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Research Advisor: Christian M. Schrader, The Colorado College

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GEOCHEMICAL VARIABILITY OF OBSIDIAN IN WESTERN NEW MEXICO WITH LABORATORY-BASED PXRF

KAREN ROTH,Washington and Lee University
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OBSIDIAN ARTIFACT PROVENANCE STUDY OF THE PIEDRAS MARCADAS PUEBLO, ALBUQUERQUE, NEW MEXICO

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Research Advisor: Christian M. Schrader, The Colorado College

INTRODUCTION

The Piedras Marcadas (PM) Pueblo, located in the Open Space Visitor's Center in Albuquerque, New Mexico, and adjacent to the Rio Grande river, contains a collection of obsidian flakes of unknown origins. The site is surrounded by several major volcanic fields, including Mount Taylor ~70 km to the west and the Valles Caldera ~145 km to the north of the site, containing obsidian-bearing rhyolitic units of Tertiary to Quaternary age (Sternberg et al., this volume). Previous studies have focused on characterizing the geochemical signatures of individual obsidian sources in New Mexico and sourcing artifact specimens to their original geologic source through trace element comparison. Research has examined large-scale socioeconomic interactions between Southwest pueblos and neighboring communities through artifact provenance (Baugh and Nelson, 1987), but little is known about the procurement patterns and trade relationships between Tigueux pueblos on a local scale (Schmader, personal comm. 2013).

Since 1983, studies using trace element data have identified a number of major obsidian quarries in western New Mexico (Nelson, 1984; Newman and Nielson, 1985; Baugh and Nelson, 1987, Stevenson and McCurry, 1990, Glascock et al., 1999). The most common obsidian in the archaeological record comes from the Jemez Mountains (Sternberg et al., this volume; Shackley, 2005). This area includes Cerro Toledo, Valles, El Rechuelos, Paliza Canyon, and Canovas Canyon Rhyolite (Fig. 2). Northeast of the Valles Caldera, the Taos Plateau hosts No Agua Peaks, comprised of two obsidian-bearing domes to the north and west of the volcanic center (Shackley, 2013). Further south, the Mount Taylor Volcanic Field contains two obsidian sources: Grants Ridge and Horace Mesa. Obsidian sources from southwestern New Mexico are not considered in this study because of their greater distances from the PM site.

Secondary sources play a major role in obsidian distribution within the Southwest. Studies on Rio Grande alluvium at sites in Las Cruces and Chihuahua, Mexico both show a numerical dominance including, in order of most to least representation, Cerro Toledo, Grants Ridge, El Rechuelos obsidian (Church, 2000). Shackley (personal comm. 2014) reports a similar trend in the Tijeras Wash just north of the PM site but without Grants Ridge. Cerro Toledo obsidian accounts for the majority of the obsidian load relative to all other sources from New Mexico due to its greater initial size and outcrop abundance.

The Piedras Marcadas, the largest of twelve Tiwa (Tiguex) settlements along the Rio Grande River, was inhabited during the Pueblo IV period from its initial settlement ~ 1300 A.D. to the invasion of the Spanish Entrada under General Coronado in 1540 C.E. (Schmader, personal comm., 2013). The few ceramic studies done on PM artifacts indicate limited contact between western pueblos and very little interaction with the Jemez Pueblo (Schmader, personal comm. 2014).

Shackley (2009) collected X-ray fluorescence (XRF) trace element data on surface obsidian samples from the PM site to explore the utility of obsidian analysis for supporting broader archaeological implications. A bivariate plot using Y vs. Nb found that the majority of obsidian came from the Cerro Toledo rhyolite and one artifact each from El Rechuelos, Valles rhyolite, and Mount Taylor. Shackley (2005) emphasizes the potential importance of the Mount Taylor artifact, as it could indicate primary source procurement and/or interaction with the Zuni Pueblo who controlled the Mount Taylor region.

My study provides trace element data for all 65 subsurface flake samples from three test pits of the PM site and uses XRF data from the collected source samples, supplemented with source data for the Keres Group and No Agua Peaks (Shackley, 2013). Geochemical characterization of sources and artifacts is achieved using the SPSS program for statistical analysis. This study determines which obsidian sources are present at the Piedras Marcadas pueblo, evidence supporting different methods of procurement, and insight into their relationships with surrounding pueblos.

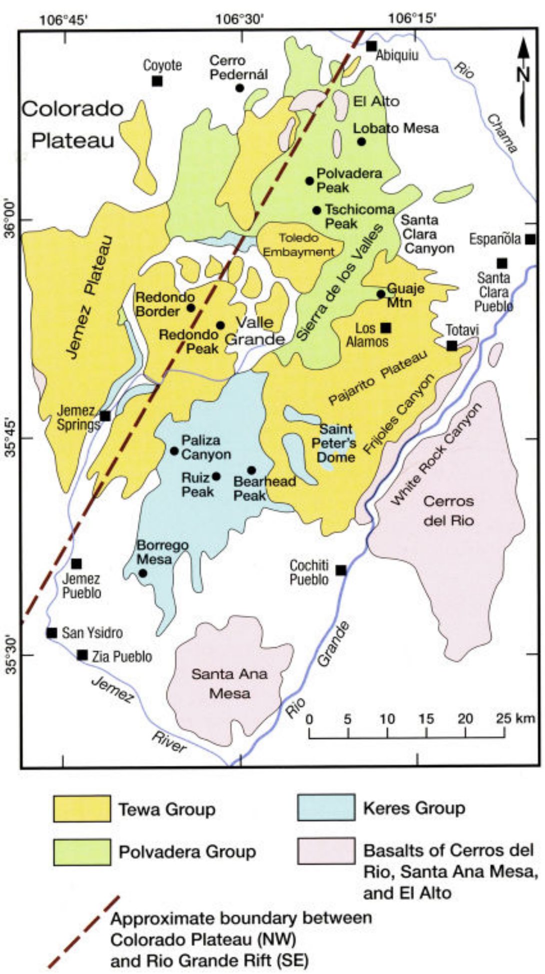

Figure 1. Map of Middle Tertiary to Quaternary age rhyolitic units of the Jemez Mountain region; at the intersection of the Rio Grande rift and the southeastern margin of the Colorado Plateau from Goff, 2009.

SOURCE DESCRIPTIONS

The major obsidian sources of New Mexico lie within a region encompassing the southeastern margin of the Colorado Plateau, the Rio Grande rift, and the northeast-trending volcanic chain of the Jemez lineament. By 36 Ma, regional plate extension marked the initial formation stages of the Rio Grande rift and prompted volcanism in southern New Mexico, producing the oldest, Tertiary-age obsidian sources of the Mongollon Datil Province (Goff, 2009). Post 21 Ma, rhyolitic eruptions migrated and intensified northwards into northern New Mexico, which produced the relatively younger obsidian sources of the Keres, Polvadera, and Tewa Groups (Goff, 2009).

THE JEMEZ MOUNTAINS AND TAOS PLATEAU

From 13 to 6 Ma, a series of high silica rhyolite (HSR) eruptions paired with simultaneous olivine tholeitic basalts deposited the Keres Group members: Canovas Canyon and Paliza Canyon rhyolite. The Canovas Canyon rhyolite is a rhyolitic dome located within the Bear Springs Peak complex in the Santa Fe National Forest (Smith et al., 1970). This source contains small obsidian marekanites (<2 cm) eroding from devitrified perlite (Shackley, 2005). The dark black nodules are of excellent artifact quality (Shackley, 2005). Secondary deposits of Canovas Canyon obsidian are transported as far as south of Las Cruces (Church, 2000). It is a minor source in the Rio Grande alluvium (Shackley, 2005).

Paliza Canyon obsidian was collected near Redondo Peak (Nelson, 1984; Baugh and Nelson, 1987) and northwest of Bearsprings Peak but the source location remains unknown (Shackley, 2013). Obsidian occurs as small (1-4 mm) HSR "apache tears" in low abundance within the Peralta tuff unit (Nelson, 1984; Baugh and Nelson, 1987; Shackley, 2013). Evidence of Paliza Canyon obsidian among secondary deposits from the Tijeras Wash in Albuquerque and Rio Grande alluvium gravels in Las Cruces shows that this source erodes into major river systems over great distances (>150 km) (Church, 2000; Shackley, personal comm. 2013).

Intermediate to rhyolitic eruptions (2 Ma) deposited the small domes of the Polvadera Peak Group including El Rechuelos rhyolite (Glascock et al., 1999). El Rechuelos obsidian source is found within the southern-most dome of three rhyolitic domes west of Polvadera Peak. The southern dome contains an abundance of loose obsidian nodules and debitage (flakes). Average nodules measure between 1-5 cm and are granular and aphyric (Shackley, 2013). Consequently, El Rechuelos offers the best artifact quality obsidian from the Jemez Mountains (Shackley, 2013). This source erodes into the Rio Chama river, which feeds into the Rio Grande river. El Rechuelos is the third most common obsidian found in alluvium gravel from the Rio Grande (Church, 2000, Shackley, 2009).

Two sequential caldera eruptions produced two large sources of obsidian found in the Valles Caldera region. Four domes along Toledo Embayment and Rabbit Mountain of the Cerro Toledo rhyolite emerged following the first caldera eruption (1.45 Ma). A hot ashy landslide off of Rabbit Mountain created Obsidian Ridge to the north (Nelson, 1984; Glascock et al., 1999). Obsidian nodules measure up to 6 cm. The abundance of obsidian at these two localities accounts for its dominance in the Rio Grande alluvium and the Tijeras wash (Shackley, 2005; Shackley, personal comm. 2014).

Flows along the Cerro del Medio dome, located on the eastern-most dome within the Valles Caldera, produced the Valles rhyolite following the second major caldera eruption (1.12 Ma) (Fig. 1). Large obsidian nodules erode from the rim of the dome. Some contain spherulites. Valles rhyolite obsidian does not occur in secondary alluvium in other parts of New Mexico because it erodes within the caldera.

MOUNT TAYLOR

Development of the bimodal volcanic system of the Mount Taylor Volcanic Field produced the rhyolitic eruptions associated with two obsidian sources: Grants Ridge and Horace Mesa. Horace Mesa obsidian formed from an earlier pyroclastic eruption, whereas Grants Ridge rhyolite formed during a later satellite event (3.34 Ma) (Lipman and Mehnert, 1979). Horace Mesa and La Jara Mesa represent the same flow, producing obsidian occurs as float nodules (3-4 cm) among Quaternary-age basalt alluvium on two mesas (Shackley 1998). Grants Ridge obsidian is found as large nodules (5- 15 cm in diameter) embedded in eroding perlitic layers on and around the ridges of East Grants Ridge (Shackley, 2005). Horace Mesa obsidian exhibits higher Zr, Y, Nb, Ce values and is aphyric, opaque to the thinnest flake, and extremely vitreous, relative to the granular, opaque, and phenocryst-rich obsidian of Grants Ridge. Despite its inferior size and lesser abundance, Horace Mesa obsidian was a preferred material because of its ideal aphyric quality for tool production (Shackley, 1998). Mount Taylor erodes into the Rio Puerco river and occurs in Rio Grande alluvium found south of Socorro (Shackley, 1998).

FIELD METHODOLOGY

Matt Schmader collected 65 artifacts samples from three excavated test pits at the PM site in 2012. Schmader bagged and grouped the samples per every 10 cm increment or less (5 cm) at depth from the datum level of 20 cm above the surface. All artifact samples are measured in this study.

A Keck group of nine students and three professors collected over two thousand obsidian nodules samples from multiple sources in three volcanic provinces: (1) Mule Creek, Antelope Creek, and Danny Welch obsidian of the Mogollon Datil Province, (2) Grants Ridge, Horace Mesa, and La Jara Mesa obsidian of the Mount Taylor Volcanic Field, and (3) Cerro Toledo (Obsidian Ridge and Rabbit Mountain) and Valles rhyolite (Qvdm4 and Qvdmw flows at Cerro del Medio) of the Valles Caldera from June 12- July 10, 2013. Fieldwork involved collecting obsidian nodules embedded in perlitic outcrops and from the "wash" of the eroding slopes of perlite fragments and georeferencing each collection bag with GPS data points for latitude, longitude, and elevation. My study measures 47 samples from the combined amount of 1103 samples from Mount Taylor Volcanic Field and more than 953 samples from the Valles Caldera for artifact comparison, supplemented with 71 archived data points from the El Rechuelos, No Agua Peaks, Paliza Canyon, and Canovas Canyon sites (Shackley, 2013). This report on obsidian provenance of PM artifacts discusses geochemical correlations between source and artifact samples and provides insight into the geological and archaeological implications of the findings.

GEOCHEMISTRY

Mid-Z trace elemental concentrations were collected using the Thermo Scientific *Quant'X* energy dispersive x-ray fluorescence spectrometer (ED XRF) at the Geoarchaeological XRF laboratory in Albuquerque, New Mexico. Source determination for each artifact was accomplished by combining qualitative cluster analysis on the SPSS program. Bivariate plots were constructed with the SPSS Hierarchical Cluster Analysis program to examine how the relationship of two trace elements defines each geologic source, to select the trace elements for the optimal spatial segregation of individual sources, and to plot each artifact into a region defined by only one geologic source. Y, Nb, Rb, Sr, and Zr concentrations (ppm) were the primary variables used for comparison because these trace elements were the most reliable and effective for source differentiation (Tab. 1).

	n	Rb (ppm)	Sr (ppm)	Y (ppm)	Zr (ppm)	Nb (ppm)
Canovas Canyon	24	116	43	21	108	53
std. deviation		*5*	*4*	*2*	*4*	*5*
Paliza Canyon	11	100	85	23	124	33
std. deviation		*5*	*5*	*2*	*7*	*3*
El Rechuelos	16	152	9	23	77	47
std. deviation		*6*	*3*	*1*	*3*	*2*
No Agua Peak (N)	3	131	36	24	74	36
std. deviation		*11*	*2*	*1*	*4*	*3*
No Agua Peak (W)	3	297	9	54	94	90
std. deviation		*3*	*1*	*1*	*1*	*1*
Grants Ridge	7	510	6	78	114	189
std. deviation		*8*	*1*	*2*	*3*	*5*
Horace Mesa	18	473	8	89	139	224
std. deviation		*18*	*3*	*3*	*5*	*7*
Cerro Toledo	12	204	4	63	175	91
std. deviation		*11*	*1*	*3*	*7*	*5*
Cerro del Medio	9	161	9	42	163	50
std. deviation		*11*	*2*	*2*	*4*	*3*

Table 1. Mean trace elemental concentrations for the archaeological specimens. All measurements in parts per million (ppm). El Rechuelos, No Agua Peak (N,W), Paliza Canyon, and Canovas Canyon from data archive (Shackley, 2013).

STATISTICAL ANALYSIS

Three artifact samples share anomalously low Rb, Y, Zr, and Sr values that do not reflect rhyolitic compositions (Fig. 2, Fig. 3). Macroscopic qualities show noticeable impurities that confirm they are not homogenous, vitreous obsidian samples. These samples are not considered for provenance.

Figures 2 show noticeable separation of the Mount Taylor chemical groups. No artifacts reflect trace element characteristics to the Mount Taylor and No Agua Peaks chemical groups, suggesting none come from Mount Taylor sources. Rb versus Zr in Figure 3 diagnoses the outlier artifact in Figure 2 to a group of four artifacts of the Canovas Canyon source. Y versus Sr in Figure 2 achieves separation between most chemical groups and correlates one artifact each with the Paliza Canyon source and the El Rechuelos source. Y, Nb, and Zr values are the best for separating the Cerro del Medio source, which correlates to three artifacts (Figure 4). Since the majority of artifacts draw most similarities to the Cerro Toledo chemical group, the remaining 53 artifacts must come from the Cerro Toledo source. The Minitab statistical program was used to conduct t-tests to verify the source diagnoses for each group of artifacts. Most p-values (>0.05), comparing Y, Sr, Zr, Rb, and Nb mean values, confirm the artifacts are not significantly different from their diagnosed sources.

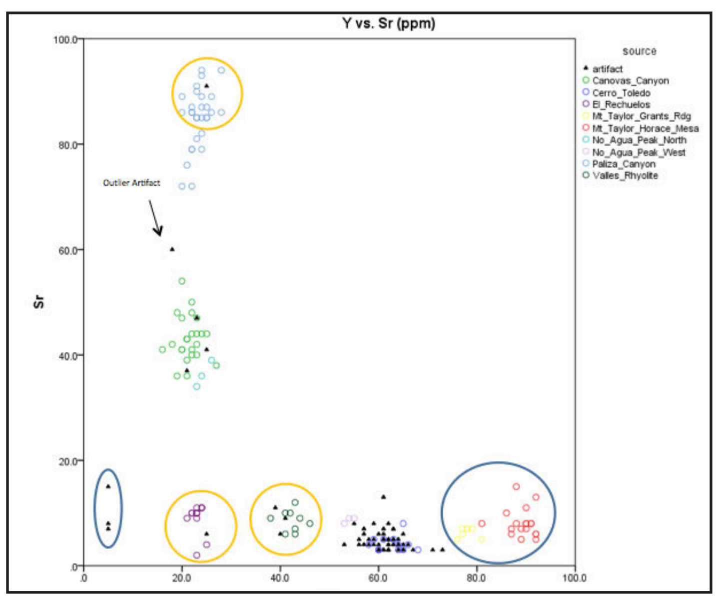

Figure 2. Bivariate plot comparing yttrium versus strontium in ppm. Orange circles highlight noticeable artifact clusters. Blue circles point out chemical group separation.

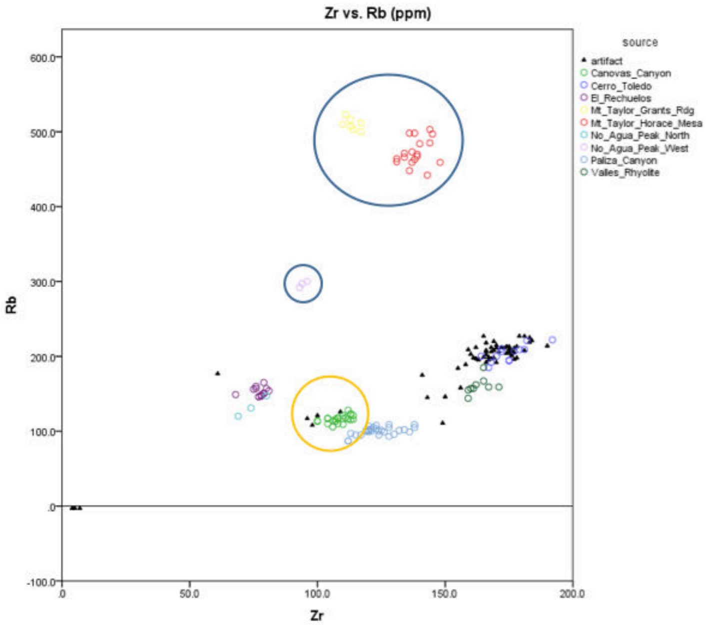

Figure 3. Bivariate plot comparing rubidium and zirconium in ppm. Orange circles highlight noticeable artifact clusters. Blue circles point out chemical group separation. Scale fit to include outlier, non obsidian artifacts on left, lower corner.

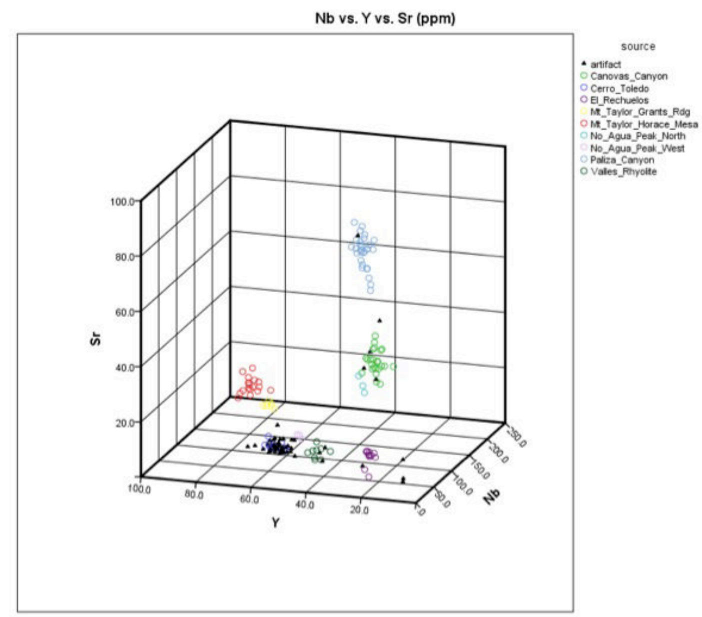

Figure 4. 3-d plot comparing niobium, yttrium, and strontium in ppm. This plot accomplishes separation of most chemical groups.

DISCUSSION

Successful provenance verifies XRF trace element data is sufficient for the geochemical characterization of different chemical groups and applicable to a relatively small data set of artifacts. Of 62 obsidian artifacts, this study identifies 53 Cerro Toledo, 4 Canovas Canyon, 3 Valles, 1 Paliza Canyon, and 1 El Rechuelos artifacts.

Geologic processes influence obsidian sources in ways that have ramifications for prehistoric procurement. Factors such as age, abundance, proximity, artifact quality, and accessibility influence procurement patterns. The younger obsidian sources of Cerro Toledo and Valles rhyolite exist as large nodules and in high abundance, relative to the older, smaller sources that have undergone the textural shift to perlite, as explained by the inverse relationship of the age of rock and the likelihood of preservation (Stevenson and McCurry, 1990). Surface exposure of Cerro Toledo rhyolite, high erosion rates, and subsequent drainage of eroding nodules into the Rio Grande river accounts for its numerical dominance in the alluvium. The close proximity of Rio Grande alluvium deposits in the Tijeras wash to the PM site suggests a high likelihood that the Cerro Toledo artifacts were collected from a secondary source.

Paliza Canyon, Canovas Canyon, and El Rechuelos rhyolite also erode into the Rio Grande alluvium. Of the three sources, El Rechuelos occurs in greatest abundance in the river deposits (Church, 2000). Shackley (2009) observes that most of the surface artifacts contain a “water worn” appearance, reinforcing the possibility the original obsidian nodules were transported by a river system. However, the combination of the small size of the nodules and distance traveled from the primary to secondary site may have resulted in nodules possibly too small for production. This may account for the lesser numerical abundance in the Tijeras Wash as well as the minor presence of these sources in the PM artifacts.

The three artifacts from the Valles rhyolite present a unique case of procurement relative to the others because Cerro del Medio units occurs in small abundance in Rio Grande alluvium as nodules too small for tool production (<2 cm) (Shackley, personal comm. 2014). Therefore, obsidian from this source must have been procured directly from the primary source. The selection of this particular obsidian is not surprising as it was a preferred tool material over Cerro Toledo obsidian among the Folsom (Shackley, 2005).

The previous discovery of one Mount Taylor surface artifact (Shackley, 2009) may have implications for prehistoric interaction in this study. Assuming surface artifacts were deposited later than subsurface test pit samples, this one sample may suggest that the Piedras Marcadas pueblo had contact or engaged in exchange with the Zuni, as they had "control" over the Mount Taylor region. More samples are needed to support this interpretation.

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