Following the Yellow Brick Road: Yellow slip clays and the production of Rio Grande Glaze Ware in north central New Mexico

Suzanne L. Eckert^{*a}, Kari L. Schleher^b, and David H. Snow^c

^{*}corresponding author: phone (520) 626-0253; fax (520) 621-2976; e-mail

sleckert@email.arizona.edu

^aArizona State Museum, University of Arizona, PO Box 210026, Tucson, AZ 85721-0026

^bCrow Canyon Archaeological Center, 23390 Road K, Cortez, CO 81321

^cIndependent Scholar, 1616 Prospect Ave NW, Albuquerque, NM 87104

Abstract

This provenance study of yellow-firing clays in north central New Mexico examines whether clays recovered in the vicinity of Tunique Pueblo (LA 240) may have been used as slip clays at contemporaneous San Marcos Pueblo (LA 98). A sample of 72 ceramic sherds, bricks, and clays were analyzed through chemical characterization using laser-ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). We argue that Tunique potters were using a subset of clays available at their village to produce pottery. Although San Marcos potters appear to have possibly been using clay from Tunique Pueblo to slip their vessels, these clays were not the same as those used by Tunique potters. Given San Marcos potters' apparent reliance on this slip clay over time, we argue our findings demonstrate that extremely stable social networks were developed and sustained among Rio Grande Pueblo households and communities across north central New Mexico during the late prehispanic and early colonial periods (AD 1400-1680).

keywords: LA-ICP-MS; pottery; ceramic slips; American Southwest; Rio

Introduction

Among ethnohistoric potters, the raw materials used to make pottery often come from a variety of locations. Some resources such as clay or temper are widely available and are typically obtained close to the area of production (Arnold 1985). Other resources, such as slip clays or pigments, are more limited in their availability and potters may travel longer distances to obtain these materials (Dillingham 1992; Najohai and Phelps 1998; Parsons 1932). Acquisition of these more specialized materials are embedded within social and economic networks of varying scales; this may have also been the case in the past (Herhahn 2006; Huntley et al. 2012; Nelson and Habicht-Mauche 2006). In this study, we are specifically examining the provenance of yellow-firing clays used in the production of Ancestral Pueblo glaze-painted pottery at two villages in north central New Mexico.

The majority of ceramic provenance studies in the Southwest United States have focused either on mineralogical analyses (Capone 2006; Eckert 2008; Habicht-Mauche 1993, 2002; Shepard 1942) or bulk chemical compositional techniques (Crown 1994; Glowacki et al. 1998; Huntley 2008). However, the development of numerous chemical compositional techniques has provided multiple avenues for archaeologists to explore the provenance of specific clays, tempers, slips, and paints (e.g., Duwe and Neff 2007; Habicht-Mauche et al. 2000). This research focuses on understanding the provenance of the yellow-firing clay used as slip on glaze-decorated pottery produced during the 14th through 17th centuries in north central New Mexico (Figure 1). Specifically, we collected chemical signatures derived from laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) of historic

Figure 1: Map of north central New Mexico, showing location of Tunque and San Marcos Pueblos, as well as other large, contemporaneous villages in the Galisteo Basin (map by Grant Coffey).

bricks, clay samples, and ceramic sherds from Tunque Pueblo (LA 240) and San Marcos Pueblo (LA 98). We interpret these data to explore the distribution of raw materials required to make pottery and to discuss social networks that may have facilitated the movement of these materials.

Our goals were threefold. First, we wanted to identify which of the clays available in the vicinity of Tunque Pueblo were used by late prehispanic and early colonial (AD 1400-1680) potters to produce yellow-slipped glaze-painted pottery. Not surprisingly, we found that Tunque Pueblo potters were using a selection of the yellow-firing clays available near their village. Second, we wanted to explore whether or not the clays available at Tunque Pueblo were used by potters at San Marcos Pueblo, located about 30 km to the northeast. We argue that San Marcos potters were probably using yellow-firing clays from Tunque Pueblo to slip at least some of their vessels, however these slip clays were not the same as those used by Tunque potters for the body of their vessels. Third, we explore what these data tell us about the nature of social networks among villages during the late prehispanic and early colonial periods in north central New Mexico. We argue that it is more appropriate in the context of our study to discuss how strategies of resource acquisition built enduring social relationships between specific households and villages within this region rather than to discuss ‘local’ versus ‘nonlocal’ pottery production *per se*.

The Archaeological Setting

Early in the fourteenth century, major demographic shifts occurred in north central New Mexico including a significant population increase (Snead et al. 2004). Villages built at this time were much larger than previously dispersed settlements (Crown et al. 1996). The rapid construction of so many large villages has led

researchers to suggest various models of social reorganization including tribalization (Habicht-Mauche 1993), clustered confederacies (Spielmann 1994), and alliances (Creamer 2000; Creamer and Haas 1998; Wilcox 1991). Archaeologists have recognized changes in other social dynamics that are associated with these settlement shifts, including new ritual systems, expansion of exchange networks, and dramatic changes in ceramic production traditions (Eckert 2008; Habicht-Mauche 1993; Habicht-Mauche et al. 2006; Huntley 2008; Spielmann 1998).

In conjunction with these demographic changes, most potters moved away from making black-on-white pottery and began to produce glaze-decorated pottery known as Rio Grande Glaze Ware (Eckert 2006). Slip color is often the defining characteristic that distinguishes among varieties and types of Rio Grande Glaze Ware vessels (Eckert 2006). Yellow as a slip color was first identified by Nelson in his study of Tano ruins (Nelson 1916). Since then the term 'yellow' has been used in the formal descriptions of various Rio Grande Glaze Ware types (Eckert 2006; Kidder and Kidder 1917; Kidder and Shepard 1936; Nelson 1916). However, the descriptor 'yellow' often refers to a broad range of light surface colors that can vary markedly even on the same vessel. Kidder and Kidder (1917) noted that the slips were "yellowish" or "pinkish-gray," and "white through cream to yellow." Mera (1933: 4) observed that, "although termed yellow," it might even be a dirty white. Kidder and Shepard (1936: 80) remarked that Pecos Glaze II slips "can only be described as light," as the color variety is "endless, and is never really white or truly yellow or positively gray, but ranges from dirty yellowish, or grayish, to pinkish buff." As such, the generic descriptive term 'yellow' has been used in the archaeological literature more to emphasize the break in technology from the preceding black-on-white

ceramic series, as well as in comparison with the contemporaneous red series of Rio Grande Glaze Ware types, than to denote a specific color.

In an attempt to increase our understanding of the production and distribution of yellow-slipped pottery, we focus this study on vessels recovered from two villages that were major centers of glaze-painted pottery manufacture: Tunique Pueblo and San Marcos Pueblo. Tunique Pueblo seems to have been at the height of its population from AD 1450 to 1550 (Armstrong et al. 2011). Both Nelson's early excavations and more recent fieldwork (Armstrong et al. 2011; Barnett 1969; Bice 1990; Morales 1997) recovered direct evidence for pottery manufacture at Tunique Pueblo including *puki* fragments (molds used for starting hand built vessels), pot-polishing stones, fired and unfired clay, and various slip clays and pigments. Pottery manufactured at Tunique Pueblo can be identified by the presence of a particular type of temper: hornblende latite ash (Habicht-Mauche 1993; Nelson and Habicht-Mauche 2006; Warren 1969, 1979, 1981).

San Marcos Pueblo's chronology is complex (Ramenofsky et al. 2009; Ramenofsky and Schleher 2017), but the site appears to have been occupied throughout the entire Rio Grande Glaze Ware sequence (A.D. 1300 - 1680). Pottery manufactured at San Marcos Pueblo can be identified by the presence of a particular type of temper: weathered augite monzonite (Habicht-Mauche 1993; Nelson and Habicht-Mauche 2006; Schleher 2010; Warren 1979, 1981). Schleher (2010: 111) has convincingly demonstrated that, depending on time period, an average of 81% of the total sample of glaze-painted pottery recovered at the pueblo was produced at this village based upon petrographic analyses.

Of specific interest to us is that, although yellow-slipped pottery was produced

at both villages, yellow-firing clays are more readily available at Tunque Pueblo than at San Marcos Pueblo. Specifically, Snow has noted in various informal settings the yellowish hue of some of the bricks produced at the historic Tonque Brick Works factory on the west edge of the ruins. He has suggested that Tunque potters not only used this easily available clay in the production of their own yellow-bodied (unslipped and polished) pottery, but might have provided the yellow slips for similar (albeit red-bodied) pottery produced at other villages during the same period, especially San Marcos Pueblo. The clay deposits closest to San Marcos pueblo fire red (Schleher 2010; Schleher et al. 2002); yet, large amounts of yellow-slipped pottery were produced at San Marcos for close to four centuries (Schleher 2010; Ramenofsky 2012).

Based on prolific amounts of glaze ware pottery exported from these two sites, San Marcos and Tunque Pueblos were arguably the largest producers of glaze-on-yellow pottery from the 1400s through the 1500s (Warren 1969, 1979); but they were not the only producers of Rio Grande Glaze Ware in the region (Creamer 2000; Nelson and Habicht-Mauche 2006; Reed 1990). Other villages in the nearby Galisteo Basin exhibit evidence of pottery production, including San Lazaro (Blinman et al. 2012; Fenn 2004; Warren 1979), San Cristobal Pueblo (Reed 1990; Warren 1979), and Pueblo Galisteo (Warren 1979). As a matter of fact, both Reed (1990) and Warren (1979) suggested that almost every site they examined in the Galisteo Basin produced at least some pottery, an observation that requires more extensive research than offered here.

Because San Marcos and Tunque Pueblos have been the focus of more extensive research on pottery production than other Galisteo Basin villages, the

unique temper signatures that exist for these two pueblos have yet to be determined for the other villages. The presence of various types of igneous rock temper is used to identify pottery production at Galisteo Basin sites other than San Marcos Pueblo (Habicht-Mauche 1993; Nelson and Habicht-Mauche 2006; Warren 1979, 1981). Based on the current evidence, none of the potters at these other Galisteo Basin villages were as major producers as the potters at San Marcos and Tunique Pueblos. With this in mind, and with our limited resources to do chemical characterization sampling, it made sense to focus this project on these two villages. If residents of Tunique Pueblo could have supplied villages such as San Marcos Pueblo in the north-central Rio Grande villages with slip clay, then this knowledge has important implications for modeling regional social networks and economic interaction during the late prehispanic and early colonial periods. Such modeling can help inform, but also be refined by, further research at other villages throughout the Galisteo Basin.

The Geological Setting

Geologically, the Galisteo-Tonque area lies on the eastern edge of the Rio Grande Depression, and extends from the north end of the Sandia Mountains to the south end of the Sagre de Cristo Mountains (Stearns 1953). The geology in this area of north-central New Mexico is highly variable (Scholle 2003), having been formed by fluvial deposition, alluvial redeposition, surface volcanism, intrusive igneous activity and associated deformation, and periods of erosion. This geological diversity is ideal for archaeological studies, allowing for potential characterization of temper, clay, and pigment across the landscape. The current study focuses on clay available within an approximately 5-kilometer radius of two sites as an initial attempt to trace the movement of slip clay; but the geology of the greater region will need to be

considered in future studies that attempt to more clearly reconstruct past social interactions.

Tunque Pueblo sits atop the Mancos Group (Scholle 2003), which is dominated by shale and other mudrocks (Stearns 1953). Within an easy walk from the site lies the Mesa Verde Formation (which overlies the Mancos Group), dominated by sandstones and shales. Unique to this area is the Cano Member of the Mesa Verde Formation, a tongue of sandstone interbedded within the underlying Mancos Group and only recognized in the Tonque Valley (Stearns 1953). Also within 5 km is the Todilto Limestone of the Wanakah Formation, overlain by massive gypsum. The Galisteo Formation (1/3 of which consists of deep-red, maroon, and purple clays) and the Dockum Group (composed of red and variegated sandstone and shale) also lie within approximately 5 km of the site (Stearns 1943, 1953).

With the exception of the Todilto Limestone, the geological setting of Tunque Pueblo provides various red (high-iron) and yellow (low-iron) firing clays suitable for pottery production. Local clays used to produce bricks at the Tonque Brick Works fired to light red, reddish yellow, and very pale brown (considered yellow for our purposes here) based on Munsell soil chart (only the yellow bricks were used in this study). Clay samples collected from on or near Tunque Pueblo and fired by the authors produced the same range of yellow and red hues as the bricks (only the yellow samples were used in this study). The unslipped surface of glaze-on-yellow pottery produced at Tunque Pueblo exhibit a slightly greater range of hues than the brick and clay samples, but include the same light red, reddish yellow, and very pale brown.

San Marcos Pueblo sits atop the Espinazo Volcanics (Scholle 2003), comprised

primarily of latite but also andesite and other intermediate volcanic material; intermediate igneous intrusions unassociated with these volcanics are also within 5 km of the site (Stearns 1953). As with Tunque Pueblo, San Marcos Pueblo is within 5 km of the Mancos Group (specifically the Dakota Sandstone Subdivision) and the Mesa Verde Formation. A poorly defined pediment - alternatively referred to as mesa gravels (Lee 1907), Tuerto Gravels (Stearn 1953), and Ortiz Gravels (Kelley and Northrop 1975) - also lies within 5 km of the village.

The most abundant and closest clay deposits to San Marcos Pueblo are weathering from the Espinaso Volcanics (Disbrow and Stoll 1957). Clay coming from some of these iron-rich outcrops fire red (Schleher 2010; Schleher et al. 2002). The clay colors of experimental tiles fired from these Espinaso Volcanics clays match pastes in pottery vessels made at San Marcos (Schleher et al. 2002); no yellow firing clays were identified. However, there are limited outcrops of the Mancos Group (including the Dakota Sandstone Subdivision) and the Mesa Verde Formation within 7 km of San Marcos Pueblo and extensive outcrops within 13 km. Unfortunately, potentially yellow-firing clays from these outcrops were not accessible at the time this research was conducted.

It should be mentioned that other sites in the Galisteo Basin (including but not limited to Pueblo Blanco, Pueblo Galisteo, and San Lazaro Pueblo) have close and more extensive outcrops of the Mancos Group and Mesa Verde Formation than those at San Marcos Pueblo (Scholle 2003) and may also have been a source of yellow-firing clays. The Espinaso Volcanics also outcrop near some of these villages (Scholle 2003). For example, experimental tiles made from clays collected from the San Lazaro clay mine (Fenn 2004: 79) fire red. As observed by Schleher, these tiles

match some glaze-on-yellow sherd pastes and may reflect production at San Lazaro Pueblo.

Overall, the geology of the study area is complex with limited research having been performed to characterize the clays of this region. As already mentioned, we know that Tunque and San Marcos Pueblos were the two major production centers for glaze-on-yellow pottery. As discussed below, we also know that finished vessels and lead to make glaze paint moved between these two villages. While we know that the yellow slip clays used on San Marcos pottery may have been collected from a number of different untested sources, we also know that three of the four yellow color groups identified on sherds produced at San Marcos Pueblo match the color groups observed on sherds produced at Tunque Pueblo. Overall, then, the experimental firing provided an initial indication in testing whether or not some of the slips applied to yellow-slipped vessels produced at San Marcos Pueblo could have originated near Tunque Pueblo. We decided to test this possibility further with chemical characterization. However, we see this research as one step in the study of interaction rather than a final explanation; we hope it will generate discussion and further research within the region.

The Sample

Our study used chemical characterization by LA-ICP-MS to examine 72 samples consisting of a combination of ceramic sherds, bricks, and ceramic tiles made from field clays (Table 1). In terms of ceramic sherds, we were specifically interested in yellow-slipped Rio Grande Glaze Ware types that were made at Tunque Pueblo and San Marcos Pueblo. Seventy years of extensive regional petrographic research on both decorated and utility wares provides confidence that production

provenance can be determined for these two sites: pottery produced at Tunique Pueblo has a characteristically light-colored paste, is normally unslipped and polished, and is tempered with hornblende-latitude ash (Warren 1969, 1979, 1981; Nelson and Habicht-Mauche 2006); pottery produced at San Marcos Pueblo has a dark gray or red paste, is yellow-slipped, and is tempered with weathered augite-monzonite (Nelson and Habicht-Mauche 2006; Schleher 2010; Warren 1979, 1981). Using these criteria, a sample of 31 sherds produced at and recovered from Tunique Pueblo was selected along with a sample of 28 sherds produced at and recovered from San Marcos Pueblo.

Six ceramic tiles made of field clay collected from the vicinity of Tunique Pueblo and seven bricks made at the historic Tonque Brick Works located along the west edge of the archaeological village were included for comparison with the archaeological ceramic samples. The Tonque Brick Works was established in 1909 and operated until 1942, resulting in the destruction of a portion of the archaeological site (Armstrong et al. 2011). The factory mined local clays; as discussed above, the resulting bricks vary in color from yellow to red. Modern access to the historic brick factory and the archaeological village is restricted and sampling is not permitted; however, prior to these restrictions, an avocational archaeologist (who has requested anonymity) collected clays and bricks. While the clays were collected from "all along the Hagen road just east of the ruin," the bricks were collected from the "spoils piles" at the abandoned factory. Although not ideal, this sample is currently the only comparative sample available for analysis and there is little reason to doubt its provenience.

Table 1: The sample. Although there is debate as to how chronologically sensitive rim forms are, the designations Glaze A-F refer to differences in bowl rim forms that are commonly used to seriate Rio Grande Glaze Ware pottery (Eckert 2006).

Sample ID	Provenience	sample type	Date	k-means cluster
brick 1	Tonque Brick Works	brick	Historic	1
brick 2	Tonque Brick Works	brick	Historic	1
brick 3	Tonque Brick Works	brick	Historic	1
brick 4	Tonque Brick Works	brick	Historic	2
brick 5	Tonque Brick Works	brick	Historic	1
brick 6	Tonque Brick Works	brick	Historic	3
brick 7	Tonque Brick Works	brick	Historic	3
clay 1	Tunque Pueblo - clay pit north	clay	Modern	4
clay 2	Tunque Pueblo - plaza	clay	Modern	3
clay 3	Tunque Pueblo - clay pit east	clay	Modern	1
clay 4	Tunque Pueblo - Hagan roadside	clay	Modern	1
clay 5	Tunque Pueblo - surface	clay	Modern	5
clay 6	Tunque Pueblo - surface	clay	Modern	5
s3	San Marcos Pueblo	Glaze B Largo Gl/y	AD 1410-1500+	1
s4	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	2
s11	San Marcos Pueblo	Glaze B Largo Gl/y	AD 1410-1500+	1
s12	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	1
s23	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	1
s24	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	1
s28	San Marcos Pueblo	Glaze C Espinoso Gl/p	AD 1410-1600+	2
s30	San Marcos Pueblo	Glaze C Espinoso Gl/p	AD 1410-1600+	2
s31	San Marcos Pueblo	Glaze B Largo Gl/y	AD 1410-1500+	2
s33	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	2
s34	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	2
s36	San Marcos Pueblo	Glaze B Largo Gl/y	AD 1410-1500+	2
s37	San Marcos Pueblo	Glaze B Largo Gl/y	AD 1410-1500+	2
s46	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	2
s48	San Marcos Pueblo	Glaze C Espinoso Gl/p	AD 1410-1600+	2
s50	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	2
s56	San Marcos Pueblo	Glaze B Largo Gl/y	AD 1410-1500+	2
s57	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	2
s65	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	2
s68A	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	2
s68C	San Marcos Pueblo	Glaze C Espinoso Gl/y	AD 1410-1600+	2
s70A	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	2
s70B	San Marcos Pueblo	Glaze B Largo Gl/p	AD 1410-1500+	2
s71	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	2
s76	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	1
s78	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	2
s79A	San Marcos Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	2
s79B	San Marcos Pueblo	Glaze B Largo Gl/y	AD 1410-1500+	2
t3	Tunque Pueblo	Glaze B Largo Gl/p	AD 1410-1500+	1
t4	Tunque Pueblo	Glaze D San Lazaro Gl/p	AD 1460-1550+	3
t5	Tunque Pueblo	Glaze B Largo Gl/p	AD 1410-1500+	2
t6C	Tunque Pueblo	Glaze C Espinoso Gl/p	AD 1410-1600+	4
t6A	Tunque Pueblo	Glaze A Cieneguilla Gl/p	AD 1321-1450+	4
t7	Tunque Pueblo	Glaze D San Lazaro Gl/p	AD 1460-1550+	4
t8	Tunque Pueblo	Glaze C Espinoso Gl/p	AD 1410-1600+	4
t9	Tunque Pueblo	Glaze D San Lazaro Gl/p	AD 1460-1550+	3
t10	Tunque Pueblo	Glaze C Espinoso Gl/p	AD 1410-1600+	4
t11	Tunque Pueblo	Glaze D San Lazaro Gl/p	AD 1460-1550+	4
t12	Tunque Pueblo	Glaze C Espinoso Gl/p	AD 1410-1600+	4
t13	Tunque Pueblo	Glaze D San Lazaro Gl/p	AD 1460-1550+	3
t14	Tunque Pueblo	Glaze D San Lazaro Gl/p	AD 1460-1550+	4
t15	Tunque Pueblo	Glaze A Cieneguilla Gl/p	AD 1321-1450+	5
t16	Tunque Pueblo	Glaze E Puaray Gl/p	AD 1480-1630+	4
t17	Tunque Pueblo	Glaze A Cieneguilla Gl/y	AD 1321-1450+	4
t18	Tunque Pueblo	Glaze C Espinoso Gl/p	AD 1410-1600+	outlier - removed
t19	Tunque Pueblo	Glaze D San Lazaro Gl/p	AD 1460-1550+	1
t20	Tunque Pueblo	Glaze D	AD 1460-1550+	4
t21	Tunque Pueblo	Glaze A Cieneguilla Gl/p	AD 1321-1450+	4
t22	Tunque Pueblo	Glaze D San Lazaro Gl/p	AD 1460-1550+	4
t23	Tunque Pueblo	Glaze C/D	AD 1410-1600+	4
t24	Tunque Pueblo	Glaze D San Lazaro Gl/p	AD 1460-1550+	5
t25	Tunque Pueblo	Glaze D San Lazaro Gl/p	AD 1460-1550+	4

t26	Tunque Pueblo	Glaze C Espinosa Gl/p	AD 1410-1600+	4
t27	Tunque Pueblo	Glaze D San Lazaro Gl/p	AD 1460-1550+	4
t28	Tunque Pueblo	Glaze C Espinosa Gl/p	AD 1410-1600+	4
t29	Tunque Pueblo	Glaze B Largo Gl/p	AD 1410-1500+	4
t30	Tunque Pueblo	Glaze D San Lazaro Gl/p	AD 1460-1550+	4
t31	Tunque Pueblo	Glaze A Cieneguilla Gl/p	AD 1321-1450+	4
t32	Tunque Pueblo	Glaze C Espinosa Gl/p	AD 1410-1600+	4

Various sociopolitical, curatorial, and economic factors limited our initial access to archaeological ceramic samples for destructive analysis and access to clay and brick samples. Methodologically, then, our sample is not ideal in terms of size or selection technique. While these conditions were less than optimal for standard ceramic characterization studies, our results presented below provide potentially significant implications for interpreting social networks between communities of potters. We hope that these preliminary results encourage other researchers to pursue similar provenance studies of pottery slips from this and other regions of the Southwest using larger and more robust samples. We also hope that our study can serve as a model for researchers, regardless of the region in which they work, who are hesitant to perform analyses on less-than-ideal assemblages. Exploring data patterns while recognizing sampling constraints allows us to broaden our analyses to include the many archaeological collections in museums with various methodological limitations, in turn allowing us to tentatively broaden our interpretations of past human behavior.

LA-ICP-MS Methodology and Statistical Analyses

LA-ICP-MS is a microprobe technique determined to be appropriate for this study because, unlike bulk analyses more suitable for homogenous materials, LA-ICP-MS allows for characterization of specific components of heterogeneous materials (Cogswell et al. 2005; Neff 2003). In this case we focused on characterizing clays used for ceramic slips and compared them to bulk raw clay and historic

bricks; the strength of the technique is that it allowed us to target clay particles in each sample while ignoring non-plastic inclusions and so we could control for the issue of differences in original material preparation. LA-ICP-MS analyses were conducted on a Perkin Elmer Elan DRCII housed at the Elemental Analysis Laboratory, Department of Chemistry, Texas A&M University under the direction of Dr. William Dennis James.

A New Wave UP-213 laser ablation system with associated software was used for sample induction. At the start of each batch of 10 samples, a series of standards were analyzed: NIST standard SRM 610, NIST standard SRM 612, Glass Buttes obsidian, Pachuca obsidian, and MURR's Ohio Red Clay. A blank (the machine was run with no sample) was also run prior to each batch. The standards and blank runs were used to calibrate data using the Gratuze method discussed below (Gratuze 1999; Neff 2003; Speakman and Neff 2005). Prior to the analyses, the following parameters were set: the diameter of the laser beam was adjusted to 30 μm ; each pass of the laser over the sample would remove approximately 5 μm of material; the repetition rate of the laser was set to 10 Hz; and the maximum energy of the beam was set to 70%. A laser pass pattern was customized for each sample to avoid non-plastic inclusions. After an initial pass over a surface to remove possible surface contaminants, a second ablation pass was needed to generate abundance data for 38 elements.

Raw count elemental signals collected from the LA-ICP-MS analyses were quantified using an approach outlined by Gratuze and colleagues (2001). The formulas for this approach are explained and provided by both Neff (2003) and Speakman and Neff (2005). Briefly put, the approach corrects for background noise,

standardizes by calculating a ratio to the counts for a single element (in our case, Al), and converts elemental signals to signals of their oxides. These signals are then converted to oxide concentrations, with a result that the sum of the oxide concentrations within each sample will equal 100. The assumption underlying this quantification is that all elements being measured represent all of the material, other than oxygen, that is ablated from the samples. This assumption may introduce some error for elements that occur in more than one oxidation state and ignores any water that may have been in the sample. Overall, however, experiments on a range of materials, including ceramic, have shown that this approach yields results in reasonable agreement with data generated by other geochemical techniques (Neff 2003; Speakman and Neff 2005). Oxide concentrations were then log base-10 transformed so as to scale the dataset to a similar order of magnitude to account for differences in concentration between major and trace elements as well as to produce a more nearly normal distribution (Baxter 2003).

Three techniques were used to explore patterning in the data and create statistically defensible and archaeologically interpretable groupings: principal components analysis (PCA), k-means clustering, and bivariate plots. Although not the only statistical methods used in compositional studies (Baxter 2003; Bishop et al. 1982), these techniques are commonly used and were selected as the best suite of techniques given our sample size. Statistics were performed using XLSTAT 19.4.

PCA (Shennan 1997) compresses a large number of variables into a smaller number of uncorrelated variables called principal components (PC); the first principal component accounts for as much of the variability as possible, and each remaining component accounts for as much of the remaining variability as possible.

K-means cluster analysis (Baxter 2003) is a non-hierarchical clustering method used for grouping cases; its advantage over other clustering methods is that as a non-hierarchical technique it minimizes intracluster variation while maximizing intercluster variation. The cluster solution with the greatest difference between the average sum of the squared distances for randomly generated data and the original data is considered to be the “best” cluster solution (Kintigh and Ammerman 1982). Bivariate plots provide an easy means to visually examine the relationship between any two elements and helps in exploring which elements may be driving separation into compositional groups.

Results

One sherd (t18) recovered from Tunique Pueblo consistently appeared as an anomaly during initial statistical analyses. This sample was relatively high in Ca, Cu, Zn and Sr when compared to the dataset as a whole. It may reflect a clay source that our study did not sample or it may reflect a vessel produced at a different village. Alternatively, this sherd may reflect sampling error during the LA-ICP-MS analysis in which the analyst accidentally sampled a portion of a non-plastic inclusion. Without further data, it is impossible to evaluate these options further; this sherd was considered an outlier and was removed from the dataset in the below analysis.

PCA was run on transformed but unstandardized data to highlight the minor and trace element optimizing the ability to identify different clays from a similar resource procurement area (Baxter 2003:78). The first two principal components account for 54.6% of the variability observed in the LA-ICP-MS analyses, while the

Figure 2: First two components of PCA on log10 oxide concentrations for 71 samples. Ceramic samples from San Marcos Pueblo plot primarily in the upper left of the graph, while ceramic samples from Tunique Pueblo plot primarily in the lower right of the graph.

first three components account for 62.5%. Samples plotted by provenience (Figure 2) show a segregation of sherds recovered from the two villages: sherds recovered from Tunique Pueblo group primarily in the lower half of the graph, especially in the lower right portion; sherds recovered from San Marco Pueblo group primarily in the upper half of the graph, especially in the upper left portion. Most of the Tunique Pueblo sherds group with two clays; while most of the San Marcos sherds group with a clay and a brick. The greater chemical diversity in the brick and clay samples when

Table 2: Summary of k-means 5-cluster solution.

Cluster	1	2	3	4	5
N	14	24	6	23	4
Sum of weights	14	24	6	23	4
In-class variance	1.174	0.786	1.057	0.767	2.403
Min dist to centroid	0.641	0.373	0.477	0.507	1.115
Ave dist to centroid	1.000	0.813	0.890	0.821	1.328
Max dist to centroid	1.797	1.881	1.314	1.589	1.539
Membership	brick 1 brick 2 brick 3 brick 5 clay 3 clay 4 s3 s11 s12 s23 s24 s76 t3 t19	brick 4 S4 s28 s30 s31 s33 s34 s36 s37 s46 s48 s50 s56 s57 s65 s68A s68C s70A s70B s71 s78 s79A s79B t5	brick 6 brick 7 clay 2 t4 t9 t13	clay 1 t6A t6C t7 t8 t10 t11 t12 t14 t16 t17 t20 t21 t22 t23 t25 t26 t27 t28 t29 t30 t31 t32	clay 5 clay 6 t15 t24
Mean $\pm$ SD of oxide concentrations					
Na23	00.6562 $\pm$ 0.3954	00.5603 $\pm$ 0.3359	00.5121 $\pm$ 0.2032	01.1901 $\pm$ 0.3227	00.5205 $\pm$ 0.1290
Mg24	01.9114 $\pm$ 0.9358	01.7148 $\pm$ 0.4589	01.8957 $\pm$ 0.5515	02.1398 $\pm$ 1.0151	02.1412 $\pm$ 0.4996
Al27	18.6262 $\pm$ 8.4417	20.8837 $\pm$ 2.4553	17.1344 $\pm$ 4.2800	26.7465 $\pm$ 2.3069	32.6180 $\pm$ 2.6750
Si29	63.8461 $\pm$ 7.6352	61.4002 $\pm$ 3.8417	66.5916 $\pm$ 3.2765	58.0690 $\pm$ 3.1145	57.0650 $\pm$ 2.6692
K39	02.1547 $\pm$ 0.5776	03.2026 $\pm$ 0.6639	02.0205 $\pm$ 0.4026	02.0590 $\pm$ 0.5185	02.1091 $\pm$ 1.0013
Ca44	08.2545 $\pm$ 6.4661	06.8998 $\pm$ 4.0566	07.4383 $\pm$ 3.6815	04.2353 $\pm$ 1.9100	02.3523 $\pm$ 1.4855
Sc45	00.0014 $\pm$ 0.0009	00.0014 $\pm$ 0.0004	00.0011 $\pm$ 0.0002	00.0008 $\pm$ 0.0001	00.0005 $\pm$ 0.0001
Ti47	00.7103 $\pm$ 0.1978	00.6605 $\pm$ 0.0958	00.6245 $\pm$ 0.1477	00.6517 $\pm$ 0.1211	00.5330 $\pm$ 0.0603
V51	00.0092 $\pm$ 0.0017	00.0084 $\pm$ 0.0008	00.0094 $\pm$ 0.0008	00.0051 $\pm$ 0.0011	00.0023 $\pm$ 0.0006
Cr52	00.0064 $\pm$ 0.0016	00.0034 $\pm$ 0.0017	00.5E-8 $\pm$ 1.9E-9	00.0025 $\pm$ 0.0010	00.0008 $\pm$ 0.0003
Mn55	00.0288 $\pm$ 0.0143	00.0786 $\pm$ 0.0246	00.0479 $\pm$ 0.0343	00.0261 $\pm$ 0.0095	00.0115 $\pm$ 0.0105
Fe57	03.3838 $\pm$ 0.9347	03.0992 $\pm$ 0.6709	03.4522 $\pm$ 0.9737	02.7349 $\pm$ 0.5900	01.9050 $\pm$ 0.3485
Co59	00.0008 $\pm$ 0.0003	00.0014 $\pm$ 0.0018	00.0011 $\pm$ 0.0005	00.0003 $\pm$ 0.0001	00.0002 $\pm$ 0.0001
Ni60	00.0025 $\pm$ 0.0007	00.0028 $\pm$ 0.0011	00.0026 $\pm$ 0.0007	00.0009 $\pm$ 0.0009	00.0007 $\pm$ 0.0001
Cu65	00.0034 $\pm$ 0.0030	00.0078 $\pm$ 0.0039	00.0028 $\pm$ 0.0011	00.0099 $\pm$ 0.0069	00.0030 $\pm$ 0.0034
Zn66	00.0196 $\pm$ 0.0130	00.0685 $\pm$ 0.0460	00.0395 $\pm$ 0.0398	00.0273 $\pm$ 0.0145	00.0152 $\pm$ 0.0160
Rb85	00.0075 $\pm$ 0.0021	00.0090 $\pm$ 0.0015	00.0069 $\pm$ 0.0007	00.0051 $\pm$ 0.0014	00.0014 $\pm$ 0.0015
Sr88	00.0234 $\pm$ 0.0110	00.0323 $\pm$ 0.0170	00.0416 $\pm$ 0.0244	00.0314 $\pm$ 0.0124	00.0216 $\pm$ 0.0100
Zr90	00.0144 $\pm$ 0.0108	00.0173 $\pm$ 0.0186	00.0108 $\pm$ 0.0040	00.0185 $\pm$ 0.0044	00.0235 $\pm$ 0.0065
Ba138	00.0456 $\pm$ 0.0323	00.0436 $\pm$ 0.0238	00.1096 $\pm$ 0.0816	00.0243 $\pm$ 0.0144	00.0190 $\pm$ 0.0296
La139	00.0027 $\pm$ 0.0009	00.0029 $\pm$ 0.0004	00.0022 $\pm$ 0.0002	00.0045 $\pm$ 0.0023	00.0053 $\pm$ 0.0019
Ce140	00.0058 $\pm$ 0.0021	00.0085 $\pm$ 0.0130	00.0047 $\pm$ 0.0004	00.0090 $\pm$ 0.0039	00.0121 $\pm$ 0.0045
Pr141	00.0006 $\pm$ 0.0002	00.0006 $\pm$ 0.0001	00.0005 $\pm$ 4.3E-5	00.0009 $\pm$ 0.0003	00.0010 $\pm$ 0.0003
Nd142	00.0024 $\pm$ 0.0007	00.0025 $\pm$ 0.0004	00.0020 $\pm$ 0.0001	00.0032 $\pm$ 0.0013	00.0039 $\pm$ 0.0010
Sm152	00.0004 $\pm$ 0.0001	00.0005 $\pm$ 0.0001	00.0004 $\pm$ 3.0E-5	00.0005 $\pm$ 0.0001	00.0007 $\pm$ 0.0001
Eu153	00.0001 $\pm$ 3.0E-5	00.0001 $\pm$ 1.9E-5	00.0001 $\pm$ 6.8E-6	00.0001 $\pm$ 1.5E-5	00.0001 $\pm$ 7.2E-6
Gd158	00.0003 $\pm$ 0.0001	00.0004 $\pm$ 0.0001	00.0003 $\pm$ 3.1E-5	00.0004 $\pm$ 0.0001	00.0005 $\pm$ 4.5E-5
Tb159	00.0001 $\pm$ 1.4E-5	00.0001 $\pm$ 1.1E-5	05.0E-5 $\pm$ 5.1E-6	00.0001 $\pm$ 1.2E-5	00.0001 $\pm$ 6.0E-6
Dy164	00.0003 $\pm$ 0.0001	00.0003 $\pm$ 0.0001	00.0003 $\pm$ 3.2E-5	00.0003 $\pm$ 0.0001	00.0004 $\pm$ 3.0E-5
Ho165	00.0001 $\pm$ 1.4E-5	00.0001 $\pm$ 1.0E-5	00.0001 $\pm$ 7.5E-6	00.0001 $\pm$ 1.4E-5	00.0001 $\pm$ 7.1E-6
Er166	00.0002 $\pm$ 3.5E-5	00.0002 $\pm$ 3.1E-5	00.0001 $\pm$ 2.1E-5	00.0002 $\pm$ 4.1E-5	00.0002 $\pm$ 3.0E-5
Tm169	02.3E-5 $\pm$ 5.5E-6	02.7E-5 $\pm$ 4.9E-6	02.3E-5 $\pm$ 4.2E-6	02.7E-5 $\pm$ 6.6E-6	03.5E-5 $\pm$ 5.4E-6
Yb174	00.0002 $\pm$ 4.6E-5	00.0002 $\pm$ 4.1E-5	00.0002 $\pm$ 3.2E-5	00.0002 $\pm$ 0.0001	00.0003 $\pm$ 0.0001
Lu175	02.5E-5 $\pm$ 5.2E-6	02.9E-5 $\pm$ 5.5E-6	02.4E-5 $\pm$ 5.2E-6	03.1E-5 $\pm$ 8.6E-6	03.8E-5 $\pm$ 1.1E-6
Hf180	00.0003 $\pm$ 0.0002	00.0003 $\pm$ 0.0001	00.0002 $\pm$ 0.0001	00.0004 $\pm$ 0.0001	00.0006 $\pm$ 0.0001

Ta181	00.0001 ± 2.4E-5	00.0001 ± 1.1E-5	00.0001 ± 1.4E-5	00.0001 ± 3.6E-5	00.0002 ± 3.4E-5
Th232	00.0010 ± 0.0004	00.0010 ± 0.0002	00.0008 ± 0.0001	00.0021 ± 0.0006	00.0032 ± 0.0006
U238	00.0004 ± 0.0002	00.0004 ± 0.0002	00.0006 ± 0.0003	00.0009 ± 0.0004	00.0014 ± 0.0005

compared to the pottery samples suggests that the geology of the Tunque area is diverse but potters were only selecting a subsample of available clays for pottery production. This selectiveness on the part of potters is no surprise, but needs to be remembered in future studies of the region; the presence of clay near a site does not necessarily mean the use of that clay by potters.

A k-means 5-cluster solution (Table 2) was determined to be the best cluster solution (Kintigh and Ammerman 1982). This solution groups the assemblage with the largest cluster (N=24) dominated by samples from San Marcos Pueblo and the other large cluster (N=23) dominated by samples from Tunque Pueblo. Both of these large clusters also contain one brick or clay sample. Samples plotted by k-means 5-cluster solution using the first two PCA components show comfortable agreement between the two methods (Figure 3).

Not surprisingly given their geological proximity, there is a great deal of chemical similarity between the clays, bricks, and sherds produced at Tunque Pueblo; yellow slips on the sherds produced at San Marcos Pueblo share in that similarity. Bivariate plots help visualize that clusters are driven by differences in Mn, Cr, Pr, Th, and U (Figures 4 and 5; see also Table 2); for example, cluster 4 samples have relatively low Mn concentrations and high U concentrations when compared to cluster 2 samples, while cluster 2 samples have relatively high Mn concentrations and low Cr concentrations when compared to cluster 1 samples. Clay 1 and the majority (N = 23) of Tunque sherds group together into Cluster 4. Cluster 4 has relatively low concentrations of Mn and Cr, and high concentrations of U, Pr

Figure 3: First two components of PCA plotted by k-means 5 cluster solution.

and Th when compared to other clusters. In other words, sherds collected during the excavation of Tunique Pueblo can be matched compositionally to a specific clay sample collected in the vicinity of the village. Clusters 3 and 5 also contain sherds from Tunique Pueblo as well as local brick and clay samples, suggesting that Tunique potters were using a variety of locally available clays to form their vessels. This is not really surprising, as archaeologists have suspected for a long time that clays used by Tunique potters were collected from the same area as the clays used by the historic Tonque Brick Works.

All of the San Marcos sherds ($N = 30$), three Tunique sherds, and the remainder of the bricks and clay samples group into Cluster 1 and 2.

Figure 4: Bivariate plot of Mn55 and U238 oxide concentrations plotted by k-means 5-cluster solution.

Interpretatively, it would seem that San Marcos potters were using clays that were available from near Tunque Pueblo to slip their vessels, but it was a different subset of clays than the Tunque potters favored to produce their own yellow-bodied vessels. This result probably speaks to the nature of the different clays available near Tunque Pueblo; while only a subset of those clays fired to the appropriate range of color desired by the potters, only a subset of that subset may have been appropriate to build a vessel. In other words, the characteristics of a clay required to produce a vessel are different than the characteristics of a clay required to slip a vessel. Tunque residents were not only aware of these differences, but were reserving

Figure 5: Bivariate plot of Cr52 and Pr141 oxide concentrations plotted by k-means 5-cluster solution.

specific body clays for their own pottery production, while making the other yellow-firing clays available to potters from other villages for use as a slip.

Discussion

We argue both San Marcos and Tunque potters were using yellow-firing clays available from the vicinity of Tunque Pueblo, but they were using these clays in different ways. Tunque potters were making yellow-bodied, self-slipped vessels with a subset of locally available clays; San Marcos potters were using a different subset of clays from the Tunque vicinity as a yellow slip on their red-bodied vessels. In other words, although potters at these two villages were using distinctive production

techniques, they were both incorporating clays available from Tunque Pueblo into their vessels. Similarly, potters at both villages were using the same lead source near San Marcos Pueblo (Habicht-Mauche et al. 2000, 2002; Nelson and Habicht-Mauche 2006; Huntley et al. 2007; Huntley 2008) and the same glaze recipes (Schleher et al. 2012) to make their paint. It is tempting to speculate that San Marcos residents controlled access to lead ore for glaze paints while Tunque residents restricted access to yellow slip clays. However, the story may not have been that straightforward: we know there are probably other sources of yellow firing clay available to San Marcos potters, including from the not-so-distant San Pedro district (Shepard 1942); further, there was lead available from the Placitas source immediately adjacent to Tunque Pueblo (Nelson and Habicht-Mauche 2006). So the question is not simply one of access.

Historically, resources for pottery production moved between Pueblo villages and between families of potters at different villages. Dillingham (1992:47) noted that “Acoma and Laguna potters have traded their desirable, fine white slip with craftspeople from Zuni”. Parsons (1932:351) observed that Isleta potters “still buy their paints from the Laguna colonists” [at Isleta], which are obtained from localities near Old Laguna. Further, in the 1920s, a Tewa-speaking potter from Santa Clara Pueblo, Monica Silva, married into Keresan Santo Domingo Pueblo (Crane 1928:243). Her children at Santo Domingo Pueblo retain kin ties with Santa Clara to this day, bringing red slip clay to potters of their mother’s lineage there (personal communication to Snow, name withheld by request; also see LeFree 1975:21). We argue that the movement of slip clays and glaze paints between San Marcos Pueblo and Tunque Pueblo may reflect similar scenarios during the late prehispanic and

early colonial eras.

It is interesting to note that decorated vessels were also moving between San Marcos Pueblo and Tunique Pueblo (Warren 1979, 1981; Nelson and Habicht-Mauche 2006; Schleher 2010); for example, approximately 9% of glaze ware sherds recovered from San Marcos were made at Tunique Pueblo (Schleher, personal observation). While this level of pottery exchange between villages was not insignificant, it suggests that the social network through which this pottery was moving had to have been of an altogether different type and scale than the one used to obtain slip clay required to make much of the yellow-slipped pottery at San Marcos over the almost 400 years of glaze ware production. Nelson and Habicht-Mauche (2006) have argued previously that within north central New Mexico glaze ware pots circulated among communities that shared a similar ethnolinguistic identity, most likely as a result of pot-luck style feasting and other inter-community activities. More specialized resources, such as lead for glaze-paint and slip clays, appear to have circulated differently, linking households across these ethnolinguistic clusters into much broader networks of regional interactions. The movement of these more specialized ceramic resources may reflect the kinds of eclectic and historically contingent, kin-based relationships between households from different ethnolinguistic villages recorded ethnographically and outlined above.

By producing pottery using resources obtained from multiple sources, potters may not only have been affirming social ties but were literally tying their pottery vessels to a broader social and cosmological landscape. Potters who produced vessels with clay from one village, but decorated with slip clay or lead for glaze-paint from the other village, would have been creating vessels that physically embodied

the potter's social world. In addition, specific resources may also have been connected to historically and cosmologically significant places on the landscape making them embodiments of a community-centered historic and mythic world. If such were the case, then the exchange of finished pottery between communities may have been of less significance to the creation of enduring regional social networks than the acquisition of specific ceramic resources required to produce pottery.

Conclusions

The results of the current study, as well as previous studies of the circulation of lead for glaze-paint production in this same region (Habicht-Mauche et al. 2000, 2002; Huntley et al. 2007; Huntley 2008; Nelson and Habicht-Mauche 2006), suggest that inter-community ties as reflected in resource procurement were amazingly stable through time. But this project is only one of a suite of projects attempting to understand the movement of different types of resources up and down the Rio Grande valley. Once completed, these studies will need to be synthesized to create a broader understanding of the nature of different scales of social networks at play in this period of ethnogenesis. In developing such a synthesis, we suggest that Whiteley's concept of 'relationality' may be of great value (Whiteley 2004). Physical access to material resources may have been of far less significance than perceptions of exchange dependencies. Social fictions about the adequacy of specific resources might have played a role in the genesis of identity on the one hand, and the development of exchange networks on the other. For example, making yellow-slipped pottery may have been an important ethnic marker for San Marcos potters, but the yellow slip clay may also have *had* to have originated from Tunque Pueblo. As Whiteley explains (2004: 149), such social fictions preserve exchange dependencies

because difference must be “established or recognized as a means for exchange, and thereby alliance, producing distinctions at one level simultaneous with identity at another.”

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