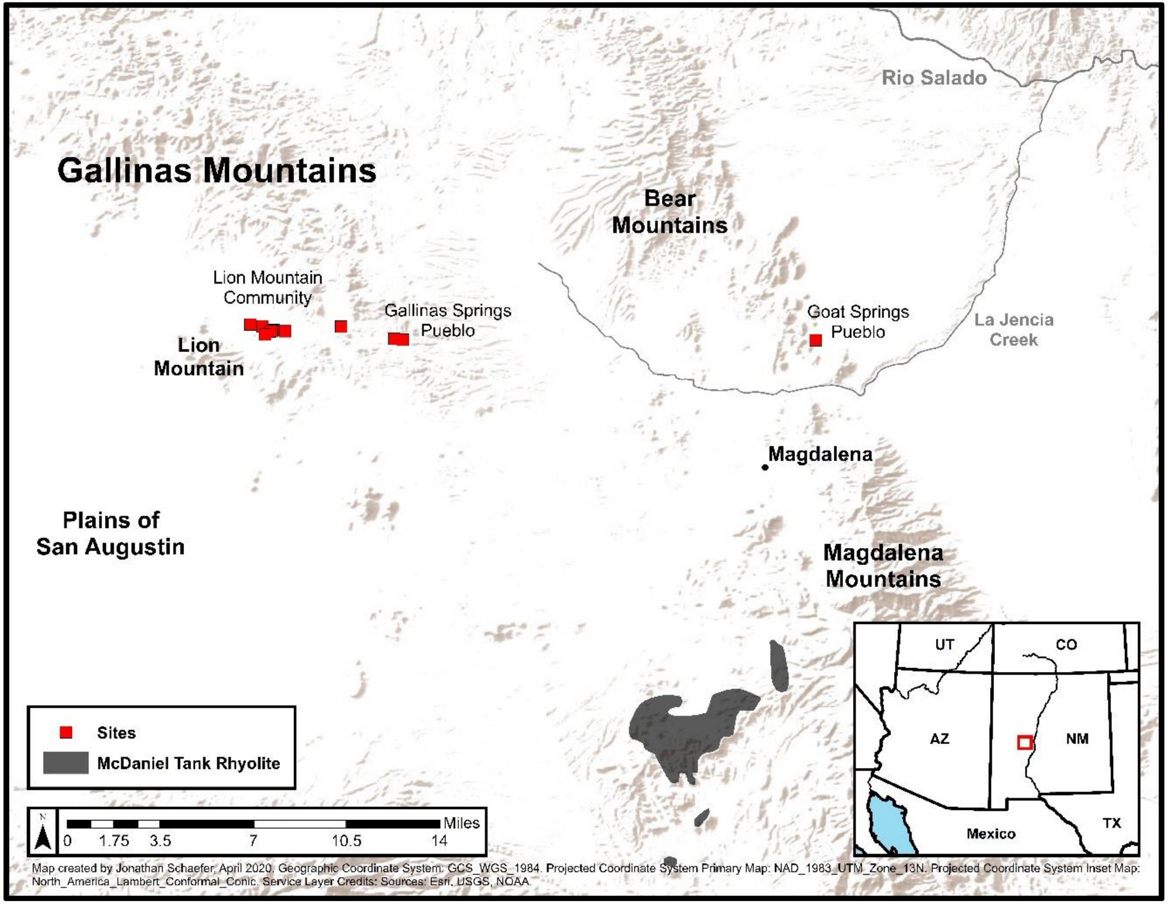
Finally in Chapter 5, the obsidian source use patterns of the people living in the Gallinas Mountains area is contextualized within the previous research that has been conducted there and in the surrounding regions. I discuss the patterns and their potential implications in terms of general trends, variation through time, and variation across cultural boundaries. I argue that the obsidian source use patterns and procurement strategies identified in this study provide important clues into the networks of exchange, social interaction, and social identity of those living in the Gallinas Mountains area during the Pithouse and Pueblo periods.

Chapter 2: Background
Part 1 - Study Area

Geographic and Environmental Context

The obsidian assemblages examined in this study belong to a number of sites in west central New Mexico. They are located in western Socorro County near the village of Magdalena. All sites are contained and protected within the lands of the Magdalena Ranger district of the Cibola National Forest. They are bounded within the Lion Mountain (n=7), Gallinas Peak (n=3), and Granite Mountain (n=1) USGS 7.5 minute series topographic quadrangles.

Figure 1. Map of study area with significant features.



Map created by Jonathan Schaefer, April 2020. Geographic Coordinate System: GCS_WGS_1984. Projected Coordinate System Primary Map: NAD_1983_UTM_Zone_13N. Projected Coordinate System Inset Map: North_America_Lambert_Conformal_Conic. Service Layer Credits: Sources: Esri, USGS, NOAA.

The study area can be described broadly as the Gallinas Mountains of west central New Mexico. This small mountain range lies just to the north of present day Magdalena. The range is oriented roughly north/northwest. Indian Mesa is the highest point in the Gallinas overall at 8,522 ft (2,597 m) (Basham 2011). The Lion Mountain and Gallinas Peak quads encompass the southwestern and southeastern edge of the Gallinas respectively. Elevation ranges from approximately 6,960-8,220 ft (2,121-2,505 m) within the Lion Mountain quad and 6,980-8,400 ft (2,127-2,560 m) within the Gallinas Peak quad. Immediately to the east/northeast of the Gallinas Mountains lie the Bear Mountains. These two ranges, while geologically distinct, are in very close proximity to one another and are often treated as a single management unit by the Cibola National Forest. The Gallinas and Bear Mountains are separated by Dry Lake Canyon and La Jencia Creek. The Bear Mountains are a north-south trending ridge with a maximum elevation of 8,205 ft (2,501 M) (Basham 2011). The Granite Mountain quad is located along the southeastern edge of the Bear Mountains and ranges in elevation from 5,700-7,340 ft (1,737-2,237 m).

The Gallinas are bordered by the Magdalena and San Mateo Mountains to the south. To the west, the Gallinas joins with the Datil Mountains to form an east-west trending arc. This arc cradles the northern extent of the Plains of San Augustin, a long northeast to southwest trending basin. Geological evidence has shown that this basin was once the site of a large Pleistocene lake (Basham 2011). The Gallinas along their north and east flanks primarily drain into the Rio Salado, an intermittently flowing waterway which empties into the Rio Grande approximately 15 miles north of Socorro. To the southwest, the Mountains drain into the Plains of San Augustin, which has no outlet.

Terrain is variable within the study area. Along the western edge of the Gallinas, a gradual rise exists when coming up from the bordering plains. Here, where the Gallinas meet the Plains of San Augustin, lies the somewhat isolated Lion Mountain. This area can generally be described as level and open, interspersed with low ridges and hills of volcanic basalt. The lower areas exhibit sandy soils that can be somewhat deep in places. Ridges exhibit relatively thinner soils and exposed basalt outcrops are common (Cartledge and Benedict 1999). As one moves further into the interior of the Gallinas, ridges gradually increase in height and grades become somewhat steeper, although level areas are still common. A number of normally dry arroyos cut paths through the interior of the Gallinas, including the aptly named Gallinas Arroyo.

The climate of this area is characterized as semiarid to semihumid (Berman 1979). Climatic data gathered by NOAA from the Magdalena climate station (Station # USC00295353), at an elevation of 6,540 ft (1,993.4 m), reports the mean annual low temperature as 36.9° F and the mean annual high as 67.7° F. The record lows and highs were -24° F and 102°F respectively. Limited standing water is available; precipitation and a small number of springs being the main sources. Average total annual precipitation is 12.29 inches. As a result of the summer monsoons, the wettest months are July and August. Average total annual snowfall is 11.86 inches.

The study area lies within the juncture of two elevational ecozones; otherwise known as an ecotone. The Upper Sonoran zone ranges in elevation from 4,500-6,500 ft (1372-1981 m) with the Transitional zone ranging from 6,500-8,000 ft (1981-2438 m). The Plains of San Augustin are characterized by open grassland. As one moves into the foothills of the Gallinas, the grasslands give way to open pinyon-juniper woodland. Small parcels of interspersed grassland can still be found, especially in the lower areas between the hills and ridges. Scattered ponderosa pine can be found as well and increase in frequency with elevation. Cottonwood can occasionally be found in close proximity to water sources such as arroyos and springs. Additional vegetation in the study area includes saltbush, sage, creosote, broom snakeweed, greasewood, wolfberry, rocky mountain bee plant, yucca, prickly pear cactus, and cholla cactus. A diverse selection of fauna can be found as well. Species include mule deer, pronghorn, and elk, black bear, mountain lion, fox, coyote, bobcat, peccary, cottontail, squirrel, prairie dog, and wild turkey (Basham 2011; Marshall and Marshall 2008).

Figure 2. Landscape of the Gallinas Mountains area.

Previous Research in the Gallinas Mountains Area

To date, no comprehensive cultural-historical overview has been published for the Gallinas Mountains area. However, there has been a number of small scale cultural resource inventories conducted by academia, private contractors, and the Cibola National Forest. These sporadic reports are primarily grey literature residing in the repositories of various governmental agencies. Despite the gaps present, these reports are the best available resource to understanding the area's cultural resources.

Mera Survey

The first archaeological survey work in the Gallinas Mountains was most likely conducted by H.P. Mera sometime in the early 1930s. Mera identified several sites in the Gallinas Mountains containing what he described as Mesa Verde type black-on-white pottery and architecture (Lincoln 2007; Mera 1935; Winkler and Davis 1961). Mera recorded a number of sites and conducted limited surface collections, most notably for a large nucleated pueblo LA1179 (Gallinas Springs Pueblo) located along Gallinas Arroyo. Unfortunately, while these notes are known to have been accounted for at least up until the time of the Davis and Winkler survey (1961), they have since been lost. Regardless, Mera's research in the area (more specifically the identification of potential Mesa Verde influence) likely inspired other future researchers to investigate the region (Lincoln 2007).

Danson survey

Beginning in the late 1940s and extending into the early 50s, the Peabody Museum of Archaeology and Ethnology at Harvard University conducted a broad investigation into the cultural resources of East Central Arizona and West Central New Mexico. The project was titled the Peabody Museum Upper Gila Expedition. This research resulted in the delineation of eight major geographic sub-regions, of which one is deemed the Rio Salado-Datil region (Danson 1957). Although very limited in scope, this survey work offered a glimpse into the cultural resources available in the Rio Salado Valley, the Datil and Gallinas Mountains and the northern plains of San Augustin.

Danson (1957) identified the earliest evidence of human activity in the area as small (likely Paleo-Indian and Archaic period) pre-pueblo campsites and activity areas along the periphery of the San Augustin basin. A lack of permanent sedentary occupation sites was noted for the basin country. The presence of pithouse period occupations in the Gallinas are briefly mentioned. Danson also notes early Pueblo period (specifically Pueblo I period) sites along the Rio Salado. These sites were characterized by mixed pithouse, jacal, and limited masonry architecture. The sites in the Gallinas Mountains exhibited mainly brown paste utility ware ceramics (often equated with Mogollon culture) while the sites just a few miles north near the Rio Salado were predominately gray paste utility wares (often equated with Anasazi culture).

During the Pueblo II to Pueblo III periods, Danson notes an increase in the number of occupation sites. In the Gallinas Mountains, the PII period brings above ground cobble masonry pueblos ranging in size from 4-12 rooms. PIII period rooms were very similar, however the total number of discrete roomblocks decreases while the range of rooms in a single roomblock increased to 6-50. Danson postulates a shift from single family units to multi-family pueblos. Many of the PII-PIII sites were reported to be accompanied by kivas. Brown paste utility wares remained dominant for sites in the Gallinas Mountains (although the Rio Abajo sites exhibit variation between brown and gray paste utility wares). Decorated ceramic wares from the PII-PIII horizon included Rio Abajo White Ware (Socorro B/w [900-1350 AD])[1], Cibola White Ware (Escavada B/w [950-1150 AD], Puerco B/w [1000-1150 AD], Reserve B/w [1000-1200 AD], and Tularosa B/w [1150-1325 AD]), and White Mountain Redware (Puerco [B/r 1030-1150 AD], Wingate B/r [1030-1175 AD], and St Johns Polychrome [1150-1300 AD]).

Towards the end of the Pueblo III and into the Pueblo IV period, a drastic decline in the number of sites in the study area is noted. The latest sites mentioned for the area are the late PIII period site of Gallinas Springs Pueblo (referred to as site 118) along the Gallinas Arroyo and the late PIV period site of Goat Springs Pueblo (referred to as site 125) near Bear Mountain.

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[1] All ceramic dates included in this study were derived from the New Mexico Office of Archaeological Studies Pottery Typology Project website (Wilson 2008).

Despite the total number of sites decreasing, Danson notes a drastic increase in size. Many of these later sites are also described as being “easily-defended”.

Winkler and Davis survey

In the late summer of 1961, James Winkler and Emma Lou Davis conducted a survey and some limited excavations of sites in the Gallinas Mountains as part of the Wetherill Mesa Project (Winkler and Davis 1961). The primary goal of their research involved investigating the possible Mesa Verde occupation reported for this area by Mera in 1930s. Most of their focus was directed at identifying and describing those sites exhibiting Mesa Verde attributes, most specifically decorated ceramics. However, the team did spend some time recording a few of the larger sites they came across, regardless of whether or not they exhibited Mesa Verde type pottery.

The Davis and Winkler survey was biased towards Pueblo period (especially PII-PIV) masonry structures. The team did not take the time to record any sites dating to the Pithouse period or earlier. Despite this bias, a large number of PII to PIII period sites were identified. Most pueblos were described as being cobble masonry. Roomblocks were typically rectangular and room number ranged from 6-60. Earlier PII roomblocks contained a relatively fewer number of rooms, and were more dispersed on the landscape. Later PIII sites tended to be aggregated clusters of roomblocks often in close proximity to one another. Some of the larger clusters may have contained roomblocks with multiple stories. Many of the larger aggregated sites also included one or more kivas. Davis and Winkler interpreted these aggregated clusters as evidence of “supra-family organization” (Winkler and Davis 1961).

The majority of the PIII period sites recorded for the area did not exhibit Mesa Verde type pottery. However, a small minority did. Gallinas Springs Pueblo was by far the largest of these. Both the non-Mesa Verde type and the Mesa Verde type sites utilized primarily brown paste utility ware. Although gray paste utility ware sherds were encountered at some sites, they were typically very few in number.

Most of the PII-PIII sites encountered exhibited decorated wares which utilized mineral based paints. While Winkler and Davis were often less than specific with the exact wares/types encountered at these sites, they did note the presence of Rio Abajo White Ware (Socorro B/w [900-1350 AD]), Cibola White Ware (Puerco B/w [1000-1150 AD]), and White Mountain Redware (Wingate B/r [1030-1175 AD], St Johns Polychrome [1150-1300 AD], and Pinedale Polychrome [1275-1325 AD]).

In sharp contrast to the sites with mineral based painted wares, were the sites exhibiting Mesa Verde type pottery with organic based paint. The Mesa Verde type pottery described was later designated Magdalena B/w (1240-1300 AD) (Lincoln 2007). Magdalena B/w dominated the decorated pottery assemblages at Gallinas Springs Pueblo, as well as a handful of relatively smaller sites in the Gallinas Mountains (Lincoln 2007; Winkler and Davis 1961). This ceramic type appears at a limited number of sites outside of the core study area as well (Ferguson et al. 2016). The term “Magdalena phase” (approximately 1240-1300 AD) has been used in reference to sites exhibiting this specific type of pottery (Ferguson et al. 2016; Lincoln 2007).

In addition to decorated ceramic technology, Winkler and Davis noticed a number of differences in architecture and site location/layout between the Magdalena phase sites and the remainder of the Pueblo period sites in the area. These differences were most pronounced at Gallinas Springs Pueblo. This ultimately led Winkler and Davis (as well as Mera years earlier) to postulate a Mesa Verde migration into the Gallinas Mountains, occurring sometime in the late PIII period. Gallinas Springs Pueblo and the Magdalena phase phenomenon would go on to become the subject of multiple investigations by different researchers throughout the remainder of the 20th century and into the 21st (Ferguson et al. 2016; Lincoln 2007).

Figure 3. Gallinas Springs Pueblo.

In addition to the sizable PII-PIII occupations in the area, Davis and Winkler also noted a small number of PIV sites. Sites dating to this period were far less common in number. For those sites identified, decorated wares were recorded as being primarily glaze wares. The only specifically differentiated type was Heshotauthla Polychrome (1275-1400 AD), a type of Zuni Glaze Ware.

Cibola National Forest investigations

In the late 1970s a non-systematic survey was conducted by Joseph Tainter along the southwestern edge of the Gallinas near Lion Mountain. Tainter, the Forest Archaeologist for the Magdalena district at the time, recorded and mapped approximately 15 pueblo period sites

(Cartledge 2000). No official report was ever drafted. However, a number of his original site forms, field notes, and sketch maps still exist (Tainter 1979). The pueblo period sites were clustered along two low parallel ridges just northeast of Lion Mountain near Indian Tank. These sites consisted of a series of masonry roomblocks of various sizes all in very close proximity to one another. Some of the roomblocks had attached plazas. A number of associated possible kivas were reported as well. The sites were estimated to be PIII period occupations based on architectural and ceramic observations, although no notes on the types present were recorded.

In 1998 the Cibola National Forest organized the Lion Mountain Passport in Time Project (PIT). The goal of this project was to revisit and more fully record the sites identified by Tainter in 1979. In addition to this, a more systematic and complete survey of the surrounding area was planned. A team of forest archaeologists and volunteers led by Tom Cartledge and Cynthia Benedict began work in 1998. Due to the extremely high site density encountered, the project was extended into 1999 (Cartledge 2000; Cartledge and Benedict 1999). An additional Damage assessment in 1998 (Cartledge 1998) and Non-compliance survey in 2000 (Des Planques 2000) were also linked to this project.

Lion Mountain PIT survey coverage focused on the two low parallel ridges immediately to the northeast of Lion Mountain. The southern of the two ridges was named Bobcat Ridge and the northern Forbidden Ridge by the survey crew. Along these two ridges a major Pueblo period occupation was encountered. The PIT and associated projects identified approximately 43 sites in total. This included all the original sites described by Tainter in 1979. It is quite possible that some of these sites were also encountered on the earlier Danson (1957) and Davis and Winkler (1961) surveys.

The vast majority of the sites encountered by the Lion Mountain PIT team fell under a series of aggregated masonry rooms and roomblocks. In several cases, multiple roomblocks were in such close proximity as to be categorized as a single site. Roomblocks were constructed of largely unshaped basalt boulders and cobbles. The majority were small to medium sized single storied buildings, however a few were larger and possibly contained second stories. Most roomblocks were rectangular in shape, although a few L-shaped and circular examples were noted. Some of the roomblocks were attached by or had attached “plaza areas” delineated by low masonry walls. Additional features included a number of circular depressions, at least a few of which were interpreted as potential kivas. A number of additional activity areas and a possible water reservoir were also noted.

Ceramic assemblages across most of the sites were largely uniform and hint at a single occupation. Utility wares were primarily plain and corrugated Mogollon Brown Ware. A small number of gray paste utility ware sherds were reported for a few sites, although these were always in the minority. The majority of decorated ceramics were Cibola White Ware and White Mountain Redware. The ceramic types encountered are indicative of a primarily PII-PIII period occupation (1000-1300 AD). However, a small number of glaze painted sherds could indicate a limited presence into the early PIV period.

Double H Ranch Lion Mountain Unit Survey

During 2007 and 2008 a large systematic survey was conducted on the privately owned lands of the Double H Ranch (Marshall and Marshall 2008). Survey was conducted in preparation for a prescribed forest thinning project. A team led by Michael and Christina Marshall, under the private contracting firm Cibola Research Consultants LLC, oversaw the project’s completion. Survey covered approximately 1270 acres in the vicinity of Lion Mountain; immediately to the north and west of the area surveyed by the Lion Mountain Passport in Time Project. In total, the survey identified 52 previously unrecorded sites within the Lion Mountain quad (and 1 additional site in the neighboring Indian Mesa quad).

Like others before, the survey team identified the highest site density occurring in the low foothills of the Gallinas just above the San Augustin plains. Survey identified a small number of non-architectural archaic activity areas. A few late Pithouse to early Pueblo period sites were also identified. These manifested as isolated pithouses or small pithouse villages along with some small PI period jacal units. By far the largest component encountered was an extensive late PII to PIII period/Socorro phase Puebloan occupation. This occupation was undoubtedly a part of the same Lion Mountain site complex identified in the Cartledge and Benedict surveys; albeit just on the other side of the National Forest boundary. In total, 44 of the identified sites were attributable to the Lion Mountain Community.

Included in the new Lion Mountain Community components were 27 single or small pueblo rooms or roomblocks, 6 medium sized roomblocks, 3 large roomblocks, 1 large community center (designated “Camelot” LA5975, this site was originally identified during the Davis and Winkler surveys), 2 non-architectural artifact scatters, 1 isolated great kiva, and 3 shrines. Architecture is exceedingly similar to that noted by Cartledge and Benedict. Clusters of rooms and roomblocks were found in relatively close proximity to one another. Cobble masonry roomblocks were typically rectangular or L-shaped. Buildings were typically single story, although the possibility of multiple stories was noted for the largest sites (such as Camelot). Some of the largest unit complexes contained associated kivas as well. Additional associated features such as a possible water catchment, low walls or berm construction, bedrock mortars, and large middens were also noted.

Also like the Lion Mountain sites recorded by Cartledge and Benedict, the majority of undecorated utility ceramics at the Lion Mountain sites are Mogollon/Gila Brown Ware. Gray paste utility ware types are also present, although again were found only in limited quantities. Based on decorated types, Marshall and Marshall differentiate between an earlier and a later Lion Mountain component. The sites associated with the earlier component (late PII to early PIII period; approximately 1000-1150 AD) are concentrated in a north settlement cluster. Socorro B/w (900-1350 AD) is by far the dominant decorated type. Early Cibola White Ware types including Puerco B/w (1000-1150 AD) and White Mountain Redware types including Wingate B/r (1030-1175 AD) and Puerco B/r (1030-1150 AD) were also encountered. A great kiva associated with the north cluster produced a number of Mimbres B/w sherds (1000-1140 AD); the only record of this type in the study area.

Sites associated with the later component (PIII period; approximately 1150-1250/1300 AD) are largely concentrated in a southern settlement cluster. For these sites, the later Cibola White Ware Tularosa B/w (1150-1325 AD) was recorded as occurring with either the same or greater frequency as Socorro B/w. Later White Mountain Redware types were also encountered, with St Johns Polychrome (1150-1300 AD) being the most common. A few sub-glaze St Johns Polychrome (1275-1300 AD) sherds were encountered at some of these later sites, although no types indicative of an early PIV occupation were recorded. It is curious to note that not a single Magdalena B/w sherd was encountered in the entire survey. This suggests a distinct demarcation between the Lion Mountain Community inhabitants, and the residents of the nearby Magdalena phase sites.

The Lion Mountain Archaeology Project

The Lion Mountain Archaeology Project (LMAP) is an ongoing archaeological survey that began in the summer of 2016. The project focuses on the portion of the Lion Mountain USGS quad contained within Cibola National Forest land. The project is spearheaded by Drs. Suzanne

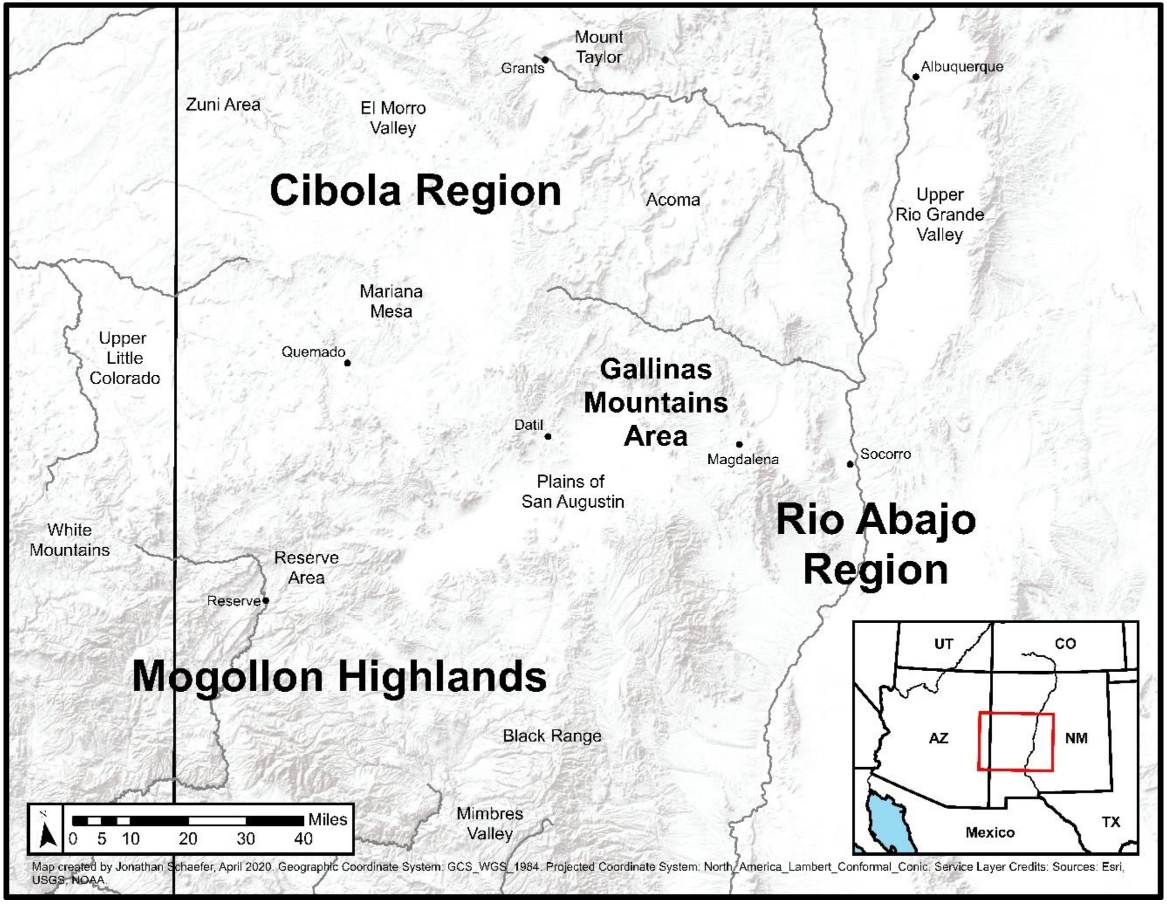
Eckert and Deborah Huntley. Work revolves around a systematic survey of the Lion Mountain area; recording previously undocumented sites as well as updating information on those previously identified. From this survey, the LMAP aims to produce a better understanding of the cultural manifestations of the area.

The primary focus of the Lion Mountain Archaeology Project has been given to better understanding the sizable late PII to PIII period (approximately 1150 - 1300 AD) occupation. The previous work conducted in the area as part of the Lion Mountain Passport in Time Project (Cartledge and Benedict 1999; Cartledge 2000) and the Double H Ranch survey (Marshall and Marshall 2008) highlighted the enormous research potential of this large aggregated pueblo community. The LMAP aims to answer several questions about the Lion Mountain Community. These include discovering the true extent of the occupation, exploring its social and ritual organization, and determining how the community interacted with its neighbors at both the local and regional scale (Eckert 2016; Eckert 2018).

Preliminary results of the LMAP show that the Lion Mountain Community shared a number of characteristics with three different neighboring regions (Eckert 2020). These include the Cibola region to the northwest, the Mogollon region so the southwest, and the Rio Abajo region to the east. The Cibola region covers a large portion of east central Arizona and west central New Mexico at the southern extent of the Colorado Plateau, is often defined as the ancestral homeland of the Zuni people (or at least has the Zuni area at its core), and itself exhibits a mixture of traits from the traditionally defined Anasazi culture area to the north and Mogollon culture area to the south (LeBlanc 1989; Peeples 2018; Peeples et al. 2017; Schachner 2012; Woodbury 1979). The Rio Abajo region occupies the portion of the Rio Grande Valley between Abeytas and the Fra Cristobal Range, is defined as the ancestral province of the Piro people, and like the Cibola region exhibits a mixture of stereotypical Anasazi and Mogollon traits

(Marshal and Walt 1984). The Mogollon tradition covers vast portions of the Southwest; especially the mountain belt that runs across much of east central Arizona and west central New Mexico south of the Colorado Plateau (Haury 1936; Haury 1985; Martin 1979). This culture area contains numerous sub-regional branches including that of the Reserve/Alpine/Tularosa Valley/Pine Lawn Valley/Cibola[2] area along its northern periphery (Bluhm 1960; Martin 1979; Martin et al. 1957; Wheat 1955).

Figure 4. Map of culture areas surrounding the Gallinas Mountains area.



Map created by Jonathan Schaefer, April 2020. Geographic Coordinate System: GCS_WGS_1984. Projected Coordinate System: North_America_Lambert_Conformal_Conic. Service Layer Credits: Sources: Esri, USGS, NOAA

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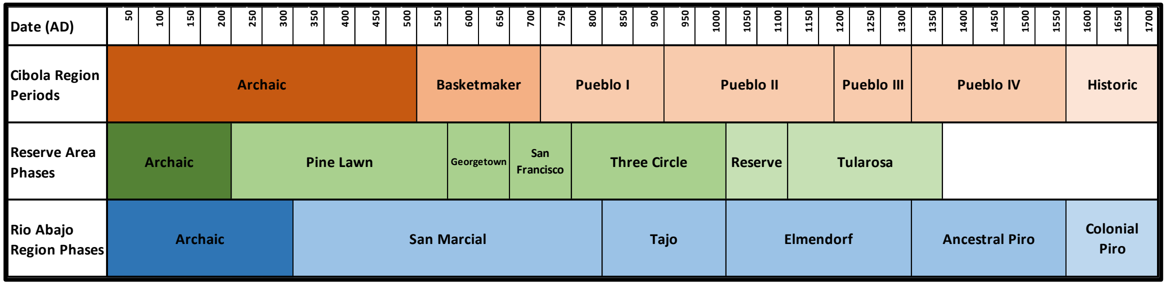
[2] Cibola here refers to a distinct branch of the Mogollon culture area and not the Cibola Region of the same name. See Martin 1979; Wheat 1955.

Figure 5. Established chronological sequences for neighboring culture areas. All dates for phases/periods are approximations. Cibola Region (Eckert 2020; Woodbury 1979). Reserve Area Mogollon (Basham 2011; Berman 1979; Bluhm 1960; Eckert 2020). Rio Abajo Region (Marshall and Walt 1984).



Date (AD)	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	1700
Cibola Region Periods	Archaic										Basketmaker				Pueblo I				Pueblo II					Pueblo III			Pueblo IV					Historic		
Reserve Area Phases	Archaic				Pine Lawn							Georgetown		San Francisco		Three Circle					Reserve		Tularosa											
Rio Abajo Region Phases	Archaic						San Marcial										Tajo				Elmendorf						Ancestral Piro					Colonial Piro		

The Lion Mountain Community appears to share some aspects of social and ritual organization, economic strategies, architecture, settlement patterns, subsistence strategies, and ceramic technology with both the Cibola, Rio Abajo, and the northern periphery of the Mogollon regions. However, the people who occupied the Lion Mountain Community do appear to be "economically and socially autonomous from the heartland traditions of these regions" (Eckert 2020). However, a full understanding of the nature of the Lion Mountain Community's relationship with these neighboring areas is yet to be fully grasped. The obsidian provenance work undertaken in the present study aims to help address these questions.

Chapter 2: Background
Part 2 - Obsidian

Geology

Obsidian is an igneous rock with a high silica content and a non-crystalline structure. It is formed during volcanic events when a highly viscous magma with a specific composition cools at a sufficiently rapid rate as to not allow the formation of crystals (Shackley 2005). The product of this event is an amorphous and vitreous (glass-like) volcanic rock. Due to the specific environmental factors required for its production, obsidian is not produced in every volcanic event. Magma may not have a sufficiently high silica content or cooling may take place over too long a time span. Far from the norm, obsidian producing volcanic events are in the minority. For this reason obsidian is limited on the landscape (Glascock et al. 1998), even in many areas with a great deal of volcanic history.

No two obsidian producing volcanic events are exactly alike in terms of magma composition and cooling factors, thus observable variation exists among the physical attributes of this material. Matrix color may range from grays to reds or even greenish tints, but by far the most common is black.[3] Conditions may further range from opaque, to translucent, to largely transparent. Inclusions in the form of phenocrysts (crystal pockets) may be present or absent. Furthermore, post depositional factors such as erosion and hydration (a gradual process in which the surface of obsidian chemically absorbs water) can shape the material further. Matrices may be largely aphyric (homogeneously glass-like) or vitrophyric (material that is less

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[3] Obsidian color can vary to a large extent both between and within sources. Studies have shown that attempting to identify source based on visual attributes, such as color, is an unreliable method (Ferguson 2012).

than aphyric; i.e. courser-grained, partially hydrated, or containing phenocrysts or devitrified spherulite pockets) (Shackley 2005). Overall nodule size is also related to a number of initial formation processes and post depositional factors.

Initial formation and post-depositional processes also have an effect on the spatial attributes of a given source. Sources may exhibit high nodule density within a relatively discrete locale (such as is the case with the Slate Mountain/Wallace Tank, Arizona source, which makes up the majority of the ground surface within an area no larger than a football field) or may exhibit a much wider primary distribution zone with relatively sporadic nodule density (as is the case with the Red Hill, New Mexico source, which occurs over several counties with nodules being somewhat rare). Additionally, erosion of material from the primary source area into secondary deposits (often via stream or river drainages) can widely expand the area in which the material of a given source may be encountered. However, many sources do not naturally extend far from their primary depositional ranges.

In addition to the large degree of variation present in the physical and spatial attributes of obsidian and obsidian sources, differences in magma composition lead to variation in internal elemental chemistry. Elemental chemistry not only varies between discrete geological magma chambers, but a single chamber may change in its chemistry over time. In regards to certain elements (especially trace elements), obsidian sources are characterized by a high amount of intra-source homogeneity and inter-source heterogeneity (Glascock et al. 1998). The Provenance Postulate states that “there exists differences in chemical composition between different natural sources that exceed, in some recognizable way, the differences observed within a given source” (Weigand et al. 1977). In regards to trace element chemistry, this statement holds true for most obsidian sources.

Prehistoric Use and Exchange

Due to its amorphous structure and vitreous nature, obsidian fractures in a highly predictable manner. Breaks produce a razor sharp edge; much finer than other microcrystalline lithic materials such as flints, cherts, chalcedonies, or jaspers. The material's physical properties make it an outstanding medium for stone tool production (i.e. great knappability[4]). This material was highly sought after by prehistoric peoples, who used it to create implements such as blades, knives, and projectile points. Specific sources of obsidian were selected over others for their accessibility (how easily the material could be obtained), their knappability, the amount of material available, nodule size, and sometimes even visual characteristics.

Figure 6. Obsidian projectile point from LA61489.

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[4] Knappability is the degree to which a stone can be shaped into a tool via lithic reduction strategies (usually through either direct or indirect percussion). Toolstones with high knappability fracture in a predictable manner.

Obsidian's superb tool making qualities, its distinct visual appearance, 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 living in close proximity or traveling to the natural distribution area for a given source. However, direct procurement was not always an option; or at least not an economically sensible one. This was especially true for more sedentary groups living further away from a resource's natural distribution area (Eerkens et al. 2008). 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. Extreme examples of indirect procurement via exchange networks have been identified, such as the artifacts found in Ohio Hopewellian contexts from the Obsidian Cliffs source of Yellowstone National Park (Wyoming) (Griffin et al. 1969) or the obsidian scraper of Pachuca (Hidalgo, Mexico) origin found in a Mississippian period mound in Eastern Oklahoma (Barker et al. 2002). While obsidian was occasionally exchanged over great geographic distances, the majority of material circulated within a more discrete distribution area around the source.

Exchange networks involving obsidian (and other goods for that matter) were often linked to a complex variety of social (and occasionally even ideological or political [Ponomarenko 2003]) factors. 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 (see Peeples 2018).

Chemical Characterization and Provenance Studies

Due to the large degree obsidian was exchanged amongst prehistoric populations, and the differences present in the elemental chemistries between discrete sources, this material is an ideal candidate for provenance studies. By obtaining precise chemical compositional data for obsidian artifacts and comparing it to that of known sources, the geographical origin of the raw material used to craft the artifact can be ascertained to a high degree of certainty. Knowing the source of an obsidian artifact allows archaeologists to make powerful inferences about human behavior. Obsidian provenancing studies provide archaeologists a narrow but precise indication of procurement strategies, exchange networks, inter-group interaction, and even cultural identity (Shackley 2005).

Obsidian falls under the Provenance Postulate (Weigand et al. 1977) in regards to its elemental chemistry. While the bulk of the elemental composition is roughly similar for all obsidian (i.e. major elements), significant differences in the proportions of trace elements are typically present between sources. Trace elements make up a minute portion of a sample, usually less than 1%. However, they are crucial in defining and subsequently differentiating between sources (Glascock et al. 1998). Trace elements commonly used in the provenancing of obsidian (by XRF) include the metals rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb).The amount of a given trace element within a sample is usually reported as parts per million (ppm).

Instrumentation

A number of methods have been developed to establish elemental composition. 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 methods in modern archaeometric obsidian compositional studies. Each of these has their own merits and drawbacks, and in practice, no one method is suitable for every situation. Considerations when selecting the best method may include analytical accuracy and precision, data comparability, effect on the sample, ease of use, speed, cost, portability, and access to instruments (Ferguson et al. 2014; Glascock et al. 1998; Shackley 2005).

LA-ICP-MS works by using a targeted laser to ablate (vaporize) a selected sample. The ablated sample is then ionized using a plasma torch and the atomic mass-to-charge ratios of the resulting ions are then recorded (Speakman and Neff 2005). LA-ICP-MS has several pros and cons. It has a high degree of accuracy and precision in elemental characterization, as well as low detection limits (very low ppm). It is also powerful in its ability to produce data for many elements. Unlike NAA the technology is relatively non-destructive, an important consideration when working with some artifacts. The precision aim of the laser allows for the targeting of specific areas of a sample, as well as very small samples that may not be suitable for testing with other methods (Eerkens et al. 2008). Although the ablation chamber itself is limited in size, so the testing of larger samples may not be feasible (at least in a non-destructive sense). Additionally, in comparison to XRF, the cost per sample is typically higher, sample prep is more time consuming and labor intensive, and overall run time per sample is much longer.

In NAA, samples are irradiated by neutrons using a nuclear reactor. Delayed gamma rays emitted from the irradiated sample are measured in order to determine the amounts of various elements present. Irradiation time and the time in which the radioactive sample is allowed to first decay can be altered in order to focus on detecting specific elements (Glascock et al. 1998; Glascock and Neff 2003). NAA provides excellent accuracy and precision and is sensitive to most elements. Other pros include that samples are often homogenized (evenly distributing any potentially variable chemistry within different parts of a sample), there is relatively little opportunity for sample contamination, and data gathered from different labs or instruments is highly comparable (Ferguson et al. 2014; Glascock and Neff 2003; Glascock 2017). Unfortunately, NAA is a destructive technique. It also produces radioactive samples which must be stored for a span of time post-analysis. Reactors set up to perform NAA are also extremely limited in number. Like LA-ICP-MS, sample prep takes more effort, run time is longer, and cost per sample is higher relative to XRF.

XRF works by irradiating the atoms in a sample with high energy x-ray photons. The photons knock electrons out of inner orbitals leaving gaps, converting the atoms into unstable ions. To restore stability, electrons from the outer orbitals will drop down to fill the gaps in the inner orbitals. This shift in electrons causes an energy emission known as fluorescence. The wavelengths of the fluorescent radiation (energy emission) are measured to determine the elements from which they originated. Relative fluorescent intensity is then used to determine elemental concentrations (Shackley 2005).

There are two main types of XRF spectrometers; wavelength dispersive (WD-XRF) and energy dispersive (ED-XRF). WD-XRF is the older of the two methods. It provides a somewhat higher resolution than ED-XRF, however it is much more time consuming, expensive, and requires a greater energy input. Additionally, WD-XRF requires a completely flat surface, often necessitating sample destruction (by grinding and pressing the sample into pellets). Unlike WD-XRF, ED-XRF analyzes the entire spectrum at once. Desired portions can then be selected. ED-XRF is thus the more flexible of the two and is the most commonly used today (Jenkins 1995;

Shackley 2005). From here forward in the text, the term XRF will be used specifically in reference to the Energy Dispersive method.

In comparison to NAA and LA-ICP-MS, XRF is less sensitive. This shortcoming is most apparent when elements are present in very low ppm. NAA and LA-ICP-MS are also able to reliably produce data for a far greater number of elements. However, XRF happens to be very adept at producing accurate data for some of the trace elements most important in discriminating between obsidian sources, especially Rb, Sr, Y, Zr, and Nb (Ferguson et al. 2014; Shackley 2005). Additionally, unlike NAA (and to a lesser extent LA-ICP-MS), XRF is a non-destructive technique. Sample preparation is negligible, cost of analysis per sample is low, sample run time is quick, and the technology is much more widely available than the other two methods.

Another advantage of XRF is the availability of portable instrument models. These models, such as the Bruker Tracer 5i XRF spectrometer, are small, lightweight, and handheld. They are often referred to in the literature as pXRF, fpXRF, or HHpXRF in the literature (Frahm 2013). The extreme portability of some XRF models, coupled with the method's non-destructive nature, opens up new opportunities for researchers (Ferguson 2012). The ability to gather artifact spectra in the field in a non-invasive manner is a powerful thing to preservation minded archaeologists.

The relatively cheap cost and availability of pXRF instruments, along with their portability, non-destructiveness, and demonstrated ability to produce usable data have made them quite popular among archaeologists wishing to determine the provenance of obsidian artifacts. The widespread use of this instrument has caused some debate over whether or not they are being used correctly. Much of the debate stems from use of qualitative and quantitative methods (Frahm 2012; Speakman and Shackley 2013). Calibrations using a set of standards allow for the quantification of gathered sample spectra. These standards are a number of set samples that have known chemical compositions. Processing sample data using a standard calibration set allows ppm to be established. Using this standardized format, newly gathered data can be compared to previous studies (Ferguson 2012).

Calibration can also correct for samples that are less than "infinitely thick". Infinite thickness is the point at which adding additional sample thickness does not increase the count rate for a specific element (Jeffrey Ferguson, personal communication 2020). Infinite thickness varies for different elements. In terms of producing accurate readings, a sample should ideally be infinitely thick for each of the elements desired. Extremely thin samples may pose issues for XRF analysis; producing lower counts for those elements which infinite thickness has not been obtained. However, calibrations can normalize for less than infinitely thick samples (Ferguson 2012; Bruker 2019). Additionally, while counts may appear lower, ratios of elements (particularly for peaks close in energy) should still be intact with or without normalization.

Obsidian in the American Southwest

The American Southwest is a phenomenal local for conducting obsidian provenance studies. The region has a long history of volcanic activity conducive to the production of obsidian. Relative to many other areas, the number of obsidian sources there is high. Over 40 distinct high quality sources exist between Arizona, New Mexico, and Northern Mexico.[5] Steven Shackley, from decades of his own and other's research, has compiled highly detailed descriptions for the majority of these in his book *Obsidian: Geology and Archaeology in the*

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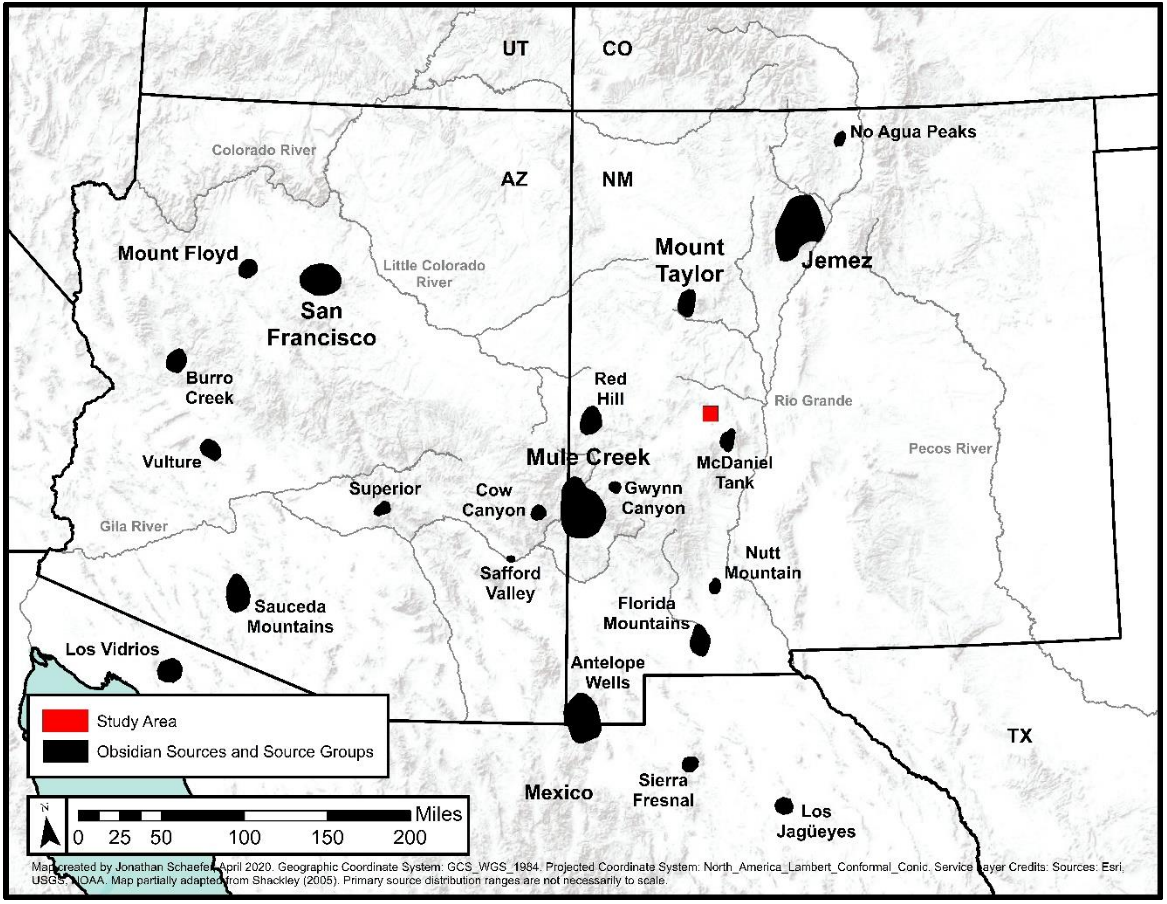
[5] High quality is a relative term. Here it is used to refer to those sources of obsidian in the American Southwest which were most suited to the production of stone tools. Excluded are sources which were, in a practical sense, not utilized due to some significant flaw(s).

North American Southwest (Shackley 2005) and on the Sources of Archaeological Obsidian in the Greater American Southwest website (Shackley 2019). A complete discussion of every high quality Southwestern obsidian source is beyond the scope of this project. However, a general description of the region’s obsidian resources is warranted.

Figure 7. Map of Southwestern obsidian sources.



Map created by Jonathan Schaefer, April 2020. Geographic Coordinate System: GCS_WGS_1984. Projected Coordinate System: North_America_Lambert_Conformal_Conic. Service Layer Credits: Sources: Esri, USGS, NOAA. Map partially adapted from Shackley (2005). Primary source distribution ranges are not necessarily to scale.

Shackley (2005) and (2019), divides obsidian sources in the Southwest into five regions; Northern Arizona, West and Central Arizona, Eastern Arizona/Western New Mexico, Northern New Mexico, and Northwest Mexico. Northern Arizona Sources consist of the San Francisco and Mount Floyd Volcanic Fields. These sources were formed during the Quaternary period.

Included in the San Francisco sources is the widely distributed Government Mountain. The West and Central Arizona region is made up of a number of dispersed Tertiary period marekanite sources[6]. Many of these sources are highly desirable in terms of knappability, although nodule sizes are typically small. The Eastern Arizona/Western New Mexico region is also primarily made up of Tertiary period marekanite sources. The Mule Creek source group is included in this region. The Northern New Mexico region includes the primarily Quaternary period sources of the Mount Taylor Volcanic Field, Jemez Mountains, Sierra de los Valles, and the Taos Volcanic Field. The Jemez and Mount Taylor sources were some of the most heavily used in the prehistoric Southwest. The Northwest Mexico region includes sources located in Sonora and Chihuahua. This region has not been researched as heavily as other areas and a number of unknown sources are suspected to be located therein. Furthermore, it should be noted that in addition to the Southwestern sources, material from outside areas occasionally enters the region.

Due to obsidian's availability in the Southwest, and it's highly desirable tool making qualities, it was an important and heavily utilized raw material to the prehistoric people living there. Projectile points, knives, blades and other cutting tools made of obsidian would have been valued in a utilitarian sense for their superior sharpness to those made of other material. From a more non-practical standpoint, value was also likely placed on the material's distinctiveness and its undeniable visual allure. While there is much variation in the proportion that obsidian makes up a given site's lithic assemblage, the presence of this material to some extent can be expected in most. This widespread presence in site assemblages makes obsidian provenance studies feasible in most prehistoric Southwestern contexts. Archaeologists working

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[6] Marekanites are small nodules of obsidian, often less than 10 cm in diameter. They often exhibit superb knappability, despite their smaller size. These sources date primarily to the late Tertiary period (Shackley 2005).

in the region have applied these kinds of studies to 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. 2012; VanPool et al. 2013).

Chapter 3: Methods

Site Selection

This study focuses on the Gallinas Mountains area of west central New Mexico. Previous research has highlighted a large number of sedentary, post-Archaic occupations within this area which range from the late Pithouse/early Pueblo to late Pueblo periods. The primary goal of this study is to produce a better understanding of the patterns of obsidian source use of the people who lived in this area during that time frame. Understanding which sources were utilized by which groups and how that utilization changed through time will ultimately provide a narrow but precise understanding of resource procurement strategies, as well as an indication of inter-regional interaction.

The study aims to capture a broad picture of obsidian source use which encompasses the full range of cultural and temporal variation present within this area during this dynamic time period. Sites were selected for inclusion in this study based on their relevancy to the research goals, as well as the presence of obsidian assemblages sufficient in size to permit analysis. The obsidian assemblages for a total of eleven sites were included in this study. Original data were gathered as part of this study for ten of these sites. Supplemental data from an additional site neighboring the core study area was included for comparative purposes. The temporal and cultural designations for these sites are tentatively based on prior research and are derived from a combination of factors including ceramic assemblages (both utility and decorated wares), architecture, and site layout.

Data Collection

As discussed earlier, XRF offers many advantages over other analytical methods in regards to chemical characterization of obsidian artifacts. These include the extreme portability of many models, their non-destructive nature, and a demonstrated ability to produce reliable obsidian trace element compositional data. These factors make conducting an in-field, minimally-invasive, preservation-minded study of obsidian artifacts possible. This study utilized portable handheld XRF spectrometry in the analysis of sites' obsidian assemblages.

Following the identification of potentially eligible sites for inclusion in this study, an examination of the site's surface obsidian assemblage was undertaken. A 100% surface area pedestrian survey was conducted for each using a team of trained archaeologists. All visually observed surface obsidian artifacts were marked with pin flags. Factors affecting the identification of artifacts included variable lighting and ground cover. Thick vegetation, blow sand, and collapsed architectural masonry hampered visibility in some cases. Furthermore, not all of the sites selected for survey produced assemblages large enough to warrant inclusion in this study.[7] The absence of observable surface obsidian artifacts at some sites could be due to any number of factors including (but not limited to) low use of the material by the people who lived there, erosion or depositional factors, or artifact collecting/looting.

Following the marking of all observable surface obsidian at a given site, each discrete artifact was assigned a unique analytical ID (ANID) in the format of LML###. Physical characteristics were then recorded for each. These included the artifact type and part, its size, and the amount of cortex present.[8] Artifact type was recorded and categorized as either tool or

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[7] Sites originally selected for inclusion in this study that did not produce surface obsidian assemblages sufficient in size to permit analysis included three Magdalena phase sites. These sites (LA5994, LA5995, and LA5996) were identified in the Davis and Winkler (1961) survey.

[8] Originally weight in grams was collected as well, however the scale was not available for all analyses.

non-tool. Artifact types included in the tool category were biface (**B**), projectile point (**P**), and uniface (**U**). Artifact types included in the non-tool category were flake (**F**), debris (**D**), core (**C**), and unmodified pebble (**UP**). Artifact part was categorized as either: complete (**C**)[9], proximal end (**P**), distal end (**D**), midsection (**M**), or unidentified (**U**). The size of the artifact was recorded as its maximum length in centimeters. The following classes were used: 1/2 cm (**0**), 1 cm (**1**), 2 cm (**2**), 3 cm (**3**), 4 cm (**4**), and 5 cm (**5**). The amount of cortex was recorded as the estimated percent present on the artifact's dorsal surface. Artifact type and part categorization, measurement, and percent cortex were all determined visually by the same researcher in order to maximize consistency. Full descriptive data for each sample is included in Appendix A.

All artifacts were then analyzed using a portable handheld Energy Dispersive X-ray fluorescence spectrometer on site. 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. Following the recording of physical characteristics and collection of spectra, all artifacts were returned to their original context (i.e. the location in which they were found by the research team).

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[9] All debris was categorized as complete.

Calibration

Upon completion of the in-field data collection portion of this study, artifact spectra files were transferred from the XRF spectrometer for processing. Artifact spectra were calibrated using the calibration developed by the Missouri University Research Reactor's (MURR) Archaeometry Laboratory (Glascock and Ferguson 2012). This calibration is based on precise and accurate elemental measurements of 37 different obsidian sources (standards). Data was produced by a combination of laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), neutron activation analysis (NAA), X-ray fluorescence (XRF), and microwave digestion inductively coupled plasma mass spectrometry (MD-ICP-MS)[10] from both MURR and other labs. Sources were selected to show a large range (high and low values) of trace element concentrations. 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 (iron [Fe]) and six trace elements (manganese [Mn], rubidium [Rb], strontium [Sr], yttrium [Y], zirconium [Zr], and niobium [Nb]). Full compositional data for each sample is included in Appendix B.

Source Assignment

Artifact samples were assigned to the most likely source on the grounds of similarity in elemental composition. Samples were compared to established source group standards for 32 discrete Southwestern obsidian sources (see Table 1). This list encompasses the vast majority of the (known) high quality obsidian sources that were utilized in the region's core (i.e. Arizona,

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[10] MD-ICP-MS, a method similar to LA-ICP-MS, uses an acid solution instead of an ablating laser to process samples for analysis (Glascock and Ferguson 2012).

New Mexico, and Northern Mexico). These source groups were compiled by the MURR Archaeometry Lab for use in provenance studies. Source group standards are housed in the lab's extensive global obsidian source material archives. Source standards were analyzed using the same instrument, operating under the same settings, and calibrated using the same calibration file as that used for the artifact samples in this study.

Table 1. Southwest obsidian sources referenced in source assignment.

Abbreviation	Source Name	Source Group
AWNM	Antelope Wells (El Berrendo)	n/a
BCAZ	Burro Creek	n/a
CCAZ	Cow Canyon	n/a
ECNM	Gwynn Canyon (Ewe Canyon; Negrito Mountain)	n/a
FM1NM	Florida Mountain 1	Florida Mountains
FM2NM	Florida Mountain 2	Florida Mountains
GMAZ	Government Mountain	San Francisco
JMBS	Bear Springs Peak (Canovas Canyon Rhyolite)	Jemez
JMCM	Cerro del Medio (Valles Rhyolite)	Jemez
JMPC	Paliza Canyon (Bearhead Rhyolite)	Jemez
JMPV	Polvadera Peak (El Rechuelos Rhyolite)	Jemez
JMRM	Rabbit Mountain (Obsidian Ridge/Cerro Toledo Rhyolite)	Jemez
LJCH	Los Jagüeyes	n/a
LVSM	Los Vidrios	n/a
MCAC	Antelope Creek	Mule Creek
MCMM	Mule Mountains	Mule Creek
MCNEW	Unnamed Mule Creek Source	Mule Creek
MCSM	North Sawmill Creek (Mule Creek)	Mule Creek
MDNM	McDaniel Tank (Alameda Spring)	n/a
MTGR	Grants Ridge	Mount Taylor
MTHM	Horace Mesa (La Jara Mesa)	Mount Taylor
NANM	No Agua Peaks	n/a
NMNM	Nutt Mountain	n/a
PWAZ	Presley Wash	Mount Floyd
RHNM	Red Hill	n/a
RMAZ	Partridge Creek (Round Mountain)	Mount Floyd
RSAZ	RS Hill	San Francisco
SFCH	Sierra Fresnal	n/a
SMAZ	Sauceda Mountains	n/a
SUAZ	Superior (Picketpost Mountain)	n/a
SVAZ	Safford Valley	n/a
VUAZ	Vulture	n/a

The 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 bi-variate scatterplots using the data for primarily five trace elements (Rb, Sr, Y, Zr, and Nb). The elemental compositions (ppm and elemental ratios) of an artifact sample were visually compared to that of the established Southwestern source groups. Dissimilar sources were gradually eliminated until only the most compositionally similar source remained. If sufficiently similar, the artifact was then assigned to that source. This process was repeated for every artifact sample. In most cases, confident assignment to a single source was obtained.

Chapter 4: Results

This study sampled and analyzed the surface assemblages of a total of ten sites via in-field handheld XRF. Sites were located within the Gallinas Mountains of west central New Mexico. In total, 502 obsidian artifacts were analyzed (with an additional 15 proving not to be obsidian upon examination of their chemistry). An additional comparative assemblage of 58 obsidian samples from a nearby site has been added for discussion purposes. This site, LA285 (Goat Springs Pueblo), is located in the Bear Mountains just to the east of the core study area. These samples were not analyzed as part of this study and were procured from an existing unpublished dataset. Unless otherwise stated, the following statistics reflect only the artifact assemblage (n=502) originally sampled and analyzed in this study.

Obsidian Sources

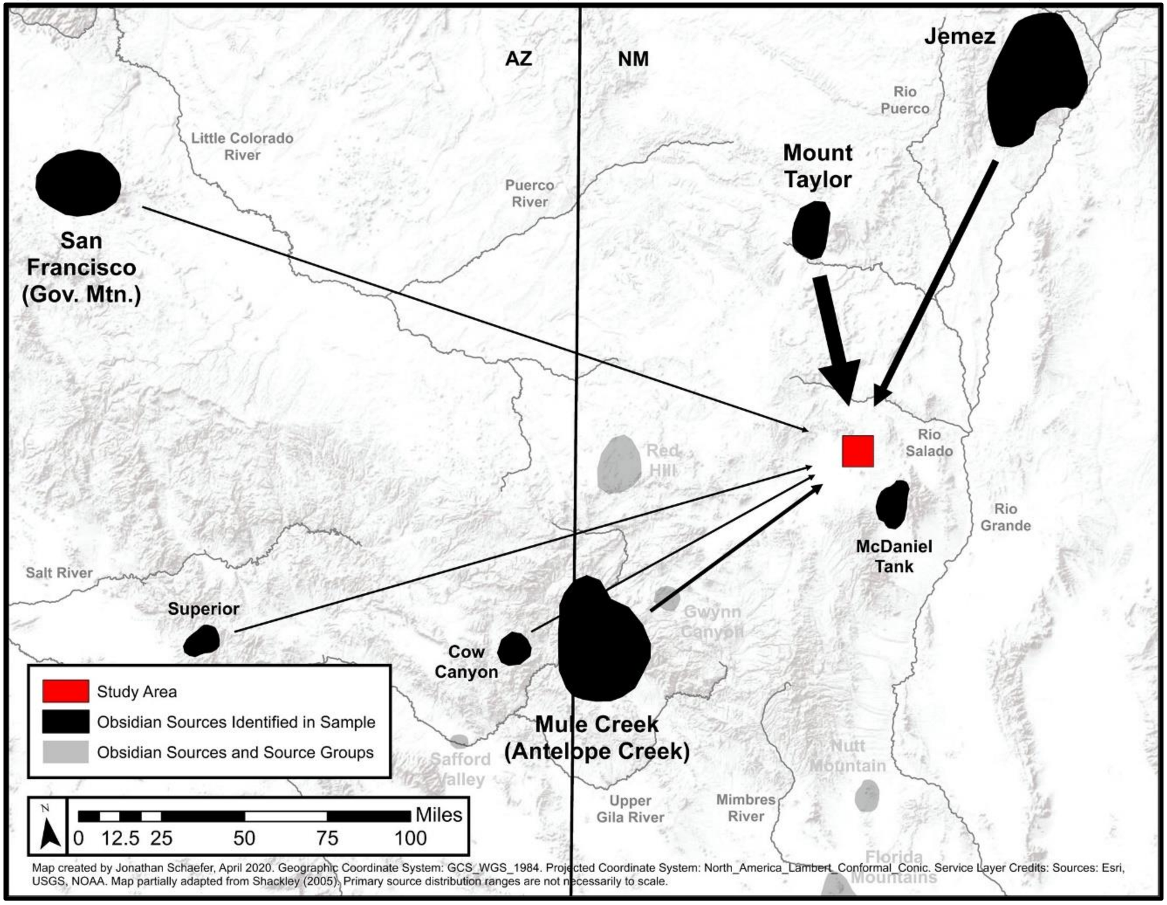
In total, 502 obsidian artifacts were analyzed via handheld XRF. Obsidian from ten discrete geological sources were identified within this sample. Several of these sources are combined under geological source groups. The results for each of the identified sources and source groups are discussed independently below. Two additional sources have been included in this discussion. One of these sources was appended based on a single sample that was tentatively (but not definitively) assigned. The other source was only identified in a comparative assemblage from a nearby site for which unpublished data already existed. The data from this additional site (LA285 - Goat Springs Pueblo) has been included in this study for discussion purposes.

Out of the entire sample (n=502), 496 artifacts (98.8%) were able to be confidently assigned to a known Southwestern geochemical source or source group. These include the Mount Taylor group (comprised of the Grants Ridge and Horace Mesa sources), McDaniel Tank, the Jemez group (comprised of the Cerro del Medio, Rabbit Mountain, Polvadera Peak, Paliza Canyon, and Bear Springs Peak sources), Antelope Creek (of the Mule Creek source group), and Superior sources. A total of six artifacts were not able to be confidently assigned to a known source or source group. One of these samples exhibited chemistry similar to Government Mountain, however this assignment is somewhat less confident than others. The five remaining unassigned samples show little chemical similarity to any of the known Southwestern sources or to each other. These samples could possibly belong to one of the yet undiscovered Southwestern obsidian sources (Shackley 2005), a yet undiscovered chemical variant within a known source group, or a non-Southwestern source. Additionally, there is the possibility of some form of surface contamination or unidentified analytical error.

Table 2. Obsidian sources identified in sample.

Source/Source Group	**Count**	**Percent**
Mount Taylor Source Group (MT)	256	51.00%
McDaniel Tank (MDNM)	188	37.45%
Jemez Source Group (Jemez)	44	8.76%
Antelope Creek (MCAC)	7	1.39%
Superior (SUAZ)	1	0.20%
Government Mountain (GMAZ)	1	0.20%
Unassigned (Unas.)	5	1.00%
Total	502	

Figure 8. Map of obsidian sources identified in sample. Includes data from LA285 (i.e. Cow Canyon).



Map created by Jonathan Schaefer, April 2020. Geographic Coordinate System: GCS_WGS_1984. Projected Coordinate System: North_America_Lambert_Conformal_Conic. Service Layer Credits: Sources: Esri, USGS, NOAA. Map partially adapted from Shackley (2005). Primary source distribution ranges are not necessarily to scale.

Mount Taylor Source Group

The Mount Taylor Volcanic Field is located in north-western New Mexico approximately 70 miles (113 km) north/northwest of the study area. Mount Taylor obsidian can also be found in limited amounts in secondary alluvial deposits. Material erodes into the Rio Puerco, eventually making its way into the Rio Grande alluvium (Church 2000). Originally, only a single source of Mount Taylor glass was recognized in the archaeological and geological literature. However, recent investigations identified two chemically and geographically distinct sources exhibiting quite different physical attributes (Shackley 2005). These are Grants Ridge and Horace Mesa/La Jara Mesa. While chemical and physical variability exists between the two, both are excellent sources of high quality volcanic glass. Mount Taylor obsidian was commonly utilized by and distributed amongst prehistoric peoples living in the Cibola region and the San Juan Basin (Arakawa 2011; Duff et al. 2012; Shackley 2019).

Mount Taylor was the most commonly encountered raw material source group within the collective sample. A total of 256 artifacts were assigned to this group (51.00% of total sample). Mount Taylor obsidian was encountered at all ten sites (and the one comparative site). This source group made up the majority of the assemblage for six sites. These were LA61489, LA193028, LA125085, LA1178, LA1180, and the comparative assemblage from LA285. Mount Taylor was tied with McDaniel Tank for the most common source at one site, LA189382. Of the collective Mount Taylor sample, 13 (5.08%) artifacts were classified as tools (bifaces and projectile points) and 243 (94.92%) as non-tools (flakes, cores, and debris).

Differentiating Between Mount Taylor Sources

Both Mount Taylor sources (Grants Ridge and Horace Mesa) were encountered within the sample. While the chemistry of the Mount Taylor source group is collectively quite distinct from most other Southwestern sources, Grants Ridge and Horace Mesa are quite similar to one another. Under ideal circumstances (i.e. infinitely thick samples) there is little issue in separating the two. However, many of the samples obtained were quite thin and therefore some loss of precision was encountered. Elemental concentrations were often erroneously lower, however relative proportions (elemental ratios) remained intact. Within the bivariate scatterplots, this manifested as samples plotting along a correlation line extending to the lower left from the source standards. The thickest samples would plot higher along the correlation line (i.e. closer to the standard source groups). The thinnest samples would plot lower on the correlation line (i.e. further away from the standard source groups).

An attempt was made to assign every Mount Taylor sample to one of the specific Mount Taylor sources (i.e. Grants Ridge or Horace Mesa). Bivariate scatter plots of Rubidium (ppm) plotted against Niobium, Zirconium, or to a lesser extent Yttrium provided the best separation the two. While the thickest samples were able to be confidently assigned to a specific source, a degree of uncertainty was present in the thinnest (lowest value) samples. As a result, two versions of the Mount Taylor source assignment were produced. The first version (Full Assignment) made a diligent attempt to assign every one of the Mount Taylor samples (n=256) to a specific source. As in all other cases, the sample was assigned to the most likely source. For the Full version, 114 of the samples (44.53%) were assigned to the Grants Ridge and 142 (55.47%) to Horace Mesa. The second version (Confident Assignment) only included those samples that were most confidently assigned to a specific source (n=128). For this version, 54 samples (42.19%) were assigned to Grants Ridge and 74 (57.81%) to Horace Mesa.

Comparison of the two versions (Full and Confident Assignments), showed that the relative proportions of the two sources (Grants Ridge and Horace Mesa) were quite similar. A Pearson's Chi-Square test was conducted to examine whether or not a significant difference existed between the two versions (Chi Square test #1; see Table 3). The Chi-Square test compared observed values to what would be expected given random chance. The null hypothesis (hypothesis of no difference) stated that no significant difference existed between the observed and expected values (H_0: O = E). The alternative hypothesis stated that the observed and expected values were significantly different (H_a: O ≠ E). The test was conducted at the .05 level of significance (α=.05). A Chi-Square value was calculated and compared to the critical value (for df=1, α=.05). For this test, the Chi Square value (0.19) did not exceed the critical value (3.84). The null hypothesis was therefore not rejected and it was concluded that no significant difference existed. Since it was determined that no significant difference existed between the two versions of the Mount Taylor source assignment, it was decided that only the data from one version (the Full Assignment) would be presented (in an effort to minimize redundancy).

Table 3. Chi-Square test #1: Full vs. Confident Mount Taylor assignment.

Source	Version	Observed	Expected	χ^2
Grants Ridge	Full	114	112	0.04
	Confident	54	56	0.07
Horace Mesa	Full	142	144	0.03
	Confident	74	72	0.06
			Chi Square Value =	0.19
			Critical Value (df=1, α=.05) =	3.84

Grants Ridge

The Grants Ridge source lies to the southwest of Mount Taylor proper and to the northwest of Grants Canyon and Horace Mesa. Here a series of coalesced rhyolitic domes produced abundant obsidian of a larger variety than the nearby Horace and La Jara Mesa ash flows (Shackley 2019). While the large majority of nodules are smaller than 5 cm in diameter, 10 cm examples are common and nodules ranging up to 15 cm have been observed. Nodule density is high reaching over 1000 per m^2 in areas (Shackley 2005). Grants Ridge glass is typically an opaque black. The glass is somewhat more brittle relative to Horace Mesa. Additionally, unlike the other Mount Taylor source, phenocrysts are quite common in the matrix (vitrophyric). These inclusions can present problems when manufacturing tools. Despite these issues however, Grants Ridge obsidian was still an important toolstone among prehistoric peoples living in the area (Shackley 2019).

Grants Ridge was encountered slightly less frequently than Horace Mesa. Under the Full Assignment, a total of 114 artifacts were assigned to this source (44.53% of Mount Taylor sample; 22.71% of total sample). Grants Ridge was encountered at most sites (with the exception of LA121884, which had a small sample size of MT artifacts; n=3). Sites LA189382, LA1178, and LA285 showed a slight majority of Grants Ridge over Horace Mesa. At sites LA121883, LA121885, and LA61489 it occurred in equal amounts with Horace Mesa. Of the entire Grants Ridge sample, two (1.75%) artifacts were classified as tools (bifaces) and 112 (98.25%) as non-tools (flakes, cores, and debris).

Horace Mesa

The Horace Mesa source lies to the southwest of Mount Taylor proper and southeast of Grants Canyon and Grants Ridge. Here a rhyolitic ash flow (of a single unit with La Jara Mesa to the north) produced obsidian of the small nodule marekanitic variety (Shackley 2019). The majority of nodules here are 3-4 cm and smaller, with the largest observed examples around 7 cm in diameter. Nodule density can reach up to 10 per m^2 (Shackley 2005). Horace Mesa glass is typically an opaque black. The matrix is aphyric (lacking phenocrysts) and knappability is excellent. While the glass occurs in smaller nodules and is less abundant than Grants Ridge, Horace Mesa seems to have been the more preferred Mount Taylor source among prehistoric peoples (no doubt because of its more aphyric matrix) (Shackley 2019).

Horace Mesa was encountered slightly more frequently than Grants Ridge. Under the Full Assignment, a total of 142 artifacts were assigned to this source (55.47% of Mount Taylor sample; 28.29% of total sample). Horace Mesa was encountered at every site. Sites LA193028, LA125085, LA121884, LA189381, and LA1180 showed a majority of Horace Mesa over Grants Ridge. The entire Mount Taylor sample for LA121884 was Horace Mesa (although the sample size was only three). At another site (LA193028) Horace Mesa made up nearly all of the Mount Taylor sample (with a much larger sample size). At sites LA121883, LA121885, and LA61489 Horace Mesa occurred in equal amounts with Grants Ridge. Of the entire Horace Mesa sample, 11 (7.75%) artifacts were classified as tools (bifaces and projectile points) and 131 (92.25%) as non-tools (flakes and debris).

McDaniel Tank

The McDaniel Tank obsidian source is part of the Mogollon-Datil Province of the Squaw Peak Volcanic center. This source is located in west central New Mexico, and is relatively local to the study area. Material can be found only about 17 miles (27 km) to the southeast), well within a day's walk from any of the sites included in this study. Obsidian associated with the McDaniel Tank Rhyolite deposits is of the small nodule marekanitic variety. The vast majority of observed nodules are under 3 cm, although can range up to 5 cm in diameter. A Paleoindian type projectile point base of McDaniel Tank obsidian was observed that may hint at the availability of yet undiscovered larger nodules. Nodule density is low and deposits are dispersed, occurring over roughly 20 square miles in scattered pockets. The material is typically an opaque black. Glass is aphyric and, like most marekanitic sources, exhibits excellent knappability (Jeffrey Ferguson, personal communication 2020).

The identification of the McDaniel Tank source is a relatively new development within the Southwestern archaeological obsidian discourse. Prior to its identification, its distinct chemistry was noted in numerous assemblages in central and west central New Mexico (LeTourneau 2010). However, it typically only made up small fractions of said assemblages. More commonly, this relatively minor marekanitic source was overshadowed by the more major source groups available in western New Mexico (i.e. the Mule Creek, Mount Taylor, and Jemez source groups).

McDaniel tank was the second most frequently encountered source overall. A total of 188 artifacts were assigned to this source (37.45% of total sample). McDaniel Tank was encountered in the assemblages of all ten sites (and the one comparative site). This source group made up the majority of the assemblage for four sites. These were LA121883, LA121884, LA121885, and LA189381. McDaniel Tank was tied (with Mount Taylor) for the most common source at one site, LA189382. Of the entire McDaniel Tank sample, 15 (7.98%) artifacts were classified as tools (bifaces, projectile points, and a uniface) and 173 (92.02%) as non-tools (flakes, cores, debris, and an unworked pebble).

Jemez Source Group

The Jemez source group is located within the Jemez Mountains in the proximity of the Valles Caldera in north central New Mexico. This source group can be found approximately 120 miles (193 km) north/northeast of the study area. However, a limited amount of Jemez source material does make its way into secondary deposits within the Rio Grande alluvium (Church 2000) which occurs much closer. The Jemez group includes five chemically and geographically distinct obsidian sources which were commonly used for stone tool production. They are Rabbit Mountain (Obsidian Ridge/Cerro Toledo Rhyolite), Cerro del Medio (Valles Rhyolite), Polvadera Peak (El Rechuelos Rhyolite), Paliza Canyon (Bearhead Rhyolite), and Bear Springs Peak (Canovas Canyon Rhyolite). The sources of the Jemez group exhibit excellent knappability. Material is abundant and several sources produced relatively large material (a somewhat rare occurrence within New Mexico). Jemez material was prized by prehistoric flintknappers and was distributed over wide portions of the American Southwest (and into the southern Great Plains) (Baugh and Nelson 1987).

Jemez was the third most commonly encountered raw material source group overall. A total of 44 artifacts were assigned to this group (8.76% of total sample). Jemez obsidian was encountered at nine sites (and the one comparative site). The only site where Jemez was not encountered was LA121884, a site with a smaller than average sample size (n=11). Since Jemez material typically only made up a small percentage of a given site's assemblage, it could be argued that the smaller sample size concealed its presence. All five (high quality) sources of Jemez obsidian were encountered within the entire sample. However, no single site exhibited material from all five sources (the most was four at site LA193028). Of the entire Jemez sample, nine (20.45%) artifacts were classified as tools (bifaces and projectile points) and 35 (79.55%) as non-tools (flakes and debris).

Rabbit Mountain

The Rabbit Mountain source (also known as Obsidian Ridge or Cerro Toledo Rhyolite obsidian) occurs to the southeast of the Valles Caldera. A series of ash flows associated with a number of volcanic events produced abundant material of the large nodule variety. Material occurs discontinuously along several ridges. In the highest density areas, soils are in large part replaced with obsidian gravel (some of the highest density observed in the Southwest). Most nodules are typically smaller than 5 cm, but 10-15 cm are common and examples up to 30 cm in diameter have been observed (Shackley 2019). Obsidian associated with the Cerro Toledo Rhyolite formations has eroded extensively and is commonly found among the Rio Grande alluvium as far south as Chihuahua (Shackley 2005). While a number of other sources are found deposited within the Rio Grande gravels, Rabbit Mountain obsidian makes up well over half

(Church 2000). The majority of Rabbit Mountain obsidian is a translucent to nearly transparent black or brownish-black glass. While aphyric varieties exist, much of this source material exhibits an abundance of devitrified spherulites and phenocrysts. While knappability is otherwise excellent, these inclusions can hamper tool production. Despite these flaws, Rabbit Mountain obsidian was one of the most commonly utilized Jemez obsidians by prehistoric people (Shackley 2005).

Rabbit Mountain was the most frequently encountered Jemez source. A total of 33 artifacts were assigned to this source (75.00% of Jemez sample; 6.57% of total sample). Rabbit Mountain was encountered in the assemblages of seven sites (and the one comparative site). These include LA61489, LA193028, LA125085, LA121883, LA121885, LA189381, LA1178, and LA285. Of the entire Rabbit Mountain sample, five (15.15%) artifacts were classified as tools (bifaces and a projectile point) and 28 (84.85%) as non-tools (flakes and debris).

Cerro del Medio

The Cerro del Medio source (also known as Valles Rhyolite obsidian) is the only one of the higher quality Jemez obsidian sources which naturally occurs within the Valles Caldera. The Cerro del Medio dome produced abundant material of the large nodule variety. Material is most abundant along its western slopes. Shackley (2005; 2019) notes that millions of pea size to 4 cm nodules are present, with sizes up to 15.5 cm in diameter being observed. Nodules have been observed in the upper reaches of San Antonio Creek and the East Fork of the Jemez River, however these are rare and likely do not make it far out of the caldera. Unlike many of the other Jemez sources Cerro del Medio has not been observed in the Rio Grande alluvium (Church 2000), so procurement from primary contexts can be safely assumed (Shackley 2005). The majority of Cerro Del Medio is an aphyric black glass, but mahogany color, granular textures (similar to Polvadera/El Rechuelos), and nodules containing phenocrysts and devitrified spherulites (like Rabbit Mountain/Obsidian Ridge/Cerro Toledo) have also been observed (Shackley 2005). Cerro del Medio exhibits excellent knappability and was likely the preferred source of Jemez by prehistoric people (Shackley 2005).

Cerro del Medio was the second most frequently encountered Jemez source. A total of seven artifacts were assigned to this source (15.91% of Jemez sample; 1.39% of total sample). Cerro del Medio was encountered in the assemblages at five sites (and at the one comparative site). These include LA61489, LA125085, LA121883, LA189382, LA1180, and LA285. Of the entire Cerro del Medio sample, four (57.14%) artifacts were classified as tools (projectile points and a biface) and three (42.86%) as non-tools (flakes and debris).

Polvadera Peak

The Polvadera Peak source (also known as El Rechuelos Rhyolite obsidian) is located north of the Valles Caldera. Here, three small domes of El Rechuelos Rhyolite located near Polvadera Peak proper (Glascock et al 1999) produced obsidian of the large nodule variety (Shackley 2019). The majority of nodules are between 1 and 5 cm, but examples ranging up to 15 cm in diameter are present (Shackley 2005). Polvadera obsidian (like many of the other Jemez sources) makes its way into the Rio Grande alluvium. Church (2000) shows Polvadera as the third most frequently encountered source in the Rio Grande gravels (behind Rabbit Mountain and Mount Taylor). Polvadera is visually distinct from many of the other Jemez sources with an almost granular appearance. The glass is aphyric and exhibits some of the best knappability of all the Jemez sources. Additionally, unlike Rabbit Mountain (and to a lesser extent Cerro del Medio) phenocrysts and devitrified spherulites are exceedingly rare in the matrix (Shackley 2005). Polvadera is common in assemblages in northern New Mexico and was distributed north and east into the Rockies and Great Plains. Despite this, it typically does not appear in assemblages to the south to quite the same extent as Rabbit Mountain or Cerro del Medio (Jeffrey Ferguson, personal communication 2020).

Polvadera Peak was the third most frequently encountered Jemez source. Only two artifacts were assigned to this source (4.55% of Jemez sample; 0.40% of total sample). One example (each) of Polvadera obsidian was encountered in two sites (and an additional single example in the comparative site). These include LA193028, LA121885, and LA285. One of the Polvadera artifacts was classified as a tool (a projectile point) and the other as a non-tool (a flake).

Paliza Canyon

The Paliza Canyon source (also known as Bearhead Rhyolite obsidian) is located south of the Valles Caldera. Here, marekanitic obsidian nodules from exposed formations of Bearhead Rhyolite erode into Paliza Canyon proper. Deposits are of a moderately high density with 20-40 per m^2 observed for some areas (Shackley et al. 2016). Nodule size is for the most part below 5 cm, although they can range up to 10 cm in diameter (Shackley et al. 2016). Paliza Canyon obsidian occurs in the Rio Grande alluvium, albeit to a much lesser extent than some sources (such as Rabbit Mountain) (Church 2000). Paliza Canyon obsidian typically ranges from a translucent to transparent grayish black. Material is aphyric and has as good of knappability as many of the other high quality Jemez obsidians (Shackley et al. 2016). However, Paliza Canyon is considered to be a relatively minor source. The material does not typically show up in archaeological assemblages to the extent of the more major Jemez sources (namely Cerro del Medio, Rabbit Mountain, and Polvadera Peak).

Paliza canyon was tied with Bear Springs Peak for the least frequently encountered Jemez source. Only one artifact was assigned to this source (2.27% of Jemez sample; 0.20% of total sample). Paliza Canyon obsidian was only encountered at one site, LA193028. This single artifact was a flake and was categorized as a non-tool.

Bear Springs Peak

The Bear Springs Peak source (also known as Canovas Canyon Rhyolite obsidian) is the oldest and southernmost of the high quality Jemez sources (Shackley 2019). Here, rhyolitic obsidian is associated with a series of domes which includes Bear Springs Peak proper. Nodules are of the small marekanitic variety. Most are under 2 cm, but can range up to 5 cm in diameter. Nodule density is moderately high, reaching approximately 100 per m^2 in areas. Bear Springs Peak obsidian does occasionally appear in secondary contexts within the Rio Grande alluvium, however it is relatively uncommon (Church 2000). Bear Springs Peak is a nearly transparent black glass with occasional banding (Shackley 2005). The obsidian is aphyric and exhibits excellent knappability. This source is considered to be one of the minor Jemez sources; often overshadowed by Cerro del Medio, Rabbit Mountain, and Polvadera Peak (Shackley 2019).

Bear Springs Peak was tied with Paliza Canyon for the least frequently encountered Jemez source. Only one artifact was assigned to this source (2.27% of Jemez sample; 0.20% of total sample). Bear Springs Peak obsidian was only encountered at one site, LA193028. This single artifact was a flake and was categorized as a non-tool.

Antelope Creek

Antelope Creek, part of the Mule Creek source group, is located primarily in west central New Mexico. Compared to many other Southwestern obsidian sources, Mule Creek occurs over a relatively large geographic area. The extensive ash flow that produced the marekanitic Mule Creek obsidian extends over a large portion of Grants and Catron county, New Mexico and west into Greenlee county, Arizona (Shackley 2019). Mule Creek obsidian has also been observed in secondary deposits in the San Francisco and Gila River alluviums which flow west into Arizona.

At least four chemically distinct sources have been identified within the Mule Creek source group; each named for the localities in which they were found (Shackley 2019). The Antelope Creek locality is located approximately 110 miles (177 km) southwest of the study area. Nodules occur in sizes up to about 10 cm in diameter (although smaller sizes are far more abundant). Nodule density is moderately high and can reach 20 per m^2 in areas. Color is variable and ranges from an opaque black to a translucent gray with banding (Shackley 2005; Shackley 2019). This marekanitic source is highly vitreous, aphyric (lacking phenocrysts), and an excellent media for tool production (Shackley 2019). Antelope Creek obsidian was likely the most popular Mule Creek source among prehistoric peoples. The material dominates most assemblages in west central New Mexico and appears in assemblages over a much wider geographic area.

Antelope Creek was the fourth most frequently encountered raw material source overall. A total of seven artifacts were assigned to this source (1.39% of total sample). Antelope Creek was encountered in the assemblages of two sites. These were LA189382 and LA1180. In the latter case, Antelope Creek was the second most plentiful source, surpassing both McDaniel Tank and Jemez in quantity. Of the entire Antelope Creek sample, two (28.57%) artifacts were classified as tools (projectile points) and five (71.43%) as non-tools (flakes).

Superior

The Superior obsidian source (also known as Picketpost Mountain) is located in Central Arizona, approximately 220 miles (354 km) west/southwest of the study area. Primary source distribution occurs over a relatively small area, primarily along the east slope of Picketpost Mountain. Material does erode into the nearby Queen Creek Drainage and can be found downstream (to the west) for a considerable distance (Shackley 2019). Superior obsidian is of the small nodule marekanitic variety. The majority of nodules are less than 5 cm in diameter but some of the larger examples may approach 8 cm. Nodule density is high with 20 per m^2 in some areas (Shackley 2005). Color is typically a nearly transparent brown. Superior obsidian exhibits an aphyric matrix and knappability is some of the best available in the Southwest. For this reason, the source was among the most heavily utilized by the prehistoric peoples residing in central and southern Arizona (Shackley 2019).

Within this study, Superior was one of the least frequently encountered raw material sources overall. Due to its geographic separation from the study area, the appearance of this source was somewhat unexpected. Only one artifact was assigned to this source (0.20% of total sample). Superior was only encountered in the assemblage of a single site, LA1180. This single artifact was a flake and was categorized as a non-tool.

Government Mountain

The Government Mountain obsidian source is part of the San Francisco Volcanic Field (San Francisco source group) in north central Arizona. The source is located approximately 260 miles (418 km) west/northwest of the study area. This source is of the large nodule variety and is associated with a single large rhyolitic dome of the same name (Shackley 2019). Nodule size is large for Southwest standards; ranging up to 30 cm in diameter. While the majority of material is smaller, 10-15 cm diameter nodules are still quite abundant. The glass has a distinct (at least within the context of the Southwest) opaque grayish-black granular appearance. Government Mountain obsidian is aphyric with exceptional knappability and was a highly popular raw material for flake stone tool production in the Southwest. This material was distributed over a wide geographic area and (while its primary distribution range was undoubtedly northern Arizona) it has appeared in assemblages as far east as Socorro, New Mexico (Shackley 2005).

Government Mountain has been included in this source discussion based on a single artifact. This artifact (LML529) was tentatively (but not definitively) assigned to this source. This artifact's chemistry is similar to that of Government Mountain. The artifact seems to be proportionally lower in all elements (with relative proportions remaining largely intact). This could point to a sample that was less than infinite thickness simply plotting low on the Government Mountain correlation line. If LML529 is in fact Government Mountain, this would be the most geographically distant source encountered in the sample. While the probability of a piece of Government Mountain obsidian occurring in an assemblage from west central New Mexico is low, it is not unheard of. If this artifact is in fact Government Mountain, it would only account for 0.20% of the total sample. LML529 was analyzed as part of the LA1180 assemblage (the same site with the only example of the almost nearly geographically distant source Superior). This artifact was indiscriminant debris and classified as a non-tool.

Cow Canyon

The Cow Canyon obsidian source is located in east central Arizona, approximately 120 miles (193 km) southwest of the study area. This source lies just east of the Mule Creek source group. The geographic extent of this source's primary depositional context is relatively small, a single remnant rhyolitic dome being the primary source (Shackley 2005). However, the source does erode to a substantial degree south and east into Eagle creek, and the Blue, San Francisco, and Gila Rivers (Shackley 2019). Cow Canyon, like the nearby Mule Creek sources, is of the small nodule marekanitic variety. Nodule density at the primary dome is moderate and can reach up to 5 per m^2 in areas. The majority of available material is near or less than 4 cm in diameter (one secondary deposit did produce nodules up to 5 cm in diameter). Color is variable, but a highly transparent brown-green seems to be the most common (Shackley 2005; Shackley 2019). The matrix is aphyric and knappability is excellent. Cow Canyon obsidian appears in many assemblages in east central Arizona and west central New Mexico, although it is commonly overshadowed by Mule Creek (especially Antelope Creek).

Cow Canyon was not encountered in any of the sites for which original surface assemblage data was procured (as part of this study). However, this source has been included in this discussion based on a single artifact derived from the comparative site LA285 (Goat Springs Pueblo). This single artifact made up 1.72% of that site's assemblage. No information on artifact type was available.

Chi-Square Analysis of Artifact Type by Source

A series of Pearson's Chi-Square tests were conducted to examine whether or not any significant differences existed among the frequencies of artifact type by source. The Chi-Square test compares observed values to what would be expected given random chance. In each test, the null hypothesis (hypothesis of no difference) stated that no significant difference existed between the observed and expected values (H_0: O = E). The alternative hypothesis stated that the observed and expected values were significantly different (H_a: O ≠ E). All tests were conducted at the .05 significance level (α=.05).

Chi-Square values were calculated and compared to critical values. In the cases where the Chi-Square value did not exceed the critical value, the null hypothesis was failed to be rejected (and thus determined that no significant difference existed between the observed and expected frequencies). In the cases where the Chi-Square value exceeded the critical value, the null hypothesis was rejected (and it was thus determined that a significant difference existed between the observed and expected). In the cases where the null was rejected, adjusted residuals were calculated in order to determine which of the observed values were significantly different than what would be expected given random chance. Positive residual values (greater than 1.96) denote that the observed frequency was significantly greater than the expected. Negative values (less than -1.96) denote that the observed frequency was significantly less than expected. All significant Chi-Square and adjusted residual values have been highlighted (appear in bold and underlined).

Chi-Square test #2 (Table 4) compared the frequency of artifact types (formal tools [unifaces, bifaces, and projectile points] and non-tools [flakes, debris, cores, and unworked pebbles]) by source. This test utilized the collective data for the 502 obsidian artifacts analyzed as part of this study. No artifact type data was available from the comparative assemblage (LA285 - Goat Springs Pueblo), so it was not included. In the case of test #2, the Chi-Square value (17.48) exceeded the critical value (12.59). The null hypothesis was therefore rejected and it was concluded that a significant difference existed. Calculated residuals showed that Mount Taylor (collectively) had a significantly lower proportion of formal tools and that Jemez (collectively) and Antelope Creek had a significantly greater proportion of formal tools.

Table 4. Chi-Square test #2: Artifact type frequency by source.

Source	Artifact Type	Observed	Expected	χ^2	Adjusted Residuals
MT	Tools	13	20.40	2.68	**-2.44**
	Non-tools	243	235.60	0.23	**2.44**
MDNM	Tools	15	14.98	0.00	0.01
	Non-tools	173	173.02	0.00	-0.01
Jemez	Tools	9	3.51	8.61	**3.20**
	Non-tools	35	40.49	0.75	**-3.20**
MCAC	Tools	2	0.56	3.73	**2.03**
	Non-tools	5	6.44	0.32	**-2.03**
SUAZ	Tools	0	0.08	0.08	-0.29
	Non-tools	1	0.92	0.01	0.29
GMAZ	Tools	0	0.08	0.08	-0.29
	Non-tools	1	0.92	0.01	0.29
Unas.	Tools	1	0.40	0.91	1.00
	Non-tools	4	4.60	0.08	-1.00
			Chi Square Value =	**17.48**	
			Critical Value (df=6, α=.05) =	12.59	

Chi-Square test #3 (Table 5) compared the frequency of artifact types (tools and non-tools) between the two Mount Taylor sources, Grants Ridge and Horace Mesa. This test utilized the collective data for the 256 Mount Taylor artifacts analyzed as part of this study (under the Full Assignment). As with test #2, test #3 did not include any data from the comparative assemblage (LA285 - Goat Springs Pueblo). In the case of test #3, the Chi-Square value (4.71) exceeded the critical value (3.84). The null hypothesis was therefore rejected and it was concluded that a significant difference existed. Calculated residuals showed that Grants Ridge had a significantly lower proportion of formal tools compared to Horace Mesa.

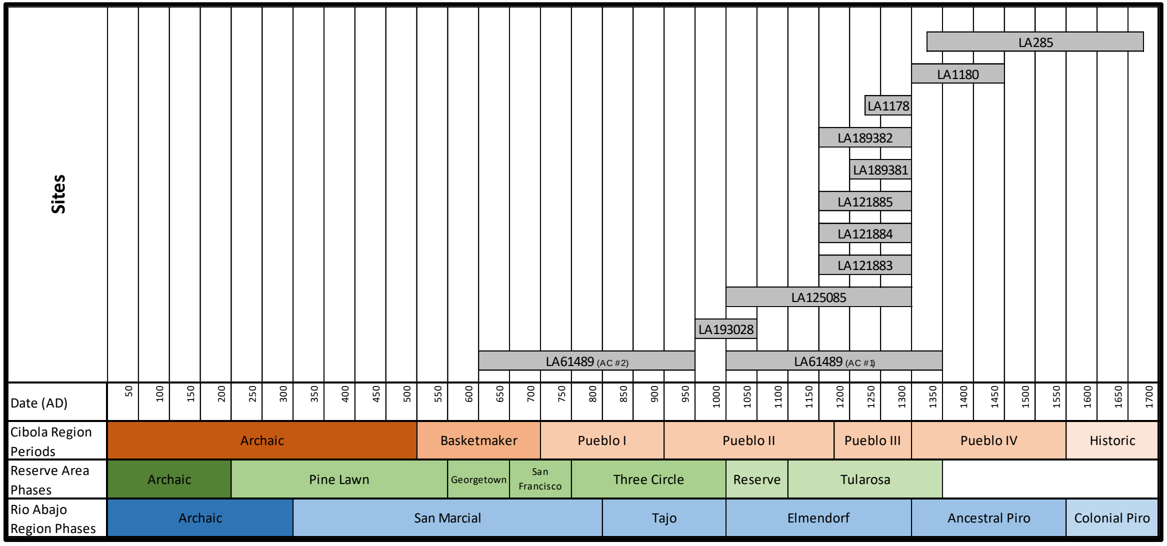
Table 5. Chi-Square test #3: Artifact type frequency by Mount Taylor source.

Source	**Artifact Type**	**Observed**	**Expected**	**χ^2**	**Adjusted Residuals**
Grants Ridge	Tools	2	5.79	2.48	**-2.17**
	Non-tools	112	108.21	0.13	**2.17**
Horace Mesa	Tools	11	7.21	1.99	**2.17**
	Non-tools	131	134.79	0.11	**-2.17**
			Chi Square Value =	**4.71**	
			Critical Value (df=1, α=.05) =	3.84	

Sites

Original data were produced for a total of ten sites as part of this study. These sites were all located on Cibola National Forest land, within the Lion Mountain and Gallinas Peak quads, in the southern extent of the Gallinas Mountains (see Figure 1). An additional comparative assemblage from LA285 (Goat Springs Pueblo) has been included below for discussion purposes. This site is located within the Granite Mountain quad, at the southern extent of the Bear Mountains, several miles to the east of the core site cluster. All sites selected for inclusion in this study were representative of sedentary, post-Archaic, occupations ranging from the late Pithouse/early Pueblo through the late Pueblo periods.

Figure 9. Approximate dates for site occupations.



LA61489

LA61489 is located within the Gallinas Peak quad. It lies within the Gallinas Mountains, about two miles east of the Lion Mountain Community site cluster. This is a multi-component site which is comprised of three distinct artifact concentrations. Artifact concentration #2 (AC#2) correlates with a late Pithouse period/San Marcial-Tajo phase occupation (approximately 600-950 AD). AC#2 is a multiple residence pithouse site. Rock alignments may point to possible above ground masonry/jacal storage rooms. The majority of utility ceramics are Mogollon Brown Ware, but a small amount of Cibola Gray Ware is also present. The decorated ceramic assemblage consists of Mogollon Red Ware (San Francisco Red [200-1200 AD] and Mogollon R/br [700-900 AD]), Mimbres White Ware (Three Circle R/w [700-900 AD]), and Rio Abajo White Ware (San Marcial B/w [600-950 AD]) (DeHaven and Turner 2016).

Artifact concentration #1 and #3 (AC#1 and AC#3) correlate with a later non-architectural Reserve-Tularosa phase/PII-PIV period component (approximately 1000-1350 AD). Utility ceramics are Mogollon Brown Ware. The decorated ceramic assemblage includes Cibola White Ware (Reserve B/w [1000-1200 AD] and Tularosa B/w [1150-1325 AD]) and Rio Abajo White Ware (Socorro B/w [900-1350 AD]) (DeHaven and Turner 2016).

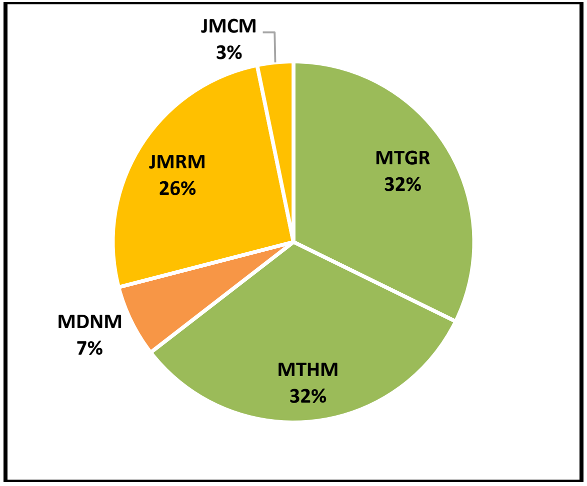
Obsidian was only analyzed from artifact concentrations #2 and #1. In addition to differences in their ceramic assemblages and architecture, AC#2 and AC#1 are separated by approximately 45 meters (25 in the case of AC#2 and AC#3). These differences in assemblages and location suggest a meaningful separation between the two. For this reason, AC#2 and AC#1 were treated as separate entities for analysis purposes.

A total of 31 obsidian artifacts were analyzed from LA61489 AC#2. Sources identified in the assemblage included Mount Taylor (collectively n=20; Grants Ridge n=10; Horace Mesa n=10), McDaniel Tank (n=2), and Jemez (collectively n=9; Rabbit Mountain n=8; Cerro del Medio n=1). Mount Taylor made up the majority of the assemblage (64.52%), followed by Jemez (29.03%), then McDaniel Tank (6.45%). Within the Mount Taylor source group, Grants Ridge and Horace Mesa made up equal proportions. Within the Jemez source group, Rabbit Mountain made up the large majority (88.89%) compared to Cerro del Medio (11.11%).

Table 6. Obsidian sources identified in LA61489 AC#2 sample.

Source	Count	Percent
Mount Taylor - Grants Ridge (MTGR)	10	32.26%
Mount Taylor - Horace Mesa (MTHM)	10	32.26%
McDaniel Tank (MDNM)	2	6.45%
Jemez - Rabbit Mountain (JMRM)	8	25.81%
Jemez - Cerro del Medio (JMCM)	1	3.23%
Total	31	

Figure 10. Source proportions for LA61489 AC#2.



Only two obsidian artifacts were analyzed as part of LA61489 AC#1. It may be meaningful that only two pieces of obsidian were encountered in this otherwise large and dense artifact scatter (suggesting a lack of use). While this sample size is too small to be included in some discussions, the results have been included here regardless. The two source groups identified in the sample were Mount Taylor (n=1) and Jemez (n=1). The Mount Taylor sample was assigned to Horace Mesa and the Jemez sample to Rabbit Mountain.

LA193028

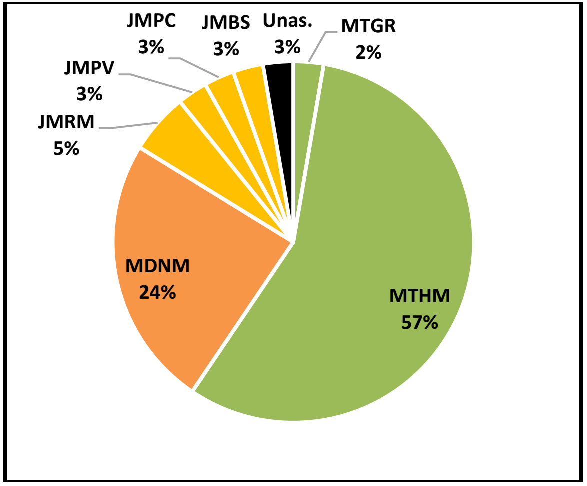
LA193028 is located within the Lion Mountain quad. The site lies to the northeast of Lion Mountain proper and just to the east of Bobcat Ridge. This is a late Pithouse/early Pueblo period site (approximately 950-1050 AD). The site consists of a possible multiple residence pithouse cluster and a large depression which has been interpreted as a Great Kiva (Huntley and Eckert 2020). Utility ceramics are primarily Mogollon Brown Ware and an unnamed locally produced type. The local utility ware is somewhat distinct from true Mogollon Brown Ware or Cibola Gray Ware types. While it occasionally exhibits attributes of both, it commonly shows a greater affinity to Mogollon Brown Ware in that it is often smudged (Deborah Huntley and Suzanne Eckert, personal communication 2020). Decorated ceramics are primarily early Cibola White Ware (Kiatuthlanna B/w [850-950 AD], Red Mesa B/w [875-1050 AD], and Reserve B/w [1000-1200 AD]). Rio Abajo White Ware (Socorro B/w [900-1350 AD]) and White Mountain Redware types are also present in limited quantities (Huntley and Eckert 2020).

A total of 37 obsidian artifacts were analyzed from LA193028. Sources identified in the assemblage included Mount Taylor (collectively n=22; Grants Ridge n=1; Horace Mesa n=21), McDaniel Tank (n=9), and Jemez (collectively n=5; Rabbit Mountain n=2; Polvadera Peak n=1; Paliza Canyon n=1; Bear Springs Peak n=1). One sample was not able to be assigned to any known Southwestern source. Mount Taylor made up the majority of the assemblage (59.46%), followed by McDaniel Tank (24.32%), then Jemez (13.51%). Within the Mount Taylor group, Horace Mesa made up the large majority (95.45%) compared to Grants Ridge (4.55%). Within the Jemez group, Rabbit Mountain occurred most often (40%) followed by Polvadera Peak (20%), Paliza Canyon (20%), and Bear Springs Peak (20%). LA193028 was the only site in which the relatively minor Jemez sources Paliza Canyon and Bear Springs Peak were encountered.

Table 7. Obsidian sources identified in LA193028 sample.

Source	Count	Percent
Mount Taylor - Grants Ridge (MTGR)	1	2.70%
Mount Taylor - Horace Mesa (MTHM)	21	56.76%
McDaniel Tank (MDNM)	9	24.32%
Jemez - Rabbit Mountain (JMRM)	2	5.41%
Jemez - Polvadera Peak (JMPV)	1	2.70%
Jemez - Paliza Canyon (JMPC)	1	2.70%
Jemez - Bear Springs Peak (JMBS)	1	2.70%
Unassigned (Unas.)	1	2.70%
Total	37	

Figure 11. Source proportions for LA193028.



LA125085

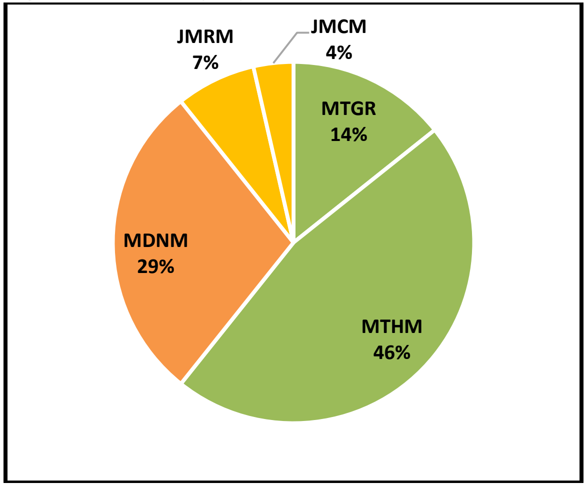
LA125085 is located within the Lion Mountain quad. The site lies to the northeast of Lion Mountain proper, midway along Forbidden Ridge. This is primarily a PII period site with some occasional use into the PIII-PIV periods (approximately 1000-1200/1300 AD). The site consists of a pueblo period residential complex. Unshaped cobble masonry was the preferred construction technique. The primary feature(s) of this site is a large (possibly) multistoried roomblock placed upon a naturally high outcrop. A berm (with possible road breaks) encircles the main roomblock. Additional features located outside of the main complex include two roomblocks and several (possible) kiva depressions (Cartledge 1998; Huntley and Eckert 2020). This site has been interpreted as a possible Chacoan Outlier (Huntley and Eckert 2020). Utility ceramics are primarily Mogollon Brown Ware and the local unnamed type, with a small amount of Cibola Gray Ware also present. Decorated ceramics are mostly Cibola White Ware (Kiatuthlanna B/w [850-950 AD], Red Mesa B/w [875-1050 AD], Puerco B/w [1000-1150 AD], Escavada B/w [950-1150 AD], Reserve B/w [1000-1200 AD], Tularosa B/w [1150-1325 AD], and Cebolleta B/w [950-1150 AD]) and White Mountain Redware (Wingate B/r [1030-1175 AD], Wingate Polychrome [1030-1175 AD], St Johns B/r [1150-1300 AD], and St Johns Polychrome [1150-1300 AD]). Limited amounts of Rio Abajo White Ware (Socorro B/w [900-1350 AD]), Mogollon Red Ware (Tularosa W/r [1100-1350 AD]), Zuni Glaze Ware (Heshotauthla Gl/r [1275-1400]), and an unnamed local B/w type are also present (Huntley and Eckert 2020).

A total of 28 obsidian artifacts were analyzed from LA125085. Sources identified in the assemblage included Mount Taylor (collectively n=17; Grants Ridge n=4; Horace Mesa n=13), McDaniel Tank (n=8), and Jemez (collectively n=3; Rabbit Mountain n=2; Cerro del Medio n=1). Mount Taylor made up the majority of the assemblage (60.71%), followed by McDaniel Tank (28.57%), then Jemez (10.71%). Within the Mount Taylor group, Horace Mesa made up the large majority (76.47%) compared to Grants Ridge (23.53%). Within the Jemez group, Rabbit Mountain was in the majority (66.66%) over Cerro del Medio (33.33%).

Table 8. Obsidian sources identified in LA125085 sample.

Source	Count	Percent
Mount Taylor - Grants Ridge (MTGR)	4	14.29%
Mount Taylor - Horace Mesa (MTHM)	13	46.43%
McDaniel Tank (MDNM)	8	28.57%
Jemez - Rabbit Mountain (JMRM)	2	7.14%
Jemez - Cerro del Medio (JMCM)	1	3.57%
Total	28	

Figure 12. Source proportions for LA125085.



LA121883

LA121883 is located within the Lion Mountain quad. The site lies to the northeast of Lion Mountain proper, along the crest of Bobcat Ridge at its eastern end. This is a late PII-PIII period site (approximately 1150-1300 AD) associated with the Lion Mountain Community (Cartledge and Benedict 1999; Huntley and Eckert 2020). The site consists of a pueblo period residential complex. Unshaped cobble masonry was the preferred construction technique. The primary feature of this site is a roomblock with an adjoining enclosed plaza space delineated by a low wall. Two possible kivas (one internal to the roomblock and one external) as well as a couple of single isolated rooms are also associated with this site (Cartledge and Benedict 1999; Huntley and Eckert 2020; Tainter 1979). Utility ceramics are Mogollon Brown Ware and the local unnamed type. Decorated ceramics are mostly Cibola White Ware (Red Mesa B/w [875-1050 AD], Reserve B/w [1000-1200 AD], and Tularosa B/w [1150-1325 AD]) and White Mountain Redware (St Johns B/r [1150-1300 AD] and St Johns Polychrome [1150-1300 AD]). Limited amounts of Rio Abajo White Ware (Socorro B/w [900-1350 AD]), Zuni Glaze Ware (Heshotauthla

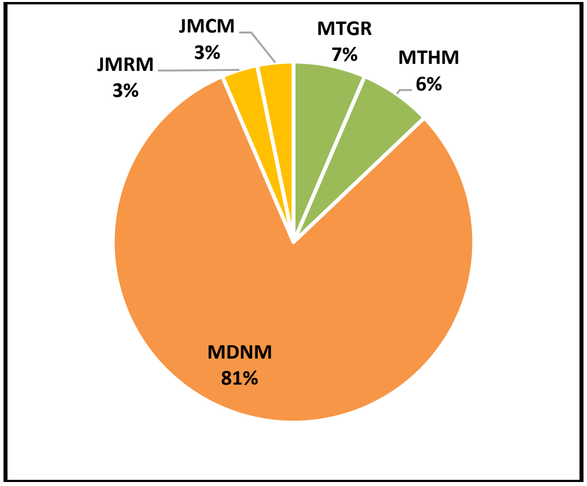
Gl/r [1275-1400 AD]), and an unnamed local B/w type are also present (Huntley and Eckert 2020).

A total of 31 obsidian artifacts were analyzed from LA121883. Sources identified in the assemblage included Mount Taylor (collectively n=4; Grants Ridge n=2; Horace Mesa n=2), McDaniel Tank (n=25), and Jemez (collectively n=2; Rabbit Mountain n=1; Cerro del Medio n=1). McDaniel Tank made up the large majority of the assemblage (80.65%), followed by Mount Taylor (12.90%), then Jemez (6.45%). Within the Mount Taylor group, Grants Ridge and Horace Mesa occurred in equal proportions. Within the Jemez group, Rabbit Mountain and Cerro del Medio also occurred in equal proportions.

Table 9. Obsidian sources identified in LA121883 sample.

Source	Count	Percent
Mount Taylor - Grants Ridge (MTGR)	2	6.45%
Mount Taylor - Horace Mesa (MTHM)	2	6.45%
McDaniel Tank (MDNM)	25	80.65%
Jemez - Rabbit Mountain (JMRM)	1	3.23%
Jemez - Cerro del Medio (JMCM)	1	3.23%
Total	31	

Figure 13. Source proportions for LA121883.



LA121884

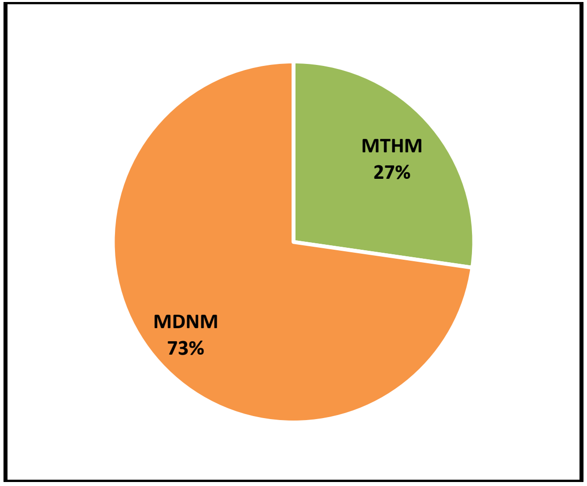
LA121884 is located within the Lion Mountain quad. The site lies to the northeast of Lion Mountain proper, along the crest of Bobcat Ridge at its eastern end. This is a late PII-PIII period site (approximately 1150-1300 AD) associated with the Lion Mountain Community (Cartledge and Benedict 1999; Huntley and Eckert 2020). The site consists of a pueblo period residential complex. Unshaped cobble masonry was the preferred construction technique. The primary feature(s) of this site are two roomblocks connected via a pair of low walls with an enclosed plaza space in between. An additional isolated room (or small roomblock) lies apart from the main complex (Cartledge and Benedict 1999; Huntley and Eckert 2020; Tainter 1979). Utility ceramics are mostly Mogollon Brown Ware and the local unnamed type, with a small amount of Cibola Gray Ware also present. Decorated ceramics are mostly Cibola White Ware (Puerco B/w [1000-1150 AD], Tularosa B/w [1150-1325 AD], and Cebolleta B/w [950-1150 AD]) and White Mountain Redware (St Johns B/r [1150-1300 AD], St Johns Polychrome [1150-1300 AD], and St Johns Polychrome with glaze paint [1275-1300 AD]). Limited amounts of Rio Abajo White Ware (Socorro B/w [900-1350 AD]) and Zuni Glaze Ware (Heshotauthla Gl/r [1275-1400 AD] and Heshotauthla Polychrome [1275-1400 AD]) are also present (Huntley and Eckert 2020).

A total of 11 obsidian artifacts were analyzed from LA121884. This was the smallest sample size for a single site obtained (not counting LA61489 AC#1). The two sources identified in this sample were Mount Taylor (Horace Mesa n=3) and McDaniel Tank (n=8). McDaniel Tank (72.73%) occurred with over twice the frequency of Mount Taylor (27.27%). This site produced the only example of a Mount Taylor assemblage made up entirely of one source (Horace Mesa), however this statement does not have much power since the sample size was so small.

Table 10. Obsidian sources identified in LA121884 sample.

Source	Count	Percent
Mount Taylor - Horace Mesa (MTHM)	3	27.27%
McDaniel Tank (MDNM)	8	72.73%
Total	11	

Figure 14. Source proportions for LA121884.



LA121885

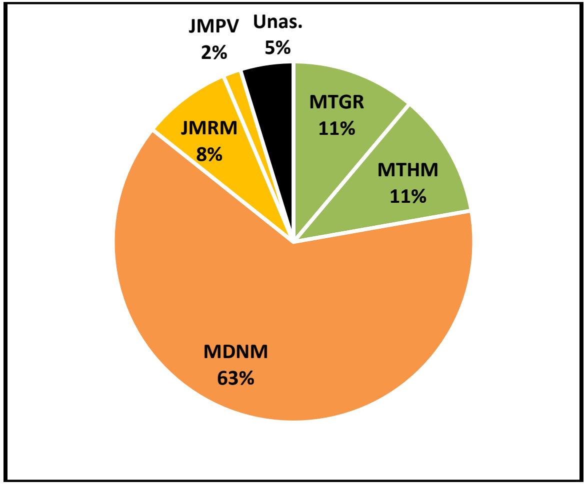
LA121885 (alternatively known as Soc-13 and possibly LA5972 [Winkler and Davis 1961]) is located within the Lion Mountain quad. The site lies to the northeast of Lion Mountain proper, along the crest of Bobcat Ridge at its eastern end. This is a late PII-PIII period site (approximately 1150-1300 AD) associated with the Lion Mountain Community (Huntley and Eckert 2020). The site consists of a large pueblo residential complex (Cartledge and Benedict 1999; Huntley and Eckert 2020). Unshaped cobble masonry was the preferred construction technique. The primary feature(s) of this site are a pair of large (possibly multistoried) roomblocks arranged in a V-shape. These roomblocks lie at the center of a large circular enclosing wall. Double rows of masonry are visible within the wall. In some places, additional small rooms (possibly for storage) are abutted to the wall. Additional features external to the main complex include another roomblock, several isolated single rooms, and a possible kiva or water reservoir (Cartledge and Benedict 1999; Huntley and Eckert 2020; Tainter 1979; Winkler and Davis 1961). Eckert and Huntley (2000) note that the unusual layout of this site (relative to the other Lion Mountain Community sites) may suggest a ceremonial purpose. Utility ceramics are mostly Mogollon Brown Ware and the local unnamed type, with a small amount of Cibola Gray Ware also present. Decorated ceramics are mostly Cibola White Ware (Red Mesa B/w [875-1050 AD], Puerco B/w [1000-1150 AD], Gallup B/w [980-1150 AD], Escavada B/w [950-1150 AD], Tularosa B/w [1150-1325 AD], and Pinedale Gl/w [1275-1325 AD]) and White Mountain Redware (Wingate B/r [1030-1175 AD], Wingate Polychrome [1030-1175 AD], St Johns B/r [1150-1300 AD], St Johns Polychrome [1150-1300 AD], and Springerville Polychrome [1250-1300 AD]). Limited amounts of Rio Abajo White Ware (Casa Colorado B/w [1240-1300 AD] and Socorro B/w [900-1350 AD]) and Zuni Glaze Ware (Heshotauthla Gl/r [1275-1400 AD] and Kwakina Polychrome [1325-1400 AD]) are also present.

A total of 63 obsidian artifacts were analyzed from LA121885. Sources identified in the assemblage included Mount Taylor (collectively n=14; Grants Ridge n=7; Horace Mesa n=7), McDaniel Tank (n=40), and Jemez (collectively n=6; Rabbit Mountain n=5; Polvadera Peak n=1). Three samples were not able to be assigned to any known Southwestern source. McDaniel Tank made up the majority of the assemblage (63.49%), followed by Mount Taylor (22.22%), then Jemez (9.52%). Within the Mount Taylor group, Grants Ridge and Horace Mesa occurred in equal proportions. Within the Jemez group, Rabbit Mountain made up the large majority (83.33%) compared to Polvadera Peak (16.66%).

Table 11. Obsidian sources identified in LA121885 sample.

Source	Count	Percent
Mount Taylor - Grants Ridge (MTGR)	7	11.11%
Mount Taylor - Horace Mesa (MTHM)	7	11.11%
McDaniel Tank (MDNM)	40	63.49%
Jemez - Rabbit Mountain (JMRM)	5	7.94%
Jemez - Polvadera Peak (JMPV)	1	1.59%
Unassigned (Unas.)	3	4.76%
Total	63	

Figure 15. Source proportions for LA121885.



LA189381

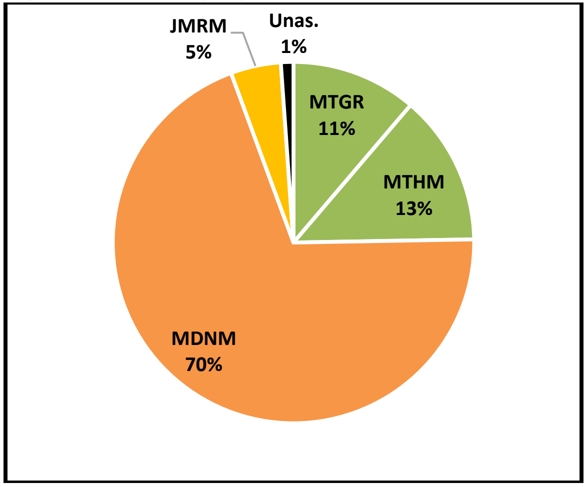
LA189381 is located within the Lion Mountain quad. The site lies to the northeast of Lion Mountain proper, approximately midway along the crest of Bobcat Ridge. This is a PIII period site (approximately 1200-1300 AD) associated with the Lion Mountain Community (Huntley and Eckert 2020). The site consists of a large pueblo period residential complex. Unshaped cobble masonry was the preferred construction technique. The primary feature(s) of this site are three large (possibly multistoried) roomblocks connected via a low wall with an enclosed plaza space in the center. Two additional roomblocks lie separate from the main complex. Utility ceramics are mostly Mogollon Brown Ware and the local unnamed type, with a small amount of Cibola Gray Ware also present. Decorated ceramics are mostly Cibola White Ware (Puerco B/w [1000-1150 AD], Tularosa B/w [1150-1325 AD], and Cebolleta B/w [950-1150 AD]) and White Mountain Redware (St Johns B/r [1150-1300 AD], St Johns Gl/r [1275-1300 AD], and St Johns Polychrome [1150-1300 AD]). Limited amounts of Rio Abajo White Ware (Socorro B/w [900-1350 AD]), Zuni Glaze Ware (Heshotauthla Gl/r [1275-1400 AD] and Heshotauthla Polychrome [1275-1400 AD]), and the unnamed local B/w type are also present (Huntley and Eckert 2020).

A total of 89 obsidian artifacts were analyzed from LA189381. Sources identified in the assemblage included Mount Taylor (collectively n=22; Grants Ridge n=10; Horace Mesa n=12), McDaniel Tank (n=62), and Jemez (Rabbit Mountain n=4). One sample was not able to be assigned to any known Southwestern source. McDaniel Tank made up the large majority of the assemblage (69.66%), followed by Mount Taylor (24.72%), then Jemez (4.49%). Within the Mount Taylor group, Horace Mesa was in the slight majority (54.55%) over Grants Ridge (45.45%). Rabbit Mountain was the only source encountered within the Jemez group.

Table 12. Obsidian sources identified in LA189381 sample.

Source	**Count**	**Percent**
Mount Taylor - Grants Ridge (MTGR)	10	11.24%
Mount Taylor - Horace Mesa (MTHM)	12	13.48%
McDaniel Tank (MDNM)	62	69.66%
Jemez - Rabbit Mountain (JMRM)	4	4.49%
Unassigned (Unas.)	1	1.12%
Total	89	

Figure 16. Source proportions for LA189381.



LA189382

LA189382 is located within the Lion Mountain quad. The site lies to the northeast of Lion Mountain proper, on a small isolated knoll off the western end of Forbidden Ridge. This is a late PII-PIII period site (approximately 1150-1300) which is likely part of the Lion Mountain Community (Huntley and Eckert 2020). The site consists of a large pueblo period residential complex. Unshaped cobble and (in several areas) large boulder masonry were the preferred construction techniques. The primary feature(s) of this site is a large roughly T-shaped compound, comprised of several roomblocks abutting and connected via a boulder masonry wall. A large open plaza space lies in the middle of this compound. Additional features include two exterior roomblocks, two isolated rooms, and two agricultural features. Utility ceramics are mostly Mogollon Brown Ware, with a small amount of the local unnamed type and Cibola Gray Ware also present. Decorated ceramics are mostly Cibola White Ware (Red Mesa B/w [875-1050 AD], Puerco B/w [1000-1150 AD], Escavada B/w [950-1150 AD], Reserve B/w [1000-1200 AD], Tularosa B/w [1150-1325 AD], and Pinedale Gl/w [1275-1325 AD]) and White Mountain Redware (Puerco B/r [1030-1150 AD], Wingate B/r [1030-1175 AD], Wingate Polychrome [1030-

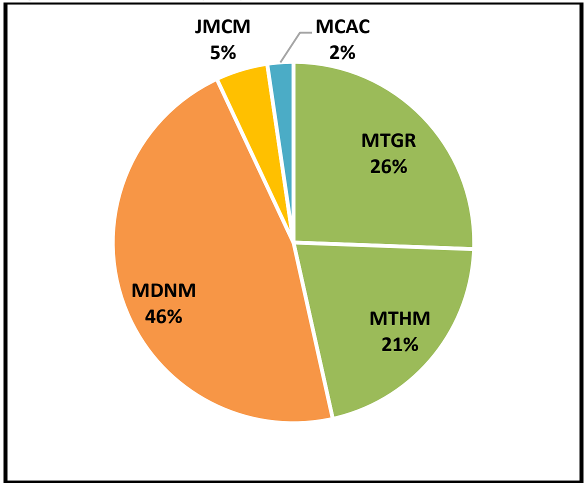
1175 AD], St Johns B/r [1150-1300 AD], St Johns Polychrome [1150-1300 AD], St Johns Polychrome with glaze paint [1275-1300 AD], Springerville Polychrome [1250-1300 AD], and Techado Polychrome [1260-1290 AD]). Limited amounts of Rio Abajo White Ware (Socorro B/w [900-1350 AD]), Mogollon Red Ware (Tularosa W/r [1100-1350 AD]), Zuni Glaze Ware (Heshotauthla Gl/r [1275-1400 AD] and Heshotauthla Polychrome [1275-1400 AD]), and the unnamed local B/w type are also present (Huntley and Eckert 2020).

A total of 43 obsidian artifacts were analyzed from LA189382. Sources identified in the assemblage included Mount Taylor (collectively n=20; Grants Ridge n=11; Horace Mesa n=9), McDaniel Tank (n=20), Jemez (Cerro del Medio n=2), and Antelope Creek (n=1). Mount Taylor and McDaniel tank made up the majority of the assemblage, occurring in equal proportions (46.51% each). Jemez was the third most common (4.65%), followed by Antelope Creek (2.33%). LA189382 was the only site where neither Mount Taylor nor McDaniel Tank clearly outnumbered the other. Additionally, it was one of only two sites where Antelope Creek material was encountered. Within the Mount Taylor group, Grants Ridge was in the slight majority (55%) over Horace Mesa (45%). Cerro del Medio was the only source encountered within the Jemez group.

Table 13. Obsidian sources identified in LA189382 sample.

Source	Count	Percent
Mount Taylor - Grants Ridge (MTGR)	11	25.58%
Mount Taylor - Horace Mesa (MTHM)	9	20.93%
McDaniel Tank (MDNM)	20	46.51%
Jemez - Cerro del Medio (JMCM)	2	4.65%
Antelope Creek (MCAC)	1	2.33%
Total	43	

Figure 17. Source proportions for LA189382.



LA1178

LA1178 (Gallinas Springs Pueblo; alternatively Gallinas Springs Ruin, site 118 [Danson 1957], or Soc-1 and Soc-2 [Winkler and Davis 1961]) is located within the Gallinas Peak quad. The site lies within the Gallinas Mountains along the banks of Gallinas Arroyo, about 4 miles east of the Lion Mountain Community site cluster. This is a Magdalena phase/late PIII period site (approximately 1240-1300 AD) (Lincoln 2007; Huntley and Eckert 2020). In terms of size, overall layout, construction methods, and decorated ceramics, Gallinas Springs Pueblo is unlike most other contemporaneous sites in the study area. Some have hypothesized that this site may have been inhabited by immigrants from the Mesa Verde area (Basham 2011; Danson 1957; Ferguson et al. 2016; Lincoln 2007; Winkler and Davis 1961).

This large nucleated pueblo consists of approximately 300-500 rooms along with a number of internal kivas and small plazas. These rooms were built multiple stories high in portions (Lincoln 2007). The entire site is split (bisected by the arroyo) into a larger southern half and a smaller northern half. Rooms were built into the slopes extending upwards along either bank of the arroyo in a multi-tiered/amphitheater-like fashion (Basham 2011; Danson 1957).

Both shaped tabular sandstone (uncommon among sites in the area) and unshaped cobble masonry were utilized in the construction of this site. Utility ceramics, like the majority of sites in the area, are mostly Mogollon Brown Ware. However, the most common decorated ceramic type by far is Magdalena B/w (1240-1300 AD) (Ferguson et al. 2016; Lincoln 2007; Winkler and Davis 1961). This carbon-based painted ceramic type stands in stark contrast to the mineral-based types encountered at the majority of contemporaneous sites in the area.

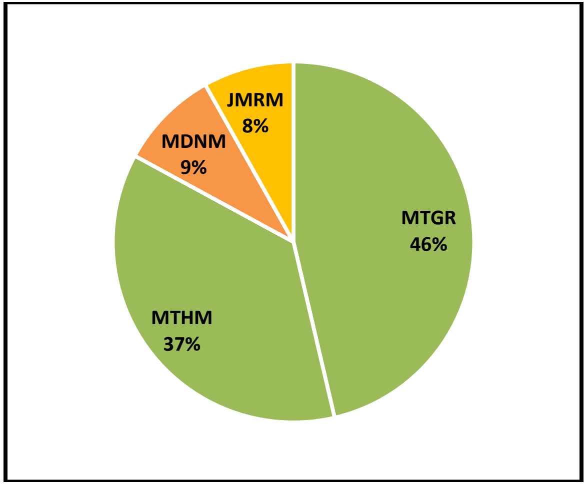
The sample for LA1178 was gathered primarily from the southern half of the site. An attempt was made to gather artifact spectra from the northern half as well, but no obsidian artifacts were encountered there. Additionally, the sample is somewhat biased towards smaller material. Many of the artifacts were recovered from anthills. However, this did not seem to have an effect on the source assignment itself (aside from differentiating between the Mount Taylor sources). Source assignments (relative proportions) produced as part of this study closely resemble that of presumably non-size biased assemblages; that is, material recovered from excavations (see Ferguson et al. 2016).

LA1178 produced the largest sample size of any one site. A total of 123 obsidian artifacts were analyzed. Sources identified in the assemblage included Mount Taylor (collectively n=102; Grants Ridge n=57; Horace Mesa n=45), McDaniel Tank (n=11), and Jemez (Rabbit Mountain n=10). Mount Taylor made up the large majority of the assemblage (82.93%), followed by McDaniel Tank (8.94%) and Jemez (8.13%), which occurred with almost the same frequency. Within the Mount Taylor group, Grants Ridge was in the majority (55.88%) over Horace Mesa (44.12%). Rabbit Mountain was the only source encountered within the Jemez group.

Table 14. Obsidian sources identified in LA1178 sample.

Source	Count	Percent
Mount Taylor - Grants Ridge (MTGR)	57	46.34%
Mount Taylor - Horace Mesa (MTHM)	45	36.59%
McDaniel Tank (MDNM)	11	8.94%
Jemez - Rabbit Mountain (JMRM)	10	8.13%
Total	123	

Figure 18. Source proportions for LA1178.



LA1180

LA1180 (alternatively known as site 117 [Danson 1957] or Soc-3 [Winkler and Davis 1961]) is located within the Gallinas Peak quad. The site lies within the Gallinas Mountains along the southern bank of Gallinas Arroyo, several hundred yards upstream from LA1178. This is an early PIV period site (approximately 1300-1450 AD) (Cartledge and Benedict 1996; Huntley and Eckert 2020; Winkler and Davis 1961). The site consists of a large pueblo period residential complex. Tabular and cobble masonry seems to be the preferred construction techniques. The site consists of a large rectangular compound. A row of rooms abut the entire length of the western wall and partially along the northern and southern walls. The remainder of the perimeter (mostly along the eastern side) is comprised of a low wall. The interior consists of a large open plaza space. A single large rectangular kiva lies in the northwestern corner backed up against the rooms. Utility ceramic types seem to be mostly Mogollon Brown Ware (Danson 1957; Winkler and Davis 1961). The most common decorated ceramics seem to be early Rio Grande Glaze Ware. Danson (1957) noted Northern Jornada Three Rivers Red Ware (Lincoln B/r [1300-1400 AD] and Three Rivers R/t [1100-1350 AD]) and late Cibola Red Ware (St Johns Polychrome [1150-1300 AD]).[11] However in their 1961 survey, Winkler and Davis noted mostly glaze ware types (undifferentiated), with no mention of any of the types identified by Danson. A ceramic inventory conducted by Drs. Deborah Huntley and Suzanne Eckert (2019) aligned with Winkler and Davis's results, identifying the most common decorated ceramic types as Rio Grande Glaze Ware, and specifically identifying Agua Fria Gl/r (1315-1425 AD) (Deborah Huntley, personal communication 2020).

A total of 44 obsidian artifacts were analyzed from LA1180. Sources identified included Mount Taylor (collectively n=31; Grants Ridge n=12; Horace Mesa n=19), McDaniel Tank (n=3), Jemez (Cerro del Medio n=2), Antelope Creek (n=6), and Superior (n=1). One artifact (LML529) exhibited chemistry similar to the Government Mountain source. The artifact seems to be proportionally lower in all elements (with relative proportions remaining largely intact). This artifact (LML529) was tentatively (but not definitively) assigned to this source. Mount Taylor made up the large majority of LA1180's assemblage (70.45%), followed by Antelope Creek (13.64%), McDaniel Tank (6.82%), Jemez (4.55%), then Superior (2.27%) and Government Mountain (2.27%). Within the Mount Taylor group, Horace Mesa made up the majority (61.29%)

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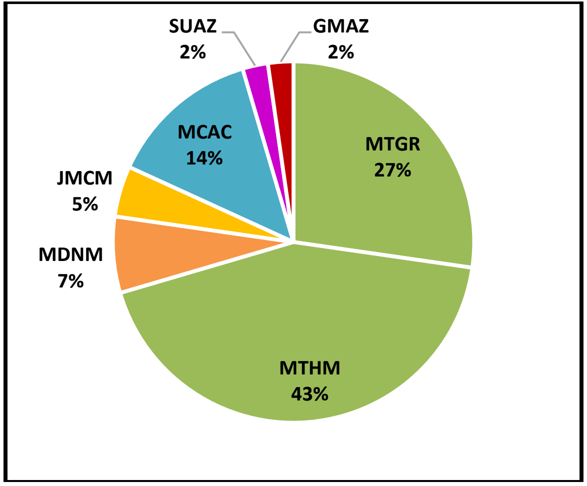
[11] Danson was not using the same ceramic classification scheme that is currently employed by archaeologists working in the area. The Northern Jornada Three Rivers Red Ware types he observed may well have been classified by modern researchers as a different ware/type. St Johns Polychrome is currently classified as a White Mountain Redware (not a Cibola Red Ware). While his classification scheme is outdated, he seems to have identified more or less the same range of ceramic wares and types identified in more recent research (Suzanne Eckert, personal communication 2020).

over Grants Ridge (38.71%). Cerro del Medio was the only source encountered in the Jemez group. Overall, LA1180 produced the most diverse assemblage in terms of the variety of sources/source groups encountered. Additionally, it included several of the most geographically distant sources. Antelope Creek (a relatively uncommon source within the collective sample) actually surpassed McDaniel Tank and Jemez (the 2nd and 3rd most frequently encountered sources within the entire sample).

Table 15. Obsidian sources identified in LA1180 sample.

Source	Count	Percent
Mount Taylor - Grants Ridge (MTGR)	12	27.27%
Mount Taylor - Horace Mesa (MTHM)	19	43.18%
McDaniel Tank (MDNM)	3	6.82%
Jemez - Cerro del Medio (JMCM)	2	4.55%
Antelope Creek (MCAC)	6	13.64%
Superior (SUAZ)	1	2.27%
Government Mountain (GMAZ)	1	2.27%
Total	44	

Figure 19. Source proportions for LA1180.



LA285 (Goat Springs Pueblo)

LA285 (Goat Springs Pueblo; alternatively known as site 125 [Danson 1957], Bear Mountain Pueblo, or Rio Abajo Site No. 122 [Marshall and Walt 1984]) is located within the Granite Mountain quad. Goat Springs Pueblo lies along the southern extent of the Bear Mountains, about 17 miles east of the Lion Mountain Community site cluster. This is a PIV period/Ancestral-Colonial Piro phase site. Excavations led by Drs. Suzanne L. Eckert and Deborah L. Huntley (Eckert and Huntley 2014; Eckert and Huntley, in prep.) indicate that the site was primarily occupied during the PIV period and into the early Spanish Colonial period; with abandonment taking place around the time of the Pueblo Revolt (approximate occupation range 1325-1680 AD).

This is a large nucleated pueblo residential complex consisting of three roomblocks and a kiva (de Smet and Eckert 2014); the southern roomblock and kiva were built early in the site's occupation, while the western and northern roomblocks appear to have been occupied later. The relationship between the early and late occupants is still unclear; there may have been a hiatus, or occupants of the village may have abandoned the southern roomblock and kiva after the other two roomblocks were established. The site contains an estimated 165 ground floor and perhaps an additional 100 second story rooms. Tabular, slab, and cobble masonry set with adobe mortar was the preferred construction technique (Marshall and Walt 1984).

Utility ceramics are primarily obliterated corrugated types, with some Middle Rio Grande micaceous utility ware types also present; this is consistent with other Rio Abajo sites of this phase (Eckert and Huntley, in prep; Marshall and Walt 1984). The most common decorated ceramics are middle and late Rio Grande Glaze Ware (Glaze C [1425-1490 AD], Glaze D [1490-1515 AD], Glaze E [1515-1650 AD], and Glaze F [1600-1700 AD]). Additional types identified through excavation include Zuni Glaze Ware, Rio Abajo White Ware (Casa Colorado B/w [1240-

1300 AD]), and Northern Jornada White Ware (Tabirá B/w [1550-1672 AD]) (Eckert and Huntley 2014).

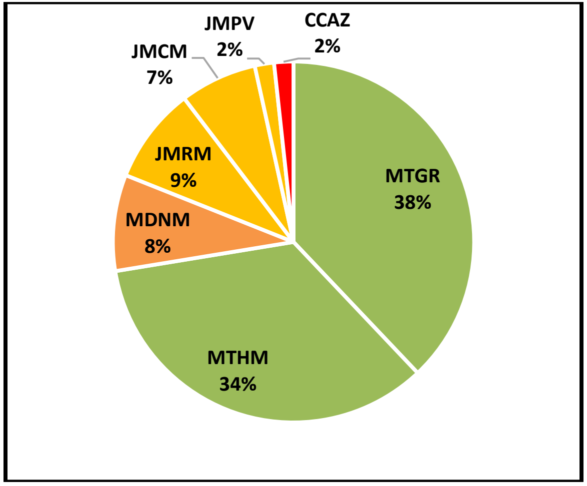
LA285 has been included in this study for comparative purposes. Original data for this site was not produced as a part of this study. Source data from this site was supplied courtesy of Drs. Jeffrey Ferguson and Suzanne Eckert. Unlike the other sites, the obsidian assemblage from LA285 was derived entirely from excavation. Artifacts were recovered in excavations led by Drs. Suzanne Eckert and Deborah Huntley in 2011, 2013, and 2017. The close proximity of LA285 to the study area (along with its representativeness of the late Pueblo period) warranted its inclusion in this study.

A total of 58 obsidian artifacts were analyzed from LA285. Sources identified included Mount Taylor (collectively n=42; Grants Ridge n=22; Horace Mesa n=20), McDaniel Tank (n=5), Jemez (collectively n=10; Rabbit Mountain n=5; Cerro del Medio n=4; Polvadera n=1), and Cow Canyon (n=1). Mount Taylor made up the large majority of the assemblage (72.41%), followed by Jemez (17.24%), McDaniel Tank (8.62%), then Cow Canyon (1.72%). This was the only example of Cow Canyon encountered in the entire study. Within the Mount Taylor group, Grants Ridge held the slight majority (52.38%) over Horace Mesa (47.62%). Within the Jemez group, Rabbit Mountain was the most common (50%), followed by Cerro del Medio (40%), then Polvadera Peak (10%).

Table 16. Obsidian sources identified in LA285 sample.

Source	Count	Percent
Mount Taylor - Grants Ridge (MTGR)	22	37.93%
Mount Taylor - Horace Mesa (MTHM)	20	34.48%
McDaniel Tank (MDNM)	5	8.62%
Jemez - Rabbit Mountain (JMRM)	5	8.62%
Jemez - Cerro del Medio (JMCM)	4	6.90%
Jemez - Polvadera Peak (JMPV)	1	1.72%
Cow Canyon (CCAZ)	1	1.72%
Total	58	

Figure 20. Source proportions for LA285.



Chi-Square Analysis of Source Use by Site

Another series of Pearson's Chi-Square tests were conducted to examine whether or not any significant differences existed among the frequencies of source material by site. The Chi-Square test compares observed values to what would be expected given random chance. In each test, the null hypothesis (hypothesis of no difference) stated that no significant difference existed between the observed and expected values (H_0: O = E). The alternative hypothesis stated that the observed and expected values were significantly different (H_a: O ≠ E). All tests were conducted at the .05 significance level (α=.05).

Chi-Square values were calculated and compared to critical values. In the cases where the Chi-Square value did not exceed the critical value, the null hypothesis was failed to be rejected (and thus determined that no significant difference existed between the observed and expected frequencies). In the cases where the Chi-Square value exceeded the critical value, the null hypothesis was rejected (and it was thus determined that a significant difference existed between the observed and expected). In the cases where the null was rejected, adjusted residuals were calculated in order to determine which of the observed values were significantly different than what would be expected given random chance. Positive residual values (greater than 1.96) denote that the observed frequency was significantly greater than the expected. Negative values (less than -1.96) denote that the observed frequency was significantly less than the expected. All significant Chi-Square and adjusted residual values have been highlighted (appear in bold and underlined).

All Sites

Chi-Square test #4 (Table 17) compared the frequency of source material by site. This test used the collective data for all ten sites analyzed as part of this study, as well as that of the comparative assemblage from LA285 - Goat Springs Pueblo (n=558). The assemblage from LA61489 AC#1 was omitted from the test due to its small sample size (n=2). In the case of test #4, the Chi-Square value (319.85) exceeded the critical value (90.53). The null hypothesis was therefore rejected and it was concluded that a significant difference existed. Residuals were calculated. Significantly less Mount Taylor (MT) was encountered at LA121883, LA121885, and LA189381 while significantly more was encountered at LA1178, LA1180, and LA285. Significantly less McDaniel Tank (MDNM) was encountered at LA61489, LA1178, LA1180, and LA285 while significantly more was encountered at LA121883, LA121884, LA121885, and LA189381.

Significantly more Jemez was encountered at LA61489 and LA285. Significantly more Antelope Creek (MCAC) was encountered at LA1180. Significantly more unassigned (Unas.) material was encountered at LA121885. Finally, all of the single examples of source material (Superior [SUAZ], Government Mountain [GMAZ], and Cow Canyon [CCAZ]) were all deemed to occur significantly more.

Table 17. Chi-Square test #4: Source material frequency by site.

Site	Source	Observed	Expected	χ^2	Adjusted Residuals
LA193028	MT	22	19.69	0.27	0.79
	MDNM	9	12.80	1.13	-1.36
	Jemez	5	3.51	0.63	0.86
	MCAC	0	0.46	0.46	-0.71
	SUAZ	0	0.07	0.07	-0.27
	GMAZ	0	0.07	0.07	-0.27
	CCAZ	0	0.07	0.07	-0.27
	Unas.	1	0.33	1.35	1.21
LA61489 AC#2	MT	20	16.50	0.74	1.30
	MDNM	2	10.72	7.10	**-3.39**
	Jemez	9	2.94	12.45	**3.82**
	MCAC	0	0.39	0.39	-0.65
	SUAZ	0	0.06	0.06	-0.24
	GMAZ	0	0.06	0.06	-0.24
	CCAZ	0	0.06	0.06	-0.24
	Unas.	0	0.28	0.28	-0.54
LA125085	MT	17	14.90	0.30	0.81
	MDNM	8	9.68	0.29	-0.69
	Jemez	3	2.66	0.04	0.23
	MCAC	0	0.35	0.35	-0.61
	SUAZ	0	0.05	0.05	-0.23
	GMAZ	0	0.05	0.05	-0.23
	CCAZ	0	0.05	0.05	-0.23
	Unas.	0	0.25	0.25	-0.52
LA121883	MT	4	16.50	9.47	**-4.63**
	MDNM	25	10.72	19.01	**5.55**
	Jemez	2	2.94	0.30	-0.60
	MCAC	0	0.39	0.39	-0.65
	SUAZ	0	0.06	0.06	-0.24

Site	Source	Observed	Expected	χ²	Adjusted Residuals
	GMAZ	0	0.06	0.06	-0.24
	CCAZ	0	0.06	0.06	-0.24
	Unas.	0	0.28	0.28	-0.54
LA121884	MT	3	5.85	1.39	-1.74
	MDNM	8	3.80	4.63	**2.69**
	Jemez	0	1.04	1.04	-1.09
	MCAC	0	0.14	0.14	-0.38
	SUAZ	0	0.02	0.02	-0.14
	GMAZ	0	0.02	0.02	-0.14
	CCAZ	0	0.02	0.02	-0.14
	Unas.	0	0.10	0.10	-0.32
LA121885	MT	14	33.53	11.38	**-5.24**
	MDNM	40	21.79	15.22	**5.12**
	Jemez	6	5.98	0.00	0.01
	MCAC	0	0.79	0.79	-0.95
	SUAZ	0	0.11	0.11	-0.36
	GMAZ	0	0.11	0.11	-0.36
	CCAZ	0	0.11	0.11	-0.36
	Unas.	3	0.56	10.51	**3.46**
LA189381	MT	22	47.37	13.59	**-5.88**
	MDNM	62	30.78	31.66	**7.59**
	Jemez	4	8.45	2.35	-1.76
	MCAC	0	1.12	1.12	-1.16
	SUAZ	0	0.16	0.16	-0.44
	GMAZ	0	0.16	0.16	-0.44
	CCAZ	0	0.16	0.16	-0.44
	Unas.	1	0.80	0.05	0.25
LA189382	MT	20	22.89	0.36	-0.92
	MDNM	20	14.87	1.77	1.71
	Jemez	2	4.08	1.06	-1.13
	MCAC	1	0.54	0.39	0.66
	SUAZ	0	0.08	0.08	-0.29
	GMAZ	0	0.08	0.08	-0.29
	CCAZ	0	0.08	0.08	-0.29
	Unas.	0	0.39	0.39	-0.65
LA1178	MT	102	65.47	20.39	**7.48**
	MDNM	11	42.54	23.39	**-6.77**
	Jemez	10	11.68	0.24	-0.59
	MCAC	0	1.54	1.54	-1.42
	SUAZ	0	0.22	0.22	-0.53
	GMAZ	0	0.22	0.22	-0.53

Site	Source	Observed	Expected	χ^2	Adjusted Residuals
	CCAZ	0	0.22	0.22	-0.53
	Unas.	0	1.10	1.10	-1.19
LA1180	MT	31	23.42	2.45	**2.39**
	MDNM	3	15.22	9.81	**-4.03**
	Jemez	2	4.18	1.14	-1.17
	MCAC	6	0.55	53.77	**7.69**
	SUAZ	1	0.08	10.76	**3.42**
	GMAZ	1	0.08	10.76	**3.42**
	CCAZ	0	0.08	0.08	-0.29
	Unas.	0	0.39	0.39	-0.66
LA285	MT	42	30.87	4.01	**3.09**
	MDNM	5	20.06	11.31	**-4.39**
	Jemez	10	5.51	3.66	**2.12**
	MCAC	0	0.73	0.73	-0.91
	SUAZ	0	0.10	0.10	-0.34
	GMAZ	0	0.10	0.10	-0.34
	CCAZ	1	0.10	7.72	**2.94**
	Unas.	0	0.52	0.52	-0.77
			Chi Square Value =	**319.85**	
			Critical Value (df=70, α=.05) =	90.53	

Chi-Square test #5 (Table 18) compared the frequency of Mount Taylor source material (Grants Ridge vs Horace Mesa) by site. As with test #4, test #5 used the collective data for all ten sites analyzed as part of this study, as well as that of the comparative assemblage from LA285 - Goat Springs Pueblo (n=297). Again, the data from LA61489 AC#1 was not included due to its small sample size (n=1). In the case of test #5, the Chi-Square value (27.51) exceeded the critical value (18.31). The null hypothesis was therefore rejected and it was concluded that a significant difference existed. Calculated residuals showed that LA193028 had a significantly larger proportion of Horace Mesa while LA1178 had significantly less.

Table 18. Chi-Square test #5: Mount Taylor source frequency by site.

Site	**Source**	**Observed**	**Expected**	**χ^2**	**Adjusted Residuals**
LA193028	MTGR	1	10.07	8.17	**-4.04**
	MTHM	21	11.93	6.90	**4.04**
LA61489 AC#2	MTGR	10	9.16	0.08	0.39
	MTHM	10	10.84	0.07	-0.39
LA125085	MTGR	4	7.78	1.84	-1.90
	MTHM	13	9.22	1.55	1.90
LA121883	MTGR	2	1.83	0.02	0.17
	MTHM	2	2.17	0.01	-0.17
LA121884	MTGR	0	1.37	1.37	-1.60
	MTHM	3	1.63	1.16	1.60
LA121885	MTGR	7	6.41	0.05	0.32
	MTHM	7	7.59	0.05	-0.32
LA189381	MTGR	10	10.07	0.00	-0.03
	MTHM	12	11.93	0.00	0.03
LA189382	MTGR	11	9.16	0.37	0.86
	MTHM	9	10.84	0.31	-0.86
LA1178	MTGR	57	46.71	2.27	**2.52**
	MTHM	45	55.29	1.92	**-2.52**
LA1180	MTGR	12	14.20	0.34	-0.84
	MTHM	19	16.80	0.29	0.84
LA285	MTGR	22	19.23	0.40	0.93
	MTHM	20	22.77	0.34	-0.93
			Chi Square Value =	**27.51**	
			Critical Value (df=10, α=.05) =	18.31	

Lion Mountain Sites

Chi-Square test #6 (Table 19) compared the frequency of source material among only those sites associated with the Lion Mountain Community. This included the collective assemblages from sites LA121883, LA121884, LA121885, LA189381, and LA189382 (n=237). In the case of test #6, the Chi-Square value (25.11) did not exceed the critical value (26.30). Therefore, the null hypothesis was not rejected and it was concluded that no significant difference existed.

Table 19. Chi-Square test #6: Source material frequency among Lion Mountain Community sites.

Site	Source	Observed	Expected	χ^2
LA121883	MT	4	8.24	2.18
	MDNM	25	20.27	1.10
	Jemez	2	1.83	0.02
	MCAC	0	0.13	0.13
	Unas.	0	0.52	0.52
LA121884	MT	3	2.92	0.00
	MDNM	8	7.19	0.09
	Jemez	0	0.65	0.65
	MCAC	0	0.05	0.05
	Unas.	0	0.19	0.19
LA121885	MT	14	16.75	0.45
	MDNM	40	41.20	0.04
	Jemez	6	3.72	1.39
	MCAC	0	0.27	0.27
	Unas.	3	1.06	3.53
LA189381	MT	22	23.66	0.12
	MDNM	62	58.21	0.25
	Jemez	4	5.26	0.30
	MCAC	0	0.38	0.38
	Unas.	1	1.50	0.17
LA189382	MT	20	11.43	6.42
	MDNM	20	28.12	2.35
	Jemez	2	2.54	0.11
	MCAC	1	0.18	3.69
	Unas.	0	0.73	0.73
			Chi Square Value =	25.11
			Critical Value (df=16, α=.05) =	26.30

Chi-Square test #7 (Table 20) compared the frequency of Mount Taylor source material (Grants Ridge vs Horace Mesa) among only those sites associated with the Lion Mountain Community. As with test #6, this included only the assemblages from LA121883, LA121884, LA121885, LA189381, and LA189382 (n=63). In the case of test #7, the Chi-Square value (3.25) did not exceed the critical value (9.49). Therefore, the null hypothesis was not rejected and it was concluded that no significant difference existed.

Table 20. Chi-Square test #7: Mount Taylor source frequency among Lion Mountain Community sites.

Site	Source	Observed	Expected	χ^2
LA121883	MTGR	2	1.90	0.00
	MTHM	2	2.10	0.00
LA121884	MTGR	0	1.43	1.43
	MTHM	3	1.57	1.30
LA121885	MTGR	7	6.67	0.02
	MTHM	7	7.33	0.02
LA189381	MTGR	10	10.48	0.02
	MTHM	12	11.52	0.02
LA189382	MTGR	11	9.52	0.23
	MTHM	9	10.48	0.21
			Chi Square Value =	3.25
			Critical Value (df=4, α=.05) =	9.49

Chapter 5: Discussion

Source Utilization in the Gallinas Mountains

This study provides an original perspective of the patterns of obsidian source use in the Gallinas Mountains area of west central New Mexico during the late Pithouse/early Pueblo to late Pueblo periods. This study identified the use of a variety of discrete obsidian sources/source groups by the people who occupied the area at that time. In total, ten (possibly 11) distinct sources were identified. These included Grants Ridge (Mount Taylor group), Horace Mesa (Mount Taylor group), McDaniel Tank, Rabbit Mountain (Jemez group), Cerro del Medio (Jemez group), Polvadera Peak (Jemez group), Paliza Canyon (Jemez group), Bear Springs Peak (Jemez group), Antelope Creek (Mule Creek group), Superior, and possibly Government Mountain. One additional source (Cow Canyon) was reported as part of a comparative assemblage.

As would be expected, several of these sources/source groups were utilized to a greater extent than others. Overall, one of two primary sources/source groups made up the majority of most every individual site assemblage. These were the Mount Taylor source group and the McDaniel Tank source. Overall, Mount Taylor was the most common (at 51%) with McDaniel Tank following closely behind (at 37.45%). While McDaniel Tank is relatively local to the study area (material can be found about 17 miles [27 km] southeast of the core site cluster) Mount Taylor (the next closest source to the study area at about 70 miles [113 km] to the north/northwest) is most likely the superior source of raw material. While both sources produce obsidian of excellent quality (in regards to knappability), Mount Taylor is far more abundant and occurs in much larger nodules at the source. 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 (Jeffrey Ferguson, personal communication 2019).

In addition to the two primary sources, material belonging to the Jemez source group was also somewhat common. Although Jemez glass only made up 8.76% of the total assemblage, material was encountered at nearly every site (most often coming in third behind Mount Taylor and McDaniel Tank). The appearance of this source group in most assemblages was somewhat expected for this area. The Jemez group includes several high quality glass sources that were widely distributed within New Mexico and beyond (Shackley 2005; Baugh and Nelson 1987). Geographically speaking, the source is somewhat distant from the study area at approximately 120 miles (193 km) to the north/northeast. However the desirable attributes of this raw material source group (one of the best sources for volcanic glass in New Mexico and debatably the entire American Southwest) undoubtedly ensured 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 (in the cases of every source except Cerro del Medio; and especially for Rabbit Mountain [Church 2000]) only shortens the geographic distance to desirable material[12]. The Rio Grande valley itself lies only about 30-35 miles (48-56 km) to the east of the study area.

Several additional minor sources were identified within the collective sample. Most common among these was Antelope Creek (of the Mule Creek source group). Material from this source was only encountered at two sites (overall 1.39% of the collective sample). The primary Antelope Creek deposits are located at a comparable distance from the study area to that of the

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[12] The presence of Cerro del Medio (which does not appear in the Rio Grande alluvium) proves that some proportion of Jemez material had to have come from primary deposits.

Jemez group (approximately 110 miles [177 km] to the southwest). However, while this source exhibits superb knappability and is typically quite common in the obsidian assemblages of sites in west central/southwestern New Mexico, it was not distributed to the extent of Jemez. Despite this, it is not surprising that Mule Creek material would be encountered within the study area. Linked to the discussion of Mule Creek is the appearance of material from the Cow Canyon source. Only one example of material from this source was observed within the study area (from the comparative assemblage). Cow Canyon lies in the same general area as Mule Creek (approximately 120 miles [193 km] southwest of the study area). While this source exhibits material of comparable knappability to that of Antelope Creek, Antelope Creek occurs in larger nodules and material is somewhat more abundant at the source. In the case of these two sources, Antelope Creek likely overshadowed the slightly inferior (only in size and abundance) Cow Canyon.

A small number of additional sources were encountered within the overall sample. In comparison to the sources discussed above, the appearance of these sources was relatively unexpected. The Superior source was the first of these. Primary source deposits are located approximately 220 miles (354 km) west/southwest of the study area. The second was (possible) material from the Government Mountain source, which is located approximately 260 miles (418 km) to the west/northwest. Both of these sources are superb sources of volcanic glass and were extensively utilized and distributed by prehistoric peoples (Shackley 2005), although their primary distribution ranges were mostly reserved to Arizona. Despite this, Government Mountain (at least) has been identified in assemblages as far east as Socorro and Chaco Canyon. The presence (albeit extremely limited) of these two sources suggests that the residents of the study area (or at least the residents of the site where this material was identified) were linked to a far-reaching social network.

This study also identified that not all of the sources encountered were being utilized or accessed in quite the same manner. Analyses showed that some sources manifested a proportionally higher or lower amount of formal tools (i.e. projectile points and bifaces). Overall, a significantly higher proportion of formal tools was identified in two of the more geographically distant sources. These were the Jemez (20.45% overall; the Cerro del Medio source had the highest proportion of any source at 57.14%) and Mule Creek (28.57%) groups. These proportions were well above the average proportion for the sample as a whole (7.97%). This may suggest that these two sources entered the 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 would be more common (i.e. more non-tools; flakes, debris, cores, and unworked pieces) (VanPool et al. 2013). Whatever the reason, a lot of the initial reduction of the material from the more geographically distant sources[13] seems to have occurred elsewhere.

Mount Taylor was found to have a significantly lower proportion of formal tools (at 5.08%) when compared to other sources. This lower proportion could be due to the large amount of Mount Taylor obsidian that was analyzed from anthills (producing a sample biased towards smaller artifacts) at LA1178/Gallinas Springs Pueblo. It could be reasoned that a small artifact size bias would also create a bias towards non-tools (flakes and indiscriminate debris are often smaller than a finished projectile point or biface). However, some projectile points (especially "true" arrow points; which would have been utilized during the Pueblo period) can be very small. A number of projectile points were in fact analyzed from anthill contexts. Additionally, a significant difference exists between the proportions of formal tools in Grants

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[13] The other three "geographically distant" sources were Superior, Government Mountain, and Cow Canyon. Superior and Government Mountain were excluded from this discussion due to their small sample sizes. No data for Cow Canyon artifact type was available.

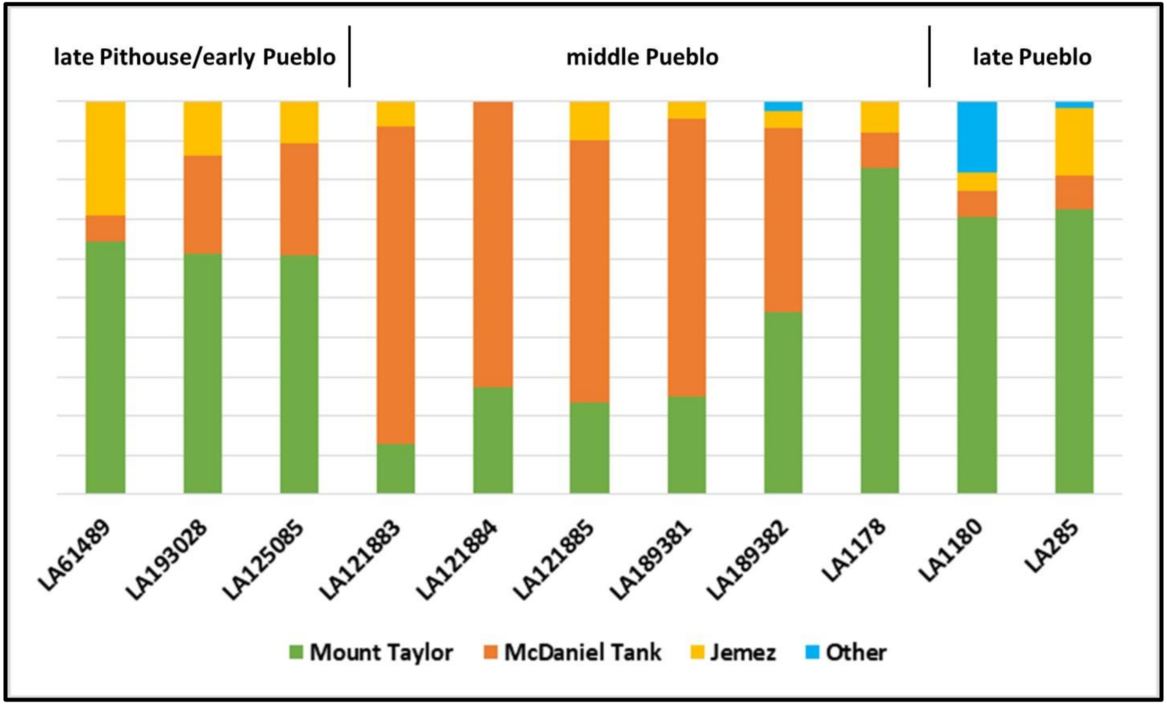
Ridge and Horace Mesa. Grants Ridge only had about 1.75% formal tools, while Horace Mesa had 7.75% (close to the average proportion for all sources [7.97%]). If the size bias had affected the proportion of formal tools within Grants Ridge, it should have affected Horace Mesa as well.

Alternatively, 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 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 these types of 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. So if Grants Ridge was less preferred in the manufacture of stone 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 different roles. While the production of bifacially flaked knives and projectile points could have been reserved primarily to Horace Mesa, Grants Ridge could have been used in the production of more expedient flake tools (which under this study would have been classified with flakes under the non-tool category).

Variation through Time

Through the analysis of the assemblages included in this study it is evident that a number of changes in obsidian source use and procurement strategy occurred in the Gallinas Mountains area through time. The Pueblo period was a dynamic time in Southwestern prehistory. I argue that this is reflected in the patterns of source utilization identified in this study.

Figure 21. Changes in obsidian source use through time. Sites are arranged in approximate sequential order according to tentative dates established in previous research (see Figure 9).



During the late Pithouse/early Pueblo period, Mount Taylor seems to be the primary source utilized. The proportion of this source remains relatively constant through this time period (making up about 2/3 of overall source use). The remaining proportion is made up of a combination of McDaniel Tank and Jemez material. Interestingly, there appears to be a gradual decrease in the use of Jemez coupled with an inverse rise in the use of McDaniel Tank. During the late Pithouse period (as represented by site LA61489), Jemez makes up a greater proportion over McDaniel Tank. By the end of the early Pueblo period (as represented by LA125085), this relationship has flipped. During the beginning of the late Pithouse/early Pueblo period, the utilization of Jemez is at its peak (LA61489 exhibited the highest observed proportions of Jemez material). Additionally, this period saw the only instance of the relatively minor Jemez sources (Paliza Canyon and Bear Springs Peak). These sources were typically not distributed to the same extent as some of the more major Jemez sources (i.e. Rabbit Mountain, Cerro del Medio, and Polvadera Peak). Taken together, this could indicate the presence of strong exchange connections (and by effect relational ties) with the areas to the north. However, this connection degrades towards the end of the early Pueblo period.

With the development of the Lion Mountain Community during the middle Pueblo period (specifically the late PII-PIII period), a new pattern emerges in procurement strategy. Immediately evident is the sharp decline in the use of Mount Taylor and an inverse rise in the exploitation of the relatively local McDaniel Tank source. McDaniel Tank was now the primary source utilized by the majority of sites. While Mount Taylor and Jemez material remained in assemblages, they made up much smaller proportions. This conspicuous drop in the utilization of northern sources and a shift to more local material during the middle Pueblo period could be explained as a disintegration of exchange ties to the north.

During the early Pueblo period, much of the land to the north and west of the study area was connected via a network of exchange and interaction as part of the Chacoan system. Included in this system was a series of roads and outlier communities spread over a vast geographic area. During the early 1100s, this system began to break down. Many arguments have been presented for why this may have occurred, however a series of droughts and subsequent crop failures seem to have played a large role (Lekson and Cameron 1995). Many argue that the decline of the Chacoan system was accompanied by a period of violence and warfare (Lekson 2008). Whatever the cause or nature of this decline, the period following was clearly one of reorganization and (in many areas) disassociation from the old system.

It's possible that the decrease in the proportion of northern source material (especially Mount Taylor) could have been linked to the collapse of the Chacoan system. If Huntley and Eckert's (2020) observations are correct, the Gallinas Mountains area would have been linked into this system during the early Pueblo period (as evidenced by the possible Chacoan Outlier LA125085). Following the collapse of the Chacoan system, networks of exchange and interaction between the people living in the Gallinas Mountains and those living to the north could have broken down (or at least fallen under 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.

The shift to the late Pueblo period brought with it a number of equally interesting changes in obsidian procurement strategy. The patterns of source use that developed during the middle Pueblo period reverted back to something similar to that of earlier periods. The utilization of McDaniel Tank dropped to levels not seen since that of the earliest site included in this study (LA61489). Mount Taylor once again came to dominate the assemblages. Jemez also makes a slight recovery during this time. The return to the use of Mount Taylor as the primary source material was likely stimulated by the emergence of new (or strengthened) connections to the north.

The late Pueblo period (PIV period) saw an increase in exchange and interaction between the growing population centers of the Zuni area (to the northwest of the study area) and those of the Rio Grande Valley (to the east) (LeBlanc 1989). This network of exchange and interaction incorporated a number of smaller population centers scattered throughout the greater Cibola Region; such as the Acoma and Laguna areas which lie directly north of the Gallinas Mountains. It appears as though the residents of the Gallinas Mountains area were linked into this network of exchange and interaction as well. Evidence for this lies 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); which were 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; Suzanne Eckert, personal communication 2020).

The people residing in the Zuni, Acoma, and Laguna areas north of the Gallinas Mountains were well aware of Mount Taylor. The peak holds a sacred place in the traditions of the modern day Zuni, Acoma, and Laguna Pueblo peoples and was an important area for the gathering of resources such as timber, medicinal herbs, and obsidian (Blake 1999; Hunt 2015). Unsurprisingly, Mount Taylor appears to have been one of the most (if not *the* most) heavily utilized sources of volcanic glass in the Zuni area (Schachner 2012). While unfortunately no published data exists for obsidian source use for the Acoma area, due to its close proximity (Mount Taylor is only about 20 miles to the north; very much in view to anyone living in that area) and the references made to the obsidian there in the Acoma origin story (Hunt 2015), it is safe to assume that the Mount Taylor source was used extensively there as well. Therefore, I argue that the increase in the use of Mount Taylor seen in the Gallinas Mountains area during the late Pueblo period was likely a result of increased interaction with groups living to the north; theoretically those living in the Zuni or Acoma areas. Additionally, the presence of a possible piece of Government Mountain (a source known to appear in assemblages from the Zuni area [Schachner 2012]) could have entered the Gallinas Mountains area through a similar vector.

Aside from the increase in Mount Taylor (and northern material in general), late Pueblo period sites in the study area also exhibited an increase in material from the southwest. Antelope Creek (Mule Creek), Cow Canyon, and Superior all make an appearance during this time period. Somewhat surprisingly, Antelope Creek was actually the second most frequently encountered at site LA1180, surpassing both McDaniel Tank and Jemez. The introduction of these new materials during this time period may be a result of the changes occurring in the Mogollon region to the southwest. By the beginning of the late Pueblo period much of the northern Mogollon region (i.e. the Mogollon Highlands) had been depopulated (Martin 1979). It has long been theorized that many of the former residents came to settle in the Zuni area (Gregory 2007). Antelope Creek and Cow Canyon were the two most widely utilized sources within the northern Mogollon region during its occupation (Taliaferro et al. 2010). Immigrants from this area would have most likely brought with them the knowledge of and/or material from these southwestern sources (and possibly Superior as well). Increased connections to the residents of the Zuni area could have then brought the material into the Gallinas Mountains area. Alternatively, based on the apparent connections between the Mogollon region and the study area (Cartledge 2000; Cartledge and Benedict 1999; DeHaven and Turner 2016; Eckert 2020; Huntley and Eckert 2020; Marshall and Marshall 2008) it could be reasoned that some of the emigrants from the Mogollon region could have found their way directly into the Gallinas Mountains area.[14]

Variation across Cultural Boundaries

Obsidian source use and procurement strategy was found to not only differ through time, but across archaeologically defined cultural boundaries as well. The middle Pueblo period (specifically the late PII-PIII periods) saw the development of a large aggregated Puebloan community deemed the Lion Mountain Community (Cartledge 2000; Cartledge and Benedict 1999; Huntley and Eckert 2020; Marshall and Marshall 2008). In contrast to this community are the Magdalena Black-on-white sites also of the middle Pueblo period (specifically the Magdalena phase or PIII periods) (Winkler and Davis 1961). Despite both occurring within the Gallinas Mountains and having been occupied at the same time, these two classes of sites have been

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[14] There is evidence of that some Mogollon populations may have migrated to the Rio Abajo region as well (Suzanne Eckert, personal communication 2020).

found to exhibit a number of differences in material culture including decorated ceramics, site layout, and architecture. By far the largest of the Magdalena phase sites is the massive nucleated pueblo LA1178 - Gallinas Springs Pueblo (Ferguson et al. 2016). This site (along with a small number of additional Magdalena phase sites) are hypothesized to have been occupied by immigrants from the Mesa Verde Region to the north/northwest (Basham 2011; Danson 1957; Ferguson et al. 2016; Lincoln 2007; Winkler and Davis 1961). In contrast, the sites of the Lion Mountain Community are hypothesized to have been occupied by a population more indigenous to the study area (Deborah Huntley and Suzanne Eckert, personal communication 2019).

As part of this study, an attempt was made to sample sites representative of both the Lion Mountain Community and the Magdalena phase occupations. Sites representative of the Lion Mountain Community included LA121883, LA121884, LA121885, LA189381, and LA189382. Although attempts were made to sample a number of the Magdalena phase sites identified by Winkler and Davis (1961), only one sample assemblage was obtained (that of LA1178 - Gallinas Springs Pueblo).[15] However, this one site with its hundreds of rooms has been estimated to have housed upwards of 1,000 people at its height (Lincoln 2007). Gallinas Springs Pueblo alone more than likely housed a large proportion of the Magdalena phase community. Furthermore, Gallinas Springs Pueblo seems to have been the main production locale for Magdalena Black-on-white pottery, the primary defining characteristic of the Magdalena phase (Ferguson et al. 2016) as well as exhibiting the most extreme differences in other aspects of material culture. To summarize, while a sample was obtained for only one Magdalena phase site, this site was by far the largest and perhaps the purest embodiment of this type of site in the study area.

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[15] An attempt was made to sample three additional Magdalena phase sites identified in the Davis and Winkler survey (LA5994, LA5995, and LA5996). The surface assemblages of these sites did not produce a sufficient amount of obsidian artifacts to permit analysis.

Clear differences in obsidian source use were observed between the Lion Mountain Community and Gallinas Springs Pueblo (see Figure 21). McDaniel Tank was the preferred material over Mount Taylor at most of the Lion Mountain Community sites.[16] The exact inverse was true for LA1178 - Gallinas Springs Pueblo, with Mount Taylor vastly outnumbering McDaniel Tank. More so, Gallinas Springs Pueblo exhibited the highest proportion of Mount Taylor out of any of the sites included in this study. The drastically different obsidian procurement strategies which exist between the Lion Mountain Community and Gallinas Springs Pueblo correlate with other differences in material culture and serves to reinforce the notion that these sites were occupied by different populations.

If Gallinas Springs Pueblo was in fact populated by northern immigrants, it makes sense that they could have brought with them a desire to use Mount Taylor glass. The people of the Mesa Verde Region were well aware of this source and consistently utilized it during their time there (Arakawa et al. 2011). Any populations leaving the Mesa Verde region and heading south towards the Gallinas Mountains area would likely have passed very near Mount Taylor itself (or at least through its primary distribution zone) and theoretically could have picked up material along the way. Additionally, the Mesa Verde Region was not depopulated in a single event (Arakawa et al. 2011), nor was Gallinas Springs Pueblo built all at once (Lincoln 2007). A stream of new arrivals coming down from the north to the growing Gallinas Springs Pueblo could have supplied a continued flow of Mount Taylor obsidian.

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[16] One Lion Mountain Community site (LA189382) exhibited a somewhat different pattern of source use relative to the rest of Lion Mountain Community sites (although not significantly so). This site exhibited an equal proportion of McDaniel Tank and Mount Taylor. Aligning with this slight difference in source use, Huntley and Eckert (2020) note that LA189382 exhibits slightly different architecture and ceramics from the rest of the Lion Mountain Community sites.

Chapter 6: 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 area of west central New Mexico during the Pithouse and Pueblo periods. This is a relatively under researched area in comparison to many parts of the Southwest. Despite this, evidence shows that that the area was home to a large population during this time. Recent and ongoing investigations in the area under the Lion Mountain Archaeology Project (led by Drs. Suzanne Eckert of the University of Arizona and Deborah Huntley of Tetra Tech, Inc.) have 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 eleven sites in the Gallinas Mountains area. These sites are believed to be representative of the full range of cultural and temporal variation present in this area spanning the late Pithouse/early Pueblo through late Pueblo periods. Original data were produced for a total of ten sites (with an additional assemblage from the nearby Goat Springs Pueblo included for comparative purposes). All observed surface obsidian artifacts from these ten sites were analyzed using portable handheld Electron Dispersive X-ray fluorescence spectrometry (ED-XRF). In total, 502 obsidian artifacts were analyzed as part of this study. Of these, 496 were able to be confidently assigned to a known southwestern geochemical source of source group.

Within the collective Gallinas Mountains area sample, ten geologically distinct sources of obsidian were identified. These include the Mount Taylor source group (comprised of the Grants Ridge and Horace Mesa sources), McDaniel Tank, the Jemez source group (comprised of the Cerro del Medio, Rabbit Mountain, Polvadera Peak, Paliza Canyon, and Bear Springs Peak sources), Antelope Creek (of the Mule Creek group), and Superior sources. An additional source, Cow Canyon was identified in the comparative assemblage. Furthermore, one example of possible Government Mountain obsidian was also encountered.

As would be expected, several of these sources were encountered far more frequently than others. Overall, Mount Taylor, McDaniel Tank, and Jemez were found to be the most common in the area in that order. Of these, Mount Taylor and McDaniel Tank typically made up the large majority of any given site assemblage. In addition to these primary sources, Antelope Creek, Cow Canyon, Superior, and (possibly) Government Mountain were also encountered, albeit far less frequently. Additionally, (in regards to tool manufacture) several of the identified sources were found to have been utilized in significantly different ways.

Significantly different patterns of source use (and by effect procurement strategy) were found to have occurred in the Gallinas Mountains area over time. Mount Taylor, the most commonly utilized source during the late Pithouse and early Pueblo periods, saw a drastic decrease during the middle Pueblo period, followed by an upturn in the late Pueblo period. Jemez saw a similar pattern, albeit in a much smaller scale. Relatively local McDaniel Tank obsidian, saw a gradual increase in use during from the late Pithouse to early Pueblo periods, followed by a sharp increase in the middle Pueblo period, and a subsequent drop in the late Pueblo period. More minor sources such as Antelope Creek, Cow Canyon, Superior, and Government Mountain were relatively unutilized in the earlier periods, but saw some use during the late Pueblo period.

In addition to this temporal variation, significant differences in source procurement were identified among contemporaneous middle Pueblo period sites. The Lion Mountain Community, a large aggregate community argued to have been occupied by a somewhat indigenous population, showed a heavy dependence on the relatively local McDaniel Tank. While Gallinas Springs, a Magdalena phase nucleated pueblo argued by some to have been occupied by immigrants from the Mesa Verde region, showed a clear preference for the more northern Mount Taylor.

In conclusion, the patterns identified in this study showcase the diverse obsidian source procurement strategies of the Gallinas Mountains area during the Pithouse and Pueblo periods. These procurement strategies offer an important glimpse into the networks of exchange, interaction, and identity of those who lived in the area during this dynamic time in Southwestern prehistory. Research into the cultural manifestations of the Gallinas Mountains area is relatively new territory. It is curious to think of whether future research in the area (both in terms of obsidian provenancing and other forms of study) will support or conflict with the patterns identified presently. Until that time we can walk away knowing that the ways in which the people of the Gallinas Mountains area chose to interact with the surrounding regions was surely as complex as that of the more heavily researched areas of the American Southwest.

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Appendix A

Descriptive Data for Samples

Table A.1. Descriptive data for samples.
Note: (*) denotes samples included in confident version of Mount Taylor source assignment.

ANID	Site	Source Assignment	Type	Part	Size	Cortex (%)
LML014	LA189381	MDNM	D	P	1	0
LML015	LA189381	Not obsidian	D	U	1	0
LML016	LA189381	MTHM	D	U	1	0
LML017	LA189381	JMRM	D	P	2	0
LML018	LA189381	MDNM	D	U	2	0
LML019	LA189381	MDNM	P	P	2	0
LML020	LA189381	MDNM	D	U	2	100
LML021	LA189381	MDNM	F	U	2	60
LML022	LA189381	MTGR*	F	M	0	0
LML023	LA189381	Not obsidian	D	U	2	0
LML024	LA189381	MDNM	F	C	1	40
LML025	LA189381	MDNM	D	U	1	5
LML026	LA189381	MDNM	F	M	2	5
LML027	LA189381	MDNM	F	D	2	30
LML028	LA189381	MDNM	F	C	2	100
LML029	LA189381	MDNM	F	P	2	35
LML030	LA189381	MDNM	D	U	1	0
LML031	LA189381	MDNM	P	P	2	0
LML032	LA189381	MDNM	F	U	2	0
LML033	LA189381	Not obsidian	C	U	3	0
LML034	LA189381	MDNM	D	U	2	0
LML035	LA189381	MTHM	F	C	1	0
LML036	LA189381	MDNM	F	M	1	0
LML037	LA189381	MTGR	F	P	1	0
LML038	LA189381	MTGR	D	U	1	0
LML039	LA189381	MTHM*	D	U	2	5
LML040	LA189381	MDNM	F	C	1	95
LML041	LA189381	MDNM	F	C	2	25
LML042	LA189381	MDNM	F	P	1	0
LML043	LA189381	MDNM	F	P	1	30
LML044	LA189381	MTHM*	D	U	2	5
LML045	LA189381	MTHM	F	C	1	0
LML046	LA189381	MDNM	F	M	1	70
LML047	LA189381	MTHM*	F	M	2	0
LML048	LA189381	MDNM	F	C	1	0
LML049	LA189381	Not obsidian	D	U	2	0
LML050	LA189381	Not obsidian	B	D	2	50
LML051	LA189381	Not obsidian	F	P	2	0
LML052	LA189381	MDNM	F	C	3	45
LML053	LA189381	MTGR*	F	C	1	0
LML054	LA189381	MDNM	D	U	1	0
LML055	LA189381	MDNM	F	P	1	5
LML056	LA189381	MTGR*	F	P	2	20
LML057	LA189381	MTHM*	D	U	3	50
LML058	LA189381	MDNM	F	P	2	80
LML059	LA189381	MDNM	D	U	2	0
LML060	LA189381	MDNM	F	D	1	0

ANID	Site	Source Assignment	Type	Part	Size	Cortex (%)
LML061	LA189381	JMRM	F	C	1	0
LML062	LA189381	MDNM	F	C	0	0
LML063	LA189381	MDNM	F	D	0	0
LML064	LA189381	MDNM	F	P	1	0
LML065	LA189381	MDNM	D	U	1	0
LML066	LA189381	MDNM	F	M	1	0
LML067	LA189381	MTGR*	F	P	2	0
LML068	LA189381	MDNM	F	C	1	5
LML069	LA189381	MDNM	F	P	2	0
LML070	LA189381	MDNM	F	D	1	0
LML071	LA189381	MTGR*	F	D	2	0
LML072	LA189381	Not obsidian	F	M	3	0
LML073	LA189381	MDNM	D	U	3	80
LML074	LA189381	MDNM	D	U	2	0
LML075	LA189381	MDNM	F	C	2	100
LML076	LA189381	Unas.	F	D	2	0
LML077	LA189381	MDNM	F	M	2	0
LML078	LA189381	MDNM	P	P	1	0
LML079	LA189381	MDNM	F	P	2	55
LML080	LA189381	MDNM	D	U	3	40
LML081	LA189381	MDNM	P	P	2	0
LML082	LA189381	MDNM	F	M	2	70
LML083	LA189381	MTHM	F	P	2	20
LML084	LA189381	MDNM	F	C	2	10
LML085	LA189381	MTGR*	D	U	2	0
LML086	LA189381	MTHM*	F	D	1	0
LML087	LA189381	MDNM	F	C	2	50
LML088	LA189381	MDNM	D	U	2	0
LML089	LA189381	MDNM	F	D	2	0
LML090	LA189381	MTGR*	D	U	3	10
LML091	LA189381	MDNM	D	U	4	40
LML092	LA189381	MDNM	F	C	2	70
LML093	LA189381	MDNM	F	C	4	45
LML094	LA189381	MDNM	D	U	3	30
LML095	LA189381	MDNM	F	M	2	0
LML096	LA189381	JMRM	D	U	2	0
LML097	LA189381	MDNM	F	P	3	35
LML098	LA189381	MTHM*	F	D	2	40
LML099	LA189381	MDNM	D	U	3	10
LML100	LA189381	JMRM	D	U	3	100
LML101	LA189381	MDNM	D	U	3	90
LML102	LA189381	MTGR*	D	U	2	0
LML103	LA189381	MDNM	D	U	2	0
LML104	LA189381	MDNM	D	U	2	0
LML105	LA189381	MDNM	D	U	2	0
LML106	LA189381	MDNM	D	U	3	40
LML107	LA189381	MDNM	F	P	3	50
LML108	LA189381	MTHM	B	M	2	0
LML109	LA189381	MTHM*	F	P	3	50

ANID	Site	Source Assignment	Type	Part	Size	Cortex (%)
LML111	LA121885	MDNM	D	U	3	50
LML112	LA121885	MDNM	F	C	2	0
LML113	LA121885	MTGR*	F	C	2	65
LML114	LA121885	MDNM	D	U	2	35
LML115	LA121885	MDNM	F	M	2	0
LML116	LA121885	MDNM	D	U	2	0
LML117	LA121885	MDNM	F	P	2	0
LML118	LA121885	MDNM	B	M	3	0
LML119	LA121885	MDNM	P	C	2	0
LML120	LA121885	MTHM*	P	M	2	0
LML121	LA121885	MDNM	F	C	2	40
LML122	LA121885	MTHM*	F	C	2	5
LML123	LA121885	MDNM	F	P	2	10
LML124	LA121885	JMRM	F	C	2	0
LML125	LA121885	MDNM	F	M	2	10
LML126	LA121885	MTGR*	F	P	2	30
LML127	LA121885	MTHM*	F	M	2	80
LML128	LA121885	MDNM	D	U	2	60
LML129	LA121885	Unas.	D	U	3	0
LML130	LA121885	MDNM	F	C	3	90
LML131	LA121885	MDNM	D	U	3	40
LML132	LA121885	MTHM*	F	M	2	0
LML133	LA121885	MTHM	F	P	1	0
LML134	LA121885	MTGR	F	P	1	0
LML135	LA121885	MDNM	F	P	4	40
LML136	LA121885	MDNM	D	U	3	50
LML137	LA121885	Unas.	F	D	3	75
LML138	LA121885	MDNM	D	U	2	20
LML139	LA121885	MDNM	F	P	2	0
LML140	LA121885	MTHM*	D	U	1	100
LML141	LA121885	MDNM	F	C	2	90
LML142	LA121885	MDNM	D	U	2	25
LML143	LA121885	MDNM	F	P	2	0
LML144	LA121885	MDNM	F	M	2	0
LML145	LA121885	MDNM	F	P	2	0
LML146	LA121885	Not obsidian	F	C	2	0
LML147	LA121885	MTGR*	C	U	3	25
LML148	LA121885	MDNM	F	P	2	100
LML149	LA121885	Not obsidian	B	M	2	0
LML150	LA121885	MDNM	F	P	2	0
LML151	LA121885	MTHM	F	C	2	5
LML152	LA121885	JMRM	F	P	3	100
LML153	LA121885	MDNM	F	C	2	10
LML154	LA121885	MDNM	F	P	2	10
LML155	LA121885	MDNM	P	P	1	0
LML156	LA121885	MDNM	D	U	3	30
LML157	LA121885	MTGR*	B	D	3	0
LML158	LA121885	JMRM	B	D	2	0
LML159	LA121885	MDNM	F	M	3	80

ANID	Site	Source Assignment	Type	Part	Size	Cortex (%)
LML160	LA121885	JMRM	F	D	2	5
LML161	LA121885	MDNM	B	D	2	80
LML162	LA121885	MDNM	F	M	2	0
LML163	LA121885	JMRM	F	C	0	0
LML164	LA121885	MTGR	F	P	0	0
LML165	LA121885	JMPV	F	P	3	0
LML166	LA121885	MTGR*	F	P	2	0
LML167	LA121885	MDNM	F	C	2	10
LML168	LA121885	MDNM	D	U	1	0
LML169	LA121885	MDNM	F	P	2	0
LML170	LA121885	MDNM	D	U	2	10
LML171	LA121885	MDNM	D	U	3	70
LML172	LA121885	MDNM	F	P	3	10
LML173	LA121885	MDNM	F	D	3	45
LML174	LA121885	MDNM	F	M	2	0
LML175	LA121885	Unas.	B	D	2	0
LML176	LA121884	MDNM	F	P	2	0
LML181	LA121884	MTHM*	F	M	2	0
LML182	LA121884	MTHM*	F	C	3	35
LML183	LA121884	MDNM	D	U	2	75
LML184	LA121884	MDNM	F	P	2	5
LML185	LA121884	MDNM	F	P	1	10
LML186	LA121884	MDNM	F	P	2	60
LML187	LA121884	MTHM*	D	U	2	100
LML188	LA121884	MDNM	D	U	2	25
LML189	LA121884	MDNM	U	C	2	0
LML190	LA121884	MDNM	F	P	2	90
LML191	LA121883	MDNM	F	C	3	60
LML192	LA121883	MDNM	D	U	3	50
LML193	LA121883	MDNM	F	M	2	40
LML194	LA121883	JMRM	P	M	2	0
LML195	LA121883	JMCM	F	M	2	0
LML196	LA121883	MDNM	F	C	2	100
LML197	LA121883	MDNM	F	C	1	0
LML198	LA121883	MDNM	D	U	2	0
LML199	LA121883	MDNM	D	U	2	40
LML200	LA121883	MDNM	D	U	3	30
LML201	LA121883	MDNM	D	U	2	60
LML202	LA121883	MDNM	D	U	2	25
LML203	LA121883	MDNM	D	U	2	40
LML204	LA121883	MDNM	F	M	1	0
LML205	LA121883	MTHM*	F	D	2	0
LML206	LA121883	MDNM	D	U	2	0
LML207	LA121883	MDNM	F	C	1	5
LML208	LA121883	MDNM	P	C	2	0
LML209	LA121883	MDNM	F	M	2	20
LML210	LA121883	MDNM	F	P	2	10
LML211	LA121883	MDNM	D	U	1	25
LML212	LA121883	MTGR*	F	M	2	10

ANID	Site	Source Assignment	Type	Part	Size	Cortex (%)
LML213	LA121883	MDNM	F	D	3	90
LML214	LA121883	MTHM*	F	P	2	70
LML215	LA121883	MDNM	D	U	1	10
LML216	LA121883	MDNM	F	P	3	15
LML217	LA121883	MDNM	F	P	2	0
LML218	LA121883	MTGR*	D	U	2	20
LML219	LA121883	Not obsidian	F	D	3	0
LML220	LA121883	MDNM	P	M	2	0
LML221	LA121883	MDNM	D	U	2	10
LML222	LA121883	MDNM	P	C	2	0
LML223	LA193028	MDNM	C	U	3	70
LML224	LA193028	MTHM*	F	M	2	70
LML225	LA193028	MTHM*	F	M	2	0
LML226	LA193028	MTHM*	F	P	2	40
LML227	LA193028	MDNM	F	P	2	5
LML228	LA193028	MTHM*	P	P	2	0
LML229	LA193028	MTHM*	F	C	3	5
LML230	LA193028	MTHM*	F	D	3	25
LML231	LA193028	MDNM	D	U	2	20
LML232	LA193028	MDNM	F	P	2	0
LML233	LA193028	MTHM	F	C	2	0
LML234	LA193028	MTHM*	F	D	2	10
LML235	LA193028	MTHM*	F	P	2	10
LML236	LA193028	JMPV	P	P	2	0
LML237	LA193028	MTHM*	F	M	2	0
LML238	LA193028	MTHM*	F	D	3	90
LML239	LA193028	MTHM*	F	M	2	0
LML240	LA193028	JMRM	F	P	2	15
LML241	LA193028	JMRM	F	C	5	0
LML242	LA193028	MDNM	D	U	3	50
LML243	LA193028	Unas.	D	U	2	-
LML244	LA193028	MTHM	F	M	2	5
LML245	LA193028	JMBS	F	C	3	40
LML246	LA193028	JMPC	F	P	3	0
LML247	LA193028	MDNM	F	M	3	0
LML248	LA193028	MDNM	P	C	2	0
LML253	LA193028	MDNM	F	C	2	25
LML254	LA193028	MTHM*	F	M	2	35
LML255	LA193028	MTHM*	F	C	2	50
LML256	LA193028	MTHM*	F	P	2	10
LML257	LA193028	MTHM*	D	U	1	25
LML258	LA193028	MTHM*	F	C	3	0
LML259	LA193028	MTHM*	D	U	2	30
LML260	LA193028	MDNM	D	U	2	25
LML261	LA193028	MTHM*	F	C	2	40
LML262	LA193028	MTHM*	F	P	2	10
LML263	LA193028	MTGR	F	C	1	0
LML270	LA189382	MCAC	P	P	3	0
LML271	LA189382	MDNM	F	C	2	0

ANID	Site	Source Assignment	Type	Part	Size	Cortex (%)
LML272	LA189382	MDNM	F	M	2	25
LML273	LA189382	MDNM	F	M	1	0
LML274	LA189382	MTGR*	F	M	2	0
LML275	LA189382	MDNM	F	P	2	0
LML276	LA189382	MDNM	D	U	2	0
LML277	LA189382	MTHM*	P	D	2	0
LML278	LA189382	MDNM	D	U	2	30
LML279	LA189382	MTHM*	F	P	2	25
LML280	LA189382	MDNM	F	D	2	100
LML281	LA189382	MDNM	F	C	3	0
LML282	LA189382	MDNM	P	P	2	0
LML283	LA189382	MTHM	D	U	1	0
LML284	LA189382	MDNM	F	D	2	30
LML285	LA189382	MTHM*	F	P	2	0
LML286	LA189382	MTGR*	F	M	3	75
LML287	LA189382	JMCM	P	C	3	0
LML288	LA189382	MDNM	D	U	2	0
LML289	LA189382	MTHM*	F	D	2	100
LML290	LA189382	MTGR*	F	M	1	0
LML291	LA189382	MTHM*	B	M	2	0
LML292	LA189382	MTGR*	D	U	2	0
LML293	LA189382	MDNM	C	U	2	70
LML294	LA189382	MTGR*	D	U	2	60
LML295	LA189382	MDNM	D	U	2	50
LML296	LA189382	MDNM	F	M	2	10
LML297	LA189382	MTHM	F	P	1	0
LML298	LA189382	MTGR*	D	U	2	0
LML299	LA189382	MDNM	C	U	3	100
LML300	LA189382	MTGR*	F	M	1	0
LML301	LA189382	MDNM	F	C	2	10
LML302	LA189382	MDNM	F	D	2	25
LML303	LA189382	JMCM	F	P	3	0
LML304	LA189382	MTHM*	F	D	3	0
LML305	LA189382	MDNM	F	C	4	40
LML306	LA189382	MDNM	P	C	2	0
LML307	LA189382	MTGR*	D	U	2	0
LML308	LA189382	MDNM	F	D	1	0
LML309	LA189382	MTGR*	D	U	2	10
LML310	LA189382	MTGR*	F	P	2	0
LML311	LA189382	MTGR	F	P	0	10
LML312	LA189382	MTHM*	F	D	3	0
LML317	LA125085	MDNM	F	P	2	15
LML318	LA125085	MTGR*	D	U	3	60
LML319	LA125085	Not obsidian	F	P	3	0
LML320	LA125085	MDNM	F	D	2	0
LML321	LA125085	MTHM*	P	P	2	0
LML322	LA125085	MTHM*	F	C	2	100
LML323	LA125085	MDNM	D	U	2	10
LML324	LA125085	MDNM	D	U	2	40

ANID	Site	Source Assignment	Type	Part	Size	Cortex (%)
LML325	LA125085	MTHM*	F	P	2	40
LML326	LA125085	MTHM*	F	D	2	100
LML327	LA125085	MTHM*	P	P	2	0
LML328	LA125085	JMRM	B	M	2	0
LML329	LA125085	Not obsidian	F	P	2	0
LML330	LA125085	MTHM*	F	D	2	100
LML331	LA125085	Not obsidian	D	U	2	50
LML332	LA125085	MTHM*	F	D	2	5
LML333	LA125085	MDNM	F	P	2	30
LML334	LA125085	MTHM*	D	U	1	0
LML335	LA125085	MTGR*	F	M	2	35
LML336	LA125085	MTHM	F	M	1	0
LML337	LA125085	MTHM*	F	M	2	100
LML338	LA125085	MDNM	F	M	1	0
LML339	LA125085	MTGR*	D	U	1	0
LML340	LA125085	JMCM	P	D	1	0
LML341	LA125085	MTGR*	F	M	1	0
LML342	LA125085	MTHM	P	D	1	0
LML343	LA125085	MDNM	F	P	1	0
LML344	LA125085	MTHM*	F	D	3	0
LML345	LA125085	MDNM	F	D	2	0
LML346	LA125085	MTHM*	F	M	2	0
LML347	LA125085	JMRM	B	D	2	0
LML348	LA1178	JMRM	D	U	3	70
LML349	LA1178	MTGR	F	C	1	0
LML350	LA1178	MTHM	F	D	1	0
LML351	LA1178	MDNM	F	D	0	70
LML352	LA1178	MTHM	F	P	1	0
LML353	LA1178	MDNM	F	C	0	0
LML354	LA1178	MTGR	F	P	0	0
LML355	LA1178	MTHM	F	M	0	0
LML356	LA1178	MDNM	D	U	2	50
LML357	LA1178	MTGR	F	P	0	0
LML358	LA1178	JMRM	F	C	1	0
LML359	LA1178	JMRM	D	U	1	0
LML360	LA1178	MTGR*	F	D	1	0
LML361	LA1178	MTGR	F	C	0	0
LML362	LA1178	MTHM	F	M	1	0
LML363	LA1178	MDNM	F	D	0	0
LML364	LA1178	MTHM	F	D	1	0
LML365	LA1178	MTGR*	F	D	1	0
LML366	LA1178	MTGR*	F	C	1	0
LML367	LA1178	MTHM	F	C	0	0
LML368	LA1178	MTGR	F	M	1	0
LML369	LA1178	MTGR*	F	C	0	5
LML370	LA1178	JMRM	F	D	1	0
LML371	LA1178	MTHM	F	D	1	0
LML372	LA1178	MTGR	F	C	1	0
LML373	LA1178	MTHM	D	U	1	0

ANID	Site	Source Assignment	Type	Part	Size	Cortex (%)
LML374	LA1178	MTGR	D	U	1	30
LML375	LA1178	MTHM	F	P	1	0
LML376	LA1178	MTGR	F	C	0	0
LML377	LA1178	MTGR	F	P	1	0
LML378	LA1178	MTGR*	F	C	0	0
LML379	LA1178	MTGR	F	C	0	40
LML380	LA1178	MTHM*	D	U	1	0
LML381	LA1178	MTHM	F	D	1	0
LML382	LA1178	MTHM	F	C	1	0
LML383	LA1178	MTHM	F	C	0	0
LML384	LA1178	MTHM	F	C	1	0
LML385	LA1178	MTGR*	F	C	0	0
LML386	LA1178	MDNM	F	D	1	0
LML387	LA1178	MTHM	F	C	1	0
LML388	LA1178	MTGR*	F	D	0	10
LML389	LA1178	MTHM	D	U	1	0
LML390	LA1178	MTGR*	F	C	0	0
LML391	LA1178	MTHM	D	U	0	0
LML392	LA1178	MTHM	F	D	0	0
LML393	LA1178	MTHM	F	C	1	0
LML394	LA1178	MTGR*	F	C	1	40
LML395	LA1178	MTGR*	F	D	2	60
LML396	LA1178	MTGR*	F	P	1	0
LML397	LA1178	MTHM*	F	C	2	0
LML398	LA1178	JMRM	F	M	2	30
LML399	LA1178	MDNM	D	U	2	25
LML400	LA1178	MTHM	F	M	1	0
LML401	LA1178	MTGR*	D	U	1	0
LML402	LA1178	MTHM*	D	U	1	0
LML403	LA1178	MTHM*	D	U	1	10
LML404	LA1178	MTGR	F	C	1	0
LML405	LA1178	MTGR*	F	C	1	0
LML406	LA1178	MTGR*	F	M	0	0
LML407	LA1178	MTGR*	F	C	1	0
LML408	LA1178	MTHM*	D	U	3	50
LML409	LA1178	MTGR*	D	U	2	40
LML410	LA1178	MTHM*	F	P	2	0
LML411	LA1178	MTGR	F	C	1	0
LML412	LA1178	MTHM	F	D	1	25
LML413	LA1178	MTHM	F	C	1	0
LML414	LA1178	MTHM	D	U	1	0
LML415	LA1178	MTGR	F	C	1	0
LML416	LA1178	MTGR	F	C	1	50
LML417	LA1178	MTHM*	F	P	0	0
LML418	LA1178	MTGR	F	C	1	0
LML419	LA1178	MDNM	F	C	0	0
LML420	LA1178	MTGR	F	C	0	0
LML421	LA1178	MTGR	D	U	0	75
LML422	LA1178	MTGR	F	C	1	0

ANID	Site	Source Assignment	Type	Part	Size	Cortex (%)
LML423	LA1178	MTGR*	F	P	0	0
LML424	LA1178	MTGR	F	C	1	0
LML425	LA1178	JMRM	F	C	1	0
LML426	LA1178	MTGR*	F	P	1	0
LML427	LA1178	MTGR	F	P	1	0
LML428	LA1178	MDNM	F	C	0	0
LML429	LA1178	MTHM	D	U	1	25
LML430	LA1178	MTGR	D	U	1	0
LML431	LA1178	MTHM	F	P	1	0
LML432	LA1178	MTGR	F	D	1	100
LML433	LA1178	JMRM	F	C	0	20
LML434	LA1178	MTGR	F	D	1	0
LML435	LA1178	MTHM	F	P	1	0
LML436	LA1178	MTGR	F	D	0	0
LML437	LA1178	MDNM	F	C	0	0
LML438	LA1178	MTGR	F	M	0	100
LML439	LA1178	JMRM	F	C	0	0
LML440	LA1178	MTHM*	F	D	1	0
LML441	LA1178	MTHM	D	U	1	0
LML442	LA1178	MTHM*	F	M	1	0
LML443	LA1178	MTGR	F	C	0	0
LML444	LA1178	MTGR	F	C	0	0
LML445	LA1178	MTGR	D	U	1	0
LML446	LA1178	MTGR	F	C	1	0
LML447	LA1178	MTHM	F	M	0	0
LML448	LA1178	MDNM	F	C	1	0
LML449	LA1178	MTHM	F	C	1	0
LML450	LA1178	MTGR*	F	C	1	0
LML451	LA1178	MTHM	B	D	1	0
LML452	LA1178	MTGR*	F	M	1	0
LML453	LA1178	MTHM*	D	U	2	100
LML454	LA1178	MTGR*	F	C	2	0
LML455	LA1178	MDNM	F	P	3	20
LML456	LA1178	MTHM*	F	P	2	10
LML457	LA1178	JMRM	D	U	2	100
LML458	LA1178	MTHM	F	C	2	10
LML459	LA1178	MTGR	F	M	1	0
LML460	LA1178	MTGR*	F	D	2	0
LML461	LA1178	MTHM	F	C	1	20
LML462	LA1178	MTGR	F	M	1	0
LML463	LA1178	MTGR	F	C	1	0
LML464	LA1178	MTHM	F	C	1	20
LML465	LA1178	MTGR	F	M	0	0
LML466	LA1178	MTGR	F	C	1	0
LML467	LA1178	JMRM	F	P	1	0
LML468	LA1178	MTGR	F	D	1	0
LML469	LA1178	MTHM	F	M	0	0
LML470	LA1178	MTHM	F	D	1	0
LML500	LA1180	MTHM	D	C	1	0

ANID	Site	Source Assignment	Type	Part	Size	Cortex (%)
LML501	LA1180	SUAZ	F	D	1	0
LML502	LA1180	MCAC	F	P	1	0
LML503	LA1180	MTHM	F	D	1	0
LML504	LA1180	MTHM*	D	C	3	0
LML505	LA1180	MTGR*	F	M	2	0
LML506	LA1180	MTHM	F	C	1	0
LML507	LA1180	MTHM	F	C	0	0
LML508	LA1180	MTHM*	D	C	1	0
LML509	LA1180	MTGR	F	P	1	0
LML510	LA1180	MTHM	F	P	1	10
LML511	LA1180	MTGR*	F	M	3	0
LML512	LA1180	MTHM*	F	C	2	10
LML513	LA1180	MTHM*	P	U	3	0
LML514	LA1180	MDNM	F	M	1	0
LML515	LA1180	MDNM	UP	C	3	100
LML516	LA1180	MCAC	F	C	1	30
LML517	LA1180	MTHM	D	C	1	0
LML518	LA1180	MTHM	F	U	0	0
LML519	LA1180	MTGR	F	D	0	0
LML520	LA1180	MCAC	F	M	1	0
LML521	LA1180	MTHM	F	C	1	0
LML522	LA1180	MCAC	F	M	1	30
LML523	LA1180	JMCM	F	M	1	0
LML524	LA1180	MTGR	F	U	1	0
LML525	LA1180	MTHM	F	C	0	0
LML526	LA1180	MTHM	F	M	1	0
LML527	LA1180	JMCM	B	M	2	0
LML528	LA1180	MCAC	F	P	1	0
LML529	LA1180	GMAZ	D	C	1	0
LML530	LA1180	MTHM	F	P	0	30
LML531	LA1180	MCAC	P	D	2	0
LML532	LA1180	MTGR	F	M	1	0
LML533	LA1180	MTHM	F	P	1	0
LML534	LA1180	MTGR	F	M	1	0
LML535	LA1180	MTHM	F	M	0	0
LML536	LA1180	MTHM	F	C	1	0
LML537	LA1180	MTGR	D	C	1	0
LML538	LA1180	MTGR	F	M	1	0
LML539	LA1180	MTGR	F	M	1	0
LML540	LA1180	MTGR*	B	P	3	0
LML541	LA1180	MTGR	F	C	1	0
LML543	LA1180	MTHM*	D	C	2	0
LML544	LA1180	MDNM	F	C	1	0
LML545	LA1180	Not obsidian	F	C	3	25
LML546	LA61489 (AC2)	JMRM	F	P	2	0
LML547	LA61489 (AC2)	JMRM	F	C	1	0
LML548	LA61489 (AC2)	MTHM	D	C	1	0
LML549	LA61489 (AC2)	MTHM	F	P	0	0
LML550	LA61489 (AC2)	MTHM	F	D	1	0

ANID	Site	Source Assignment	Type	Part	Size	Cortex (%)
LML551	LA61489 (AC2)	MTHM*	D	C	3	0
LML552	LA61489 (AC2)	MTHM*	D	C	1	0
LML553	LA61489 (AC2)	MTHM*	P	C	1	0
LML554	LA61489 (AC2)	MTGR	F	C	1	0
LML557	LA61489 (AC2)	JMRM	B	M	2	0
LML558	LA61489 (AC2)	JMRM	F	D	2	0
LML559	LA61489 (AC2)	MTHM	F	M	1	0
LML560	LA61489 (AC2)	MTGR	D	C	1	0
LML561	LA61489 (AC2)	JMCM	D	C	1	0
LML562	LA61489 (AC2)	MTGR	F	C	1	30
LML563	LA61489 (AC2)	MTGR	F	C	1	0
LML564	LA61489 (AC2)	MDNM	F	C	0	20
LML565	LA61489 (AC2)	JMRM	F	C	0	0
LML566	LA61489 (AC2)	MTGR	D	C	1	0
LML567	LA61489 (AC2)	JMRM	F	M	1	0
LML568	LA61489 (AC2)	MTGR	F	P	1	0
LML569	LA61489 (AC2)	MTHM	F	P	0	0
LML570	LA61489 (AC2)	MTGR	F	D	1	0
LML571	LA61489 (AC2)	MTGR	F	M	0	0
LML572	LA61489 (AC2)	JMRM	F	P	1	0
LML573	LA61489 (AC2)	MDNM	D	C	1	10
LML574	LA61489 (AC2)	MTGR	F	C	1	0
LML575	LA61489 (AC2)	MTHM	D	C	1	0
LML576	LA61489 (AC2)	JMRM	F	C	0	0
LML577	LA61489 (AC2)	MTHM	D	C	1	0
LML578	LA61489 (AC2)	MTGR	F	D	1	0
LML580	LA61489 (AC1)	JMRM	F	P	2	10
LML581	LA61489 (AC1)	MTHM*	F	C	2	0
LML582	LA61489 (AC1)	Not obsidian	F	C	2	0

Appendix B

Compositional Data for Samples

Table A.2. Compositional data for samples.
Note: all compositional data are in elemental parts per million (ppm)

ANID	Mn	Fe	Rb	Sr	Y	Zr	Nb
LML014	610.00	11461.03	142.00	163.42	29.22	210.69	28.52
LML015	25.54	2087.34	0.00	23.02	1.14	0.00	0.25
LML016	747.05	9082.55	476.98	5.16	66.49	109.39	181.47
LML017	514.15	8713.65	224.80	7.58	58.03	192.64	99.38
LML018	602.67	9136.30	164.72	150.74	39.69	247.14	42.64
LML019	479.73	10290.38	152.34	169.69	34.44	275.42	34.76
LML020	604.97	11458.11	153.89	172.65	36.18	284.10	38.43
LML021	608.84	9955.12	153.85	178.94	31.17	250.76	43.79
LML022	948.18	6191.22	531.54	1.04	68.70	111.72	182.91
LML023	141.57	2756.39	11.28	40.67	2.29	2.23	0.00
LML024	458.47	11266.80	158.86	167.70	31.95	224.60	28.83
LML025	468.77	9138.14	128.39	133.93	28.03	190.37	23.30
LML026	504.07	10457.17	163.46	155.52	34.99	263.12	44.17
LML027	498.07	9593.64	152.35	172.90	31.13	238.57	39.05
LML028	555.29	9520.35	148.26	156.53	28.18	210.31	31.38
LML029	570.97	8455.49	138.14	158.39	28.40	217.73	31.51
LML030	521.29	11047.30	147.73	131.99	24.93	220.51	33.65
LML031	555.35	10568.00	157.31	170.33	33.51	245.05	38.29
LML032	585.91	11153.51	173.86	174.77	34.01	246.19	35.60
LML033	259.47	1514.63	3.58	30.88	2.21	0.35	0.98
LML034	587.98	9449.43	139.66	151.99	24.31	247.34	35.46
LML035	747.24	7659.88	520.19	3.68	77.79	124.47	212.82
LML036	482.51	10478.13	135.15	151.40	31.01	296.98	28.86
LML037	707.28	7451.70	450.07	0.32	67.61	99.68	168.82
LML038	946.77	6088.59	507.08	1.43	61.25	108.44	174.03
LML039	792.95	7355.50	478.50	2.41	84.50	124.00	213.34
LML040	621.71	9569.23	149.41	158.25	31.23	235.19	32.85
LML041	673.72	10144.85	164.40	187.45	36.28	256.48	39.17
LML042	346.57	10870.55	147.55	167.54	26.06	226.58	30.16
LML043	737.35	10757.00	157.43	174.50	37.93	244.66	34.70
LML044	800.89	9734.01	556.22	2.95	97.02	161.69	251.26
LML045	496.02	6889.42	457.49	0.75	64.65	117.40	174.77
LML046	562.19	10402.77	139.71	155.05	31.94	221.59	29.24
LML047	676.35	6882.11	462.88	1.33	76.57	116.34	196.47
LML048	456.48	10846.78	138.90	155.21	28.97	208.20	27.14
LML049	56.11	2236.28	7.00	49.35	5.79	10.54	1.01
LML050	4084.90	2825.82	0.00	0.71	0.00	0.00	0.00
LML051	1291.77	1684.28	13.52	7.67	0.00	3.77	11.14
LML052	655.31	10718.22	156.51	173.97	35.22	263.59	40.31
LML053	797.19	8361.23	504.50	1.11	75.11	109.15	184.81
LML054	353.39	8373.23	127.03	147.94	28.19	234.92	29.49
LML055	473.09	12091.36	158.79	180.46	30.78	249.87	34.73
LML056	765.94	6283.41	556.48	0.00	84.64	115.34	187.56
LML057	778.00	7320.07	490.74	2.20	84.49	136.60	221.25
LML058	559.86	9294.78	157.21	168.69	34.26	250.79	37.67
LML059	531.05	9455.84	142.32	159.52	28.49	233.33	34.58
LML060	778.05	11927.36	171.67	176.81	32.11	244.44	35.39

ANID	Mn	Fe	Rb	Sr	Y	Zr	Nb
LML061	468.48	8093.37	187.43	0.00	46.52	144.19	75.85
LML062	578.20	11778.10	136.13	169.47	27.03	220.34	29.76
LML063	816.34	14050.40	134.34	142.65	19.90	233.46	28.23
LML064	374.81	10199.08	145.24	150.84	25.05	213.57	30.60
LML065	638.04	10165.92	144.19	162.69	30.71	259.15	30.44
LML066	337.27	10257.12	144.53	145.51	26.00	207.87	28.31
LML067	1277.80	6822.79	583.39	1.68	60.26	93.74	169.08
LML068	584.82	10626.66	147.22	170.16	34.90	243.05	32.23
LML069	573.58	10364.55	143.09	173.50	29.27	255.57	36.29
LML070	710.74	11694.50	160.39	176.83	30.74	233.67	30.10
LML071	1059.67	6308.87	567.46	2.75	73.47	111.65	190.64
LML072	135.49	2915.97	7.07	36.45	0.81	6.06	0.83
LML073	764.10	16437.24	215.03	220.14	44.71	322.75	45.61
LML074	661.46	13353.04	171.89	186.27	36.98	275.55	37.81
LML075	255.33	10489.22	136.41	166.11	32.38	269.70	32.40
LML076	455.30	51229.22	59.84	228.71	20.14	95.14	19.25
LML077	511.99	10116.45	150.63	173.35	30.54	246.21	34.51
LML078	523.24	10306.52	167.55	174.12	34.93	253.52	35.62
LML079	569.26	9456.59	151.94	167.10	29.77	282.07	42.48
LML080	745.67	12650.97	177.01	182.98	42.36	292.90	44.28
LML081	533.61	9560.78	141.83	172.71	30.06	227.64	34.20
LML082	447.94	9576.09	151.18	160.44	37.19	247.38	39.38
LML083	685.54	8171.59	537.62	3.85	77.61	132.01	204.86
LML084	518.39	12224.33	174.48	191.08	25.94	252.55	35.45
LML085	933.17	6186.17	516.36	2.39	65.40	106.85	178.61
LML086	704.72	8697.02	482.05	1.81	71.98	125.93	202.23
LML087	737.69	12039.61	162.53	174.39	32.57	247.86	37.47
LML088	460.70	11545.19	152.63	171.32	34.19	271.24	38.20
LML089	523.10	10848.35	148.12	166.94	34.98	266.88	34.41
LML090	999.42	7126.20	565.01	3.65	80.74	117.82	194.38
LML091	558.92	11608.91	147.85	171.93	37.74	250.82	42.01
LML092	653.61	11459.71	162.44	172.48	34.05	270.21	38.21
LML093	686.96	11271.01	157.08	187.54	40.71	282.89	39.38
LML094	543.86	11182.83	162.95	175.94	33.58	262.46	40.54
LML095	536.66	10644.74	162.66	178.86	30.80	266.70	39.48
LML096	711.36	8962.67	218.67	0.00	66.27	179.94	101.37
LML097	646.60	9917.58	159.80	175.38	36.15	263.17	40.91
LML098	814.18	7083.12	460.71	2.21	76.91	120.10	199.61
LML099	550.92	10832.28	157.60	168.78	31.17	255.21	35.91
LML100	652.47	7753.27	194.07	1.25	58.98	174.39	100.76
LML101	694.10	9025.80	157.34	168.28	28.91	242.99	36.75
LML102	1010.19	6756.75	545.99	5.51	74.59	110.31	196.42
LML103	591.95	10170.33	146.34	166.90	34.23	271.64	41.87
LML104	490.22	13243.22	152.01	165.64	34.08	261.49	38.75
LML105	496.12	9783.41	147.13	167.90	35.20	236.64	32.67
LML106	529.65	9518.19	155.10	176.86	35.34	268.24	40.67
LML107	674.94	9869.33	150.22	169.26	32.41	245.31	37.22
LML108	641.96	7211.90	456.26	2.46	69.10	110.36	175.98
LML109	840.61	7328.77	512.89	2.97	88.31	140.79	240.15

ANID	Mn	Fe	Rb	Sr	Y	Zr	Nb
LML111	620.34	9514.17	154.53	180.19	36.55	280.39	39.22
LML112	469.74	9869.60	144.18	171.62	29.44	223.21	35.41
LML113	896.19	5852.45	529.23	1.35	71.88	102.00	184.18
LML114	696.39	9821.08	171.02	168.26	34.84	295.17	50.14
LML115	461.87	9814.44	139.32	172.57	32.70	296.81	36.95
LML116	580.19	10107.43	155.01	174.09	32.15	236.64	40.33
LML117	578.28	9401.37	150.91	164.15	31.61	252.75	35.57
LML118	792.08	9863.26	158.98	168.61	35.17	255.20	36.58
LML119	540.74	13527.06	157.28	176.75	33.22	298.21	41.81
LML120	711.12	7335.40	463.97	1.37	68.46	108.51	189.71
LML121	567.72	9034.21	158.41	172.30	31.36	251.21	34.96
LML122	747.37	6871.67	479.60	2.85	79.36	128.79	209.70
LML123	609.48	9756.03	159.56	165.91	31.07	255.05	39.18
LML124	631.67	8446.08	203.34	0.00	51.38	164.16	79.07
LML125	536.92	8870.64	140.35	155.80	31.78	222.08	31.45
LML126	867.77	5845.67	530.55	1.21	74.24	103.94	179.75
LML127	802.67	7146.82	519.06	2.78	81.18	138.47	239.08
LML128	592.67	9029.95	143.10	158.00	31.90	237.51	34.80
LML129	0.00	21722.55	37.18	568.92	35.77	125.66	36.01
LML130	593.14	11059.59	169.79	190.35	35.20	278.68	43.13
LML131	568.91	9167.02	147.41	182.61	34.87	272.44	39.06
LML132	722.22	6965.83	470.57	2.55	77.34	120.17	210.24
LML133	659.04	7312.47	459.49	1.19	68.59	103.98	178.76
LML134	678.22	9084.54	488.13	2.77	56.32	105.09	172.13
LML135	585.56	10506.43	165.59	190.72	41.91	278.30	42.11
LML136	509.16	10714.27	156.69	183.61	34.29	252.91	40.89
LML137	0.00	36216.55	126.14	487.54	32.74	176.12	19.68
LML138	483.05	10340.33	150.81	164.11	33.62	250.15	35.14
LML139	549.67	10668.11	152.39	176.71	39.53	264.29	40.28
LML140	467.71	6862.28	419.28	0.94	63.88	110.35	174.68
LML141	653.29	9654.19	156.64	166.02	37.13	251.62	37.18
LML142	547.34	9211.88	141.09	159.74	35.24	240.38	35.59
LML143	603.76	10689.66	162.48	186.53	41.71	283.31	39.22
LML144	702.99	10385.63	156.38	173.38	36.31	256.61	39.33
LML145	414.37	9640.72	141.66	161.53	30.37	242.65	34.11
LML146	39.92	940.57	2.55	3.16	0.00	0.00	1.75
LML147	1084.39	5795.40	537.17	3.64	77.55	109.76	179.37
LML148	769.21	10150.00	161.13	169.24	33.50	276.73	39.32
LML149	6524.10	4222.68	11.64	74.57	0.00	2.21	8.77
LML150	562.56	9459.77	144.11	165.48	35.60	233.63	37.25
LML151	282.76	6122.68	413.69	2.54	63.62	96.72	163.72
LML152	608.96	8313.60	218.82	1.30	59.70	187.20	102.31
LML153	449.10	10477.87	159.04	177.28	32.87	229.85	32.32
LML154	593.15	10150.97	147.65	177.39	37.75	250.05	35.26
LML155	587.56	9479.93	139.30	171.14	31.26	227.81	30.69
LML156	654.27	10389.02	166.07	172.82	39.99	280.25	39.48
LML157	978.96	8873.00	531.70	0.94	73.58	114.32	183.98
LML158	733.80	8042.36	204.98	0.00	61.46	187.53	100.83
LML159	500.81	10073.44	167.34	176.13	36.82	267.51	42.32

ANID	Mn	Fe	Rb	Sr	Y	Zr	Nb
LML160	425.90	8714.68	213.84	0.00	56.67	177.52	90.69
LML161	518.65	10649.83	145.37	168.36	33.93	232.78	28.73
LML162	425.72	9244.63	152.68	146.10	28.57	232.91	29.66
LML163	682.98	8735.30	172.03	0.00	37.80	125.99	62.79
LML164	796.48	8389.65	455.35	0.42	57.36	104.53	149.33
LML165	564.93	5079.22	151.06	1.51	15.71	61.08	44.42
LML166	827.32	6021.66	556.55	0.66	70.19	114.22	181.77
LML167	561.59	12190.78	183.72	196.11	32.67	258.08	38.47
LML168	231.64	8289.37	105.41	129.88	14.95	173.46	23.33
LML169	622.71	10413.75	159.25	176.96	34.68	287.65	39.49
LML170	459.03	9416.29	145.14	172.50	27.78	263.06	32.89
LML171	576.40	10291.69	157.56	178.01	35.70	249.07	35.97
LML172	568.40	8993.89	150.84	169.31	37.18	260.13	35.24
LML173	615.54	9835.64	151.20	161.16	35.88	274.65	44.70
LML174	559.33	11130.67	150.19	161.37	29.42	233.80	35.29
LML175	584.66	10506.02	244.32	159.75	32.89	240.47	29.48
LML176	585.10	10217.87	148.37	180.79	33.75	231.43	31.43
LML181	759.42	6542.10	486.73	2.46	93.00	132.64	225.35
LML182	695.12	7128.61	496.67	2.79	72.02	128.49	213.84
LML183	598.19	10783.08	153.64	173.47	36.81	268.20	36.66
LML184	457.42	8989.60	147.29	166.11	35.24	242.90	32.34
LML185	409.47	9451.33	140.24	147.83	23.03	203.07	33.35
LML186	544.08	10030.93	161.20	185.40	37.69	288.54	37.11
LML187	715.36	7206.34	516.61	3.15	84.22	134.45	230.64
LML188	617.99	10548.82	182.33	187.56	38.04	263.72	43.11
LML189	478.77	10589.58	160.74	185.26	31.96	257.35	37.07
LML190	591.99	9539.80	157.72	166.29	32.69	244.82	33.88
LML191	631.86	11467.99	177.94	135.90	38.05	254.11	44.57
LML192	723.30	9830.03	170.43	195.04	40.23	262.52	38.17
LML193	694.77	9848.15	157.18	181.46	32.86	264.17	41.46
LML194	529.49	7976.65	208.52	0.00	58.80	173.67	95.30
LML195	369.76	7293.80	155.26	4.24	42.23	152.24	50.91
LML196	478.43	10847.65	154.20	176.84	34.01	251.88	39.94
LML197	457.55	9990.96	152.38	164.40	25.87	218.77	31.09
LML198	601.09	10341.30	143.71	173.54	35.55	251.78	35.08
LML199	499.51	10956.06	151.75	180.93	33.29	250.67	35.15
LML200	655.71	10722.71	168.40	175.85	32.92	288.95	36.26
LML201	599.63	9505.94	152.09	174.73	35.72	248.21	34.46
LML202	429.50	9233.20	132.17	161.40	33.51	253.70	32.34
LML203	559.32	10727.09	164.80	181.07	32.99	239.39	32.59
LML204	474.43	9159.68	153.73	171.02	32.15	244.99	32.92
LML205	564.00	7363.55	501.36	0.93	71.36	128.24	201.89
LML206	450.72	11649.45	154.47	160.05	30.27	221.89	30.41
LML207	560.78	10220.87	140.24	149.36	22.25	190.94	29.68
LML208	457.36	9365.77	146.48	160.29	29.53	241.75	34.46
LML209	567.54	10160.00	155.12	165.39	34.61	273.56	39.67
LML210	623.02	11218.52	167.75	204.42	31.38	252.56	38.76
LML211	594.08	10346.04	160.01	176.54	28.67	236.31	39.26
LML212	784.44	6334.82	500.71	0.00	68.17	101.56	164.74

ANID	Mn	Fe	Rb	Sr	Y	Zr	Nb
LML213	451.80	9695.36	150.66	171.89	32.05	240.73	40.05
LML214	714.04	7481.25	509.34	2.24	86.75	141.83	229.66
LML215	483.14	10226.70	150.06	163.31	26.38	221.46	34.68
LML216	515.93	10207.92	156.71	170.26	38.76	242.50	38.99
LML217	601.15	9905.90	154.84	181.48	34.27	257.25	35.77
LML218	789.24	5557.41	541.09	0.21	70.38	107.87	188.36
LML219	190.87	2093.23	0.00	0.00	0.36	0.00	0.81
LML220	631.93	11116.72	149.15	164.02	32.08	233.52	34.64
LML221	421.49	9743.19	135.91	152.93	27.88	213.34	30.26
LML222	469.30	9379.99	148.75	183.94	35.34	252.00	39.22
LML223	646.32	9723.48	158.41	164.32	38.09	252.97	35.05
LML224	688.16	7192.00	507.41	2.44	84.18	129.09	219.32
LML225	653.78	7259.64	485.32	3.48	75.70	119.94	191.95
LML226	682.72	7363.16	505.11	5.77	94.85	130.00	218.57
LML227	528.29	8600.60	134.78	148.07	27.84	218.46	30.80
LML228	665.79	9402.36	535.15	3.45	87.52	129.74	207.67
LML229	879.49	7190.04	517.81	2.86	83.06	135.11	232.99
LML230	849.51	7833.21	510.95	2.42	89.24	138.80	221.36
LML231	581.84	9906.59	161.09	174.17	36.58	268.64	37.60
LML232	547.95	11228.10	155.50	173.34	32.78	248.49	38.22
LML233	666.24	7158.91	512.10	1.39	81.33	121.30	204.19
LML234	820.38	7709.90	516.34	3.71	87.86	144.73	238.02
LML235	880.37	10908.71	542.33	3.85	83.16	137.76	211.32
LML236	415.67	4462.57	152.75	2.03	13.44	55.87	41.07
LML237	681.98	6984.34	490.09	3.06	79.63	132.73	221.61
LML238	671.87	6648.09	477.65	1.29	75.08	134.15	222.24
LML239	884.48	8270.80	536.81	1.00	85.26	146.14	222.93
LML240	497.75	8314.36	198.70	0.00	54.54	167.51	90.44
LML241	703.86	8133.72	205.94	0.00	57.69	171.57	96.14
LML242	652.49	10422.13	171.23	153.00	37.74	257.02	45.68
LML243	543.77	7127.93	271.22	7.34	56.48	121.02	34.61
LML244	803.87	7977.73	499.73	1.23	69.66	120.74	199.56
LML245	596.59	6206.87	117.92	28.33	17.48	101.87	53.06
LML246	394.94	5932.52	112.53	61.90	19.11	120.69	41.51
LML247	626.63	11312.61	162.10	185.28	37.09	271.45	39.63
LML248	669.78	9559.46	159.86	174.94	27.44	271.77	37.54
LML253	631.18	9414.71	187.60	135.43	42.57	294.79	43.16
LML254	760.84	8146.09	501.28	2.07	82.00	127.61	213.36
LML255	658.67	7154.37	489.02	0.00	76.40	128.19	210.65
LML256	698.15	7268.37	483.20	1.89	73.67	121.83	203.35
LML257	707.18	7238.50	457.14	1.09	69.68	113.59	181.79
LML258	667.64	7078.74	515.28	0.50	82.97	131.69	218.10
LML259	682.92	8380.66	490.74	3.09	83.12	130.46	213.34
LML260	497.31	9199.69	177.13	120.82	31.89	235.99	39.99
LML261	629.48	6510.22	453.03	0.50	69.12	116.82	194.21
LML262	595.02	7674.75	519.07	2.81	92.52	139.62	231.92
LML263	709.76	8720.78	453.77	2.99	48.19	90.08	144.54
LML270	419.52	7232.96	251.64	12.74	37.80	120.94	22.96
LML271	462.32	10969.44	143.97	154.07	27.80	228.39	30.20

ANID	Mn	Fe	Rb	Sr	Y	Zr	Nb
LML272	584.00	11244.58	162.61	187.66	32.96	256.77	39.09
LML273	507.87	9884.87	154.25	174.39	30.95	232.33	36.90
LML274	821.97	5899.90	538.39	1.17	66.22	99.68	172.62
LML275	487.56	10694.94	148.49	163.59	31.33	240.57	32.02
LML276	553.07	10500.04	153.66	172.81	31.99	251.46	40.18
LML277	661.73	7738.51	467.59	1.98	80.24	122.95	197.64
LML278	651.53	10042.75	150.26	166.38	26.59	237.32	35.34
LML279	732.83	7104.89	487.34	2.62	81.49	123.08	188.21
LML280	573.91	10061.84	151.18	158.21	27.81	237.09	33.64
LML281	698.74	10959.16	170.57	181.48	37.33	258.20	41.91
LML282	604.11	10906.67	183.40	156.45	32.58	274.97	43.76
LML283	543.52	5804.60	392.97	0.91	54.52	104.13	166.27
LML284	421.36	10435.19	151.36	169.83	34.19	257.52	34.15
LML285	563.85	7815.64	503.30	1.81	82.16	139.62	191.85
LML286	977.39	6130.51	537.42	2.24	74.85	115.18	185.91
LML287	456.18	7644.87	157.55	2.67	40.55	154.32	48.92
LML288	474.13	10708.26	156.57	169.61	35.44	253.92	37.19
LML289	821.95	7302.07	506.48	1.51	93.87	143.84	221.86
LML290	900.49	6279.22	522.90	0.59	60.26	98.69	165.21
LML291	753.58	6967.58	497.58	1.56	84.35	133.77	220.37
LML292	990.72	7119.71	582.14	2.67	76.58	120.42	192.38
LML293	454.12	11001.17	161.95	180.85	32.32	245.10	37.77
LML294	875.18	5981.15	514.61	4.72	76.84	114.97	190.52
LML295	402.67	8662.35	137.73	148.60	29.86	226.03	35.22
LML296	440.15	9924.61	152.72	165.71	37.89	230.70	37.59
LML297	749.87	7768.01	437.41	1.11	55.00	100.62	162.72
LML298	727.39	6236.95	535.54	2.97	73.63	117.63	195.96
LML299	565.20	11608.88	165.34	174.83	39.58	260.93	42.14
LML300	909.39	6683.63	534.38	0.41	65.58	97.42	159.87
LML301	355.32	9487.87	156.65	166.02	34.76	267.95	37.33
LML302	605.14	10585.47	176.95	184.78	37.58	260.54	40.18
LML303	443.60	8058.01	171.16	3.47	37.66	160.43	54.76
LML304	752.46	7210.56	501.50	2.57	85.78	140.92	234.24
LML305	617.11	9851.24	157.97	185.10	31.07	269.09	39.03
LML306	558.00	10037.97	157.26	168.64	32.04	250.48	35.16
LML307	950.67	6056.52	523.11	4.28	73.10	106.48	178.60
LML308	479.14	11320.68	144.28	165.43	29.45	224.80	33.01
LML309	968.49	6293.90	525.17	2.01	62.97	104.65	179.26
LML310	909.47	5655.34	497.36	0.00	52.97	100.64	176.25
LML311	831.21	5590.33	443.77	0.76	46.46	81.79	129.87
LML312	775.01	7040.42	477.66	1.99	80.50	132.88	232.98
LML317	526.44	9574.36	141.02	165.04	30.98	247.87	32.27
LML318	980.68	6293.40	554.12	3.26	85.73	122.69	193.77
LML319	1526.89	2064.64	9.31	18.48	0.00	0.00	9.51
LML320	456.96	9735.10	154.70	169.23	32.28	252.61	35.39
LML321	717.12	7064.50	453.43	2.06	76.37	120.00	196.54
LML322	607.80	6813.27	497.02	2.79	87.51	135.46	227.90
LML323	456.57	8794.74	138.36	152.70	27.68	246.60	31.01
LML324	431.43	8937.55	139.37	161.00	30.12	253.69	36.02

ANID	Mn	Fe	Rb	Sr	Y	Zr	Nb
LML325	631.22	7110.72	473.95	1.45	84.91	126.64	210.22
LML326	686.85	7146.85	507.34	1.14	79.11	124.96	204.84
LML327	755.34	8636.18	513.07	3.43	79.05	135.93	212.34
LML328	696.97	7710.41	204.17	0.00	58.35	177.26	92.95
LML329	4605.71	3246.67	10.05	38.74	0.00	0.00	11.66
LML330	828.41	7049.02	516.78	2.80	84.15	139.59	225.57
LML331	116.78	1344.62	1.41	3.33	0.00	0.00	1.61
LML332	697.70	7331.40	487.80	1.36	77.69	123.01	211.53
LML333	575.04	10975.98	170.08	182.38	33.05	249.95	39.19
LML334	516.84	7091.90	446.23	0.89	62.41	112.63	181.15
LML335	1047.24	5812.82	475.98	1.61	65.22	98.06	169.81
LML336	645.34	6279.63	394.04	0.32	63.84	101.11	165.46
LML337	839.87	7753.81	536.69	1.10	90.79	140.98	225.23
LML338	538.52	9631.94	143.65	160.72	28.11	229.35	31.74
LML339	1014.46	6492.00	543.92	0.83	59.53	100.83	159.15
LML340	273.16	7329.10	132.38	0.24	32.94	135.33	39.67
LML341	989.31	6161.40	530.98	0.94	64.89	97.73	167.98
LML342	627.85	7078.81	422.99	3.05	65.12	100.59	162.22
LML343	315.28	8949.11	135.10	144.33	28.53	210.51	30.24
LML344	646.63	7849.36	526.16	1.30	83.90	138.41	231.63
LML345	657.31	10922.68	166.99	172.98	32.72	249.04	37.42
LML346	641.76	7538.73	506.02	2.85	78.84	136.55	224.72
LML347	735.71	8927.26	225.62	0.00	57.56	184.80	97.88
LML348	577.55	7138.95	195.47	0.00	52.04	174.15	99.75
LML349	1064.20	9526.53	478.93	2.54	62.29	112.15	150.32
LML350	652.38	6784.96	409.19	0.00	63.15	97.59	164.94
LML351	530.00	9803.06	128.91	96.43	25.85	155.29	27.59
LML352	468.19	6475.40	433.70	0.00	59.61	104.25	166.89
LML353	472.83	11378.65	127.17	123.25	16.71	168.72	23.09
LML354	817.77	8837.67	443.94	1.06	56.20	97.71	139.13
LML355	899.44	8347.73	371.37	0.00	49.94	77.82	127.22
LML356	386.40	9853.53	142.17	159.65	24.77	211.97	28.79
LML357	600.84	7884.40	431.74	1.91	64.30	96.13	144.66
LML358	403.59	7857.61	190.07	0.00	46.77	144.47	76.07
LML359	399.74	7695.68	167.17	0.00	46.06	125.25	65.10
LML360	1007.66	7038.30	566.12	0.00	63.21	97.21	168.07
LML361	555.49	7544.90	402.32	1.14	46.30	89.47	137.03
LML362	793.83	8850.45	410.07	1.25	53.83	88.39	142.19
LML363	341.44	10532.69	119.72	145.35	19.95	170.25	24.60
LML364	756.14	7797.90	455.24	1.63	60.22	110.07	158.87
LML365	948.59	6932.18	444.48	0.00	38.81	80.07	111.97
LML366	1113.60	9612.93	487.18	0.98	46.19	97.35	149.69
LML367	581.39	7510.87	381.64	0.79	44.41	83.31	136.50
LML368	635.12	7089.22	456.19	0.00	61.95	97.25	164.27
LML369	763.22	9662.51	431.88	0.73	41.83	92.48	148.77
LML370	564.33	8652.66	171.32	0.00	39.05	126.77	58.60
LML371	1216.87	9583.86	422.02	3.21	47.57	105.58	138.42
LML372	987.16	10883.64	467.39	2.45	55.06	101.13	163.57
LML373	809.10	7243.02	402.58	1.13	52.77	91.81	142.20

ANID	Mn	Fe	Rb	Sr	Y	Zr	Nb
LML374	784.79	7667.47	441.41	0.49	54.62	92.49	153.52
LML375	862.19	9214.85	443.30	3.08	62.35	102.88	165.06
LML376	914.01	6206.23	397.41	2.07	43.48	68.58	121.38
LML377	701.27	8081.86	411.74	2.01	46.78	85.31	130.92
LML378	1538.99	12948.75	510.02	6.94	73.72	112.67	162.59
LML379	761.27	8198.20	426.38	0.00	49.56	94.29	137.45
LML380	642.83	7639.12	438.40	0.76	64.51	103.76	178.17
LML381	937.54	9153.27	426.59	3.72	54.70	97.30	152.68
LML382	661.54	8618.49	439.54	1.45	50.63	97.30	161.36
LML383	774.64	8867.20	423.90	0.49	42.39	97.61	146.75
LML384	548.19	6870.47	412.36	1.68	57.49	93.69	151.03
LML385	1107.55	9120.99	450.00	3.25	50.76	81.47	150.10
LML386	638.50	10729.42	131.64	144.53	22.37	173.57	28.69
LML387	604.47	6855.69	422.01	0.07	56.42	97.09	150.50
LML388	1388.58	8265.12	423.56	4.32	39.84	72.86	106.99
LML389	487.99	6840.49	392.77	0.00	52.96	80.65	132.51
LML390	1274.21	10079.55	459.17	5.15	47.34	105.10	134.27
LML391	382.56	6588.28	351.80	0.00	47.38	87.08	126.13
LML392	744.32	8227.96	396.18	0.00	54.87	91.34	139.55
LML393	508.57	7291.83	414.94	0.00	50.56	87.82	143.87
LML394	836.99	6117.01	425.37	0.30	39.61	76.55	111.21
LML395	789.18	5961.43	475.92	0.14	64.91	98.13	161.50
LML396	719.60	8333.79	483.48	1.21	71.09	108.99	171.55
LML397	601.30	6518.93	455.06	2.51	63.70	121.44	186.71
LML398	491.03	7866.08	195.49	0.00	56.59	165.49	85.53
LML399	318.69	10087.58	136.78	158.50	28.13	224.33	30.68
LML400	582.82	7566.81	476.27	0.27	61.96	119.18	175.18
LML401	754.67	5629.28	471.29	1.87	51.44	81.37	149.18
LML402	615.22	6788.61	432.16	1.65	63.77	116.23	188.14
LML403	556.62	6813.82	420.93	0.83	56.63	102.41	174.39
LML404	713.26	8284.04	455.52	2.40	57.55	98.14	161.83
LML405	1221.10	11214.37	495.56	6.28	66.71	107.67	161.69
LML406	787.72	6461.89	467.05	0.45	47.30	73.85	123.67
LML407	1021.41	9735.64	466.38	2.50	61.30	91.29	153.16
LML408	758.88	7504.89	515.47	2.50	94.53	139.63	230.62
LML409	1162.74	6771.82	561.93	2.55	78.16	110.52	190.20
LML410	691.44	7347.03	527.01	0.11	102.38	149.13	239.14
LML411	836.32	8329.10	446.24	2.05	63.48	98.27	153.17
LML412	617.34	7192.69	418.48	1.91	62.02	93.09	164.97
LML413	545.83	7540.95	399.41	1.61	50.69	91.72	159.50
LML414	618.76	6782.22	385.85	0.06	57.46	87.90	134.67
LML415	612.89	7748.93	441.48	0.01	62.26	103.56	159.88
LML416	726.32	8805.16	410.71	1.19	49.91	90.44	137.99
LML417	729.93	8541.47	446.56	1.35	53.41	113.67	179.18
LML418	916.32	9389.70	467.00	1.06	60.06	101.30	145.39
LML419	335.14	10475.00	114.96	136.50	23.10	254.53	23.26
LML420	1045.74	12232.27	458.12	4.69	40.49	92.89	136.46
LML421	744.08	6016.28	404.57	2.76	44.32	68.82	117.26
LML422	815.95	8499.66	454.58	1.95	53.34	100.82	155.35

ANID	Mn	Fe	Rb	Sr	Y	Zr	Nb
LML423	887.22	6643.60	457.29	3.06	48.61	80.82	121.69
LML424	878.82	9068.97	455.86	0.25	54.68	96.79	145.59
LML425	338.81	7603.04	168.16	0.00	36.00	116.83	63.52
LML426	962.98	6230.69	488.27	0.85	58.99	91.63	163.81
LML427	904.93	9953.34	440.47	0.97	55.29	94.86	141.21
LML428	653.55	11852.47	127.79	143.70	23.04	208.56	24.76
LML429	503.01	5946.38	352.36	0.00	51.12	84.62	139.83
LML430	855.34	5911.56	439.29	1.23	46.96	73.60	131.50
LML431	596.36	9199.42	435.15	2.81	48.43	111.18	161.13
LML432	923.57	8927.37	466.43	1.82	55.85	99.60	155.28
LML433	250.02	7532.74	150.71	0.00	40.10	122.96	63.90
LML434	1225.90	7905.31	508.81	1.96	41.82	78.69	134.67
LML435	1773.11	13926.45	537.10	10.59	87.06	134.90	194.25
LML436	1175.24	10443.73	427.76	1.34	51.37	94.76	142.84
LML437	880.61	16117.56	147.89	132.25	22.79	167.95	22.63
LML438	501.19	7563.83	436.03	1.25	59.49	85.36	131.39
LML439	472.08	8643.21	155.14	0.00	32.40	108.28	51.75
LML440	474.42	7800.29	421.87	2.06	61.22	93.12	160.68
LML441	631.41	6578.76	382.66	0.94	48.16	87.90	137.03
LML442	559.79	7471.07	501.75	4.02	74.58	130.58	205.34
LML443	1131.30	9151.78	446.16	1.97	60.60	99.02	144.45
LML444	763.86	10084.59	422.36	0.00	62.34	92.70	143.79
LML445	975.38	9376.66	444.19	0.00	55.15	99.19	157.98
LML446	713.46	9996.17	440.25	4.38	47.28	94.92	140.38
LML447	664.30	7981.90	371.34	1.54	36.74	77.73	119.89
LML448	271.61	9481.76	100.55	145.73	22.47	179.45	24.28
LML449	756.92	8269.25	349.30	0.53	33.40	67.76	117.84
LML450	954.88	6144.65	455.61	0.67	54.00	71.47	132.64
LML451	622.68	7037.53	396.50	1.82	60.80	95.40	146.33
LML452	801.86	6014.07	455.15	0.00	48.50	74.90	128.61
LML453	760.78	7433.18	520.36	3.92	93.56	141.18	234.09
LML454	896.33	6306.04	567.92	4.45	91.40	128.48	205.91
LML455	530.30	10655.11	165.62	180.92	38.11	260.50	38.54
LML456	719.36	7332.22	514.53	2.74	90.05	142.78	228.55
LML457	593.33	8480.39	206.20	0.49	53.81	185.86	98.70
LML458	791.71	8182.91	532.74	1.61	79.23	126.41	210.83
LML459	646.61	8474.66	452.33	1.15	56.18	96.87	145.39
LML460	895.07	6304.32	518.17	1.52	63.01	97.22	172.12
LML461	435.09	6926.66	399.20	1.94	49.88	102.23	149.59
LML462	660.84	8502.81	421.85	0.67	47.11	97.17	140.74
LML463	862.52	9436.67	454.40	0.00	53.57	102.19	134.51
LML464	480.42	7052.86	417.35	1.00	57.94	96.51	154.42
LML465	709.14	8404.63	459.09	1.35	52.66	103.54	144.94
LML466	1019.62	9136.91	452.72	0.80	60.58	106.78	151.47
LML467	443.85	9032.70	190.07	0.00	47.64	132.42	71.13
LML468	650.87	9554.40	457.73	0.48	54.97	94.94	153.33
LML469	513.55	6456.24	378.58	1.65	48.41	85.18	147.43
LML470	756.94	8332.67	423.93	1.17	56.98	91.75	147.27
LML500	578.88	7519.95	351.69	0.00	53.24	83.21	135.30

ANID	Mn	Fe	Rb	Sr	Y	Zr	Nb
LML501	250.93	8807.55	120.77	0.00	24.16	97.00	26.26
LML502	329.16	7070.07	177.69	4.87	21.86	78.32	16.13
LML503	678.03	7671.66	494.13	0.82	76.00	117.31	188.97
LML504	724.32	7312.65	491.44	0.32	84.68	129.97	223.53
LML505	673.97	8045.25	513.40	2.63	70.58	119.73	193.07
LML506	483.25	7266.95	402.38	1.56	47.85	94.63	150.94
LML507	505.23	8355.22	394.17	0.00	56.53	83.81	143.82
LML508	619.12	6076.48	396.10	2.23	56.01	104.52	165.35
LML509	765.14	8575.84	454.84	2.77	64.21	104.20	158.98
LML510	564.81	7395.25	451.45	2.80	63.46	106.95	178.27
LML511	911.02	8171.20	522.62	1.84	80.28	113.22	188.53
LML512	587.95	7863.51	516.19	1.63	81.52	143.82	232.37
LML513	792.50	7116.31	495.17	1.83	77.65	131.42	205.79
LML514	495.42	9038.43	132.13	142.53	24.57	186.16	25.88
LML515	514.09	9410.64	164.72	175.21	30.60	269.51	41.79
LML516	368.13	9121.47	199.73	9.73	19.88	84.95	12.75
LML517	825.86	8280.94	379.95	1.33	54.87	88.06	138.59
LML518	1017.48	8197.73	414.80	2.20	47.37	94.84	142.30
LML519	1108.27	11790.60	435.80	0.00	61.34	104.58	135.43
LML520	476.18	9287.49	188.01	9.69	15.22	94.35	12.20
LML521	571.48	7337.19	394.97	0.69	55.02	94.44	146.46
LML522	732.27	9994.00	206.33	9.62	25.46	84.04	11.13
LML523	695.40	11894.17	158.60	0.53	32.12	132.72	39.35
LML524	736.64	10273.09	421.44	0.03	50.47	94.61	132.27
LML525	1176.36	9705.30	410.21	1.80	44.61	96.20	136.39
LML526	863.66	7871.28	399.53	2.86	43.73	89.93	147.39
LML527	416.90	7003.69	145.90	0.00	34.26	136.19	44.87
LML528	455.73	9973.23	210.88	7.29	14.16	75.22	15.01
LML529	595.94	7987.87	86.93	58.57	10.74	50.21	34.33
LML530	482.91	6515.65	382.87	1.87	52.98	97.23	145.31
LML531	417.10	7372.03	227.10	9.49	30.21	111.18	18.71
LML532	778.20	8840.84	452.69	2.49	59.88	94.29	155.22
LML533	732.54	8116.84	413.88	3.67	59.19	93.01	152.28
LML534	567.64	8527.92	397.45	3.27	45.54	92.01	127.63
LML535	764.47	8036.78	349.79	0.81	49.16	90.35	118.17
LML536	745.99	8080.72	431.64	0.00	54.71	95.71	150.72
LML537	906.76	8410.43	393.18	0.00	48.35	90.62	135.94
LML538	955.86	8387.34	402.13	0.00	54.25	91.09	139.54
LML539	995.73	8131.06	403.22	1.64	58.16	82.65	137.48
LML540	921.08	6279.44	558.84	2.10	81.34	119.98	197.92
LML541	790.54	8729.97	474.32	2.06	61.26	107.96	185.45
LML543	699.57	6931.09	495.15	1.09	85.67	132.70	210.31
LML544	417.46	8637.82	140.28	165.71	26.57	232.15	35.30
LML545	254.51	1037.25	0.00	23.60	1.42	0.00	0.68
LML546	814.83	7708.64	195.83	0.00	61.91	174.70	95.71
LML547	705.34	9403.22	210.85	0.00	52.96	172.33	82.63
LML548	563.82	5991.49	426.54	1.73	58.28	98.94	171.29
LML549	1089.25	9668.36	459.66	1.74	56.64	118.96	165.17
LML550	813.69	8556.47	391.55	0.00	63.83	97.33	141.95

ANID	Mn	Fe	Rb	Sr	Y	Zr	Nb
LML551	787.39	7210.15	532.65	3.14	82.71	138.95	235.97
LML552	666.77	7265.76	471.07	1.54	69.19	119.17	194.48
LML553	731.39	6944.11	484.02	3.29	72.59	123.52	207.07
LML554	884.97	9173.41	459.30	4.30	52.36	99.57	161.29
LML557	552.07	7504.04	190.75	0.00	57.94	177.51	87.49
LML558	513.19	7913.66	197.35	0.00	59.37	176.14	96.52
LML559	480.65	5913.89	408.41	2.22	61.21	111.69	166.25
LML560	760.02	5359.37	422.52	1.47	37.63	75.82	124.34
LML561	340.57	8163.42	134.95	0.12	31.08	124.26	33.75
LML562	839.72	7984.60	436.49	1.04	55.94	98.12	156.81
LML563	1004.98	8817.34	424.15	1.16	50.01	88.36	134.70
LML564	699.90	11210.57	121.66	138.24	19.27	201.76	21.14
LML565	648.46	9524.19	156.28	0.00	33.84	112.57	55.76
LML566	1148.19	7497.25	446.69	1.65	48.86	75.71	130.48
LML567	616.95	8830.76	173.17	0.00	37.96	148.39	63.45
LML568	1106.78	9558.34	428.69	2.95	39.07	99.32	144.39
LML569	498.19	6495.38	348.97	0.26	49.65	79.41	129.18
LML570	1251.58	11246.20	467.82	1.37	62.54	114.17	150.40
LML571	983.32	8576.76	451.68	0.00	49.39	94.60	155.41
LML572	908.47	11068.11	184.74	0.00	46.90	120.95	63.35
LML573	672.30	11123.47	141.52	140.12	20.52	185.05	28.14
LML574	874.73	8172.39	408.75	1.21	56.21	93.28	127.47
LML575	477.10	5617.26	335.68	0.00	45.08	83.25	128.16
LML576	585.44	8750.30	147.56	0.00	43.40	108.64	54.72
LML577	693.60	5232.65	320.92	1.95	61.54	84.23	148.48
LML578	800.80	8859.43	428.43	0.48	52.96	93.57	141.52
LML580	580.24	8798.34	189.29	0.00	55.72	168.55	96.89
LML581	525.66	6720.03	479.47	0.75	83.76	126.33	201.64
LML582	108.30	41702.18	27.72	82.61	16.74	121.47	7.36