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Analysis of Ceramic Compositional Data from Late Developmental Period Sites in the Tewa Basin, New Mexico

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The presence of Cibola white ware ceramic types at Late Developmental period sites in the Northern Rio Grande (NRG) region of New Mexico has been interpreted as a strong indicator of cultural interaction with, or immigration from, communities associated with the Chaco regional system in the American Southwest. We report the results of an analysis of chemical composition data obtained from neutron activation analysis (NAA) of pottery sherds originating from three Late Developmental sites in the southern Tewa Basin of the NRG. Our results revealed three compositional groups, one local and two non-local. Comparison with existing data sets allowed us to identify specific production areas and great house communities within the Chaco regional system as likely sources for one of the two non-local groups. Our findings also revealed five sherds of a local NRG pottery type, Kwahe'e B/w that were made with non-local clay from the Chaco regional system, but were tempered with local materials.

La presencia de los tipos de tradicion cerámica de Cibola en los sitios arqueológico en la región norte de Río Grande (NRG) de Nuevo México del período Late Developmental se ha interpretado como un fuerte indicador de la interacción cultural con las comunidades asociadas con el sistema regional de Chaco en el suroeste de Estados Unidos o la inmigración. Presentamos los resultados de un análisis de los datos de composición química obtenidos a

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partir del análisis de activación de neutrones (NAA) de tiestos de cerámica originados desede tres sitios arqueológico del período Late Developmental en la Cuenca Tewa. Nuestros resultados revelaron tres agrupaciones compositivas, una local y dos no locales. La comparación con los conjuntos de datos existentes nos permitió identificar áreas de producción específicas y grandes comunidades de viviendas dentro del sistema regional de Chaco como fuentes probables para uno de los dos grupos no locales. Nuestros hallazgos también revelaron cinco tiestos de un tipo de cerámica NRG local, Kwahe'e B/w, que se hicieron con arcilla no local desde el sistema regional del Chaco, pero se templaron con materiales locales.

KEYWORDS Kwahe'e B/w, Cibola white wares, pottery, Chaco Canyon, Northern Rio Grande, communities of practice, communities of identity, ceramic analysis

Identifying non-local artifacts in archaeological assemblages is essential for inferring cultural, economic and demographic interaction with other communities or culture regions (Druc 2013:485). Archaeologists interested in identifying interaction among communities have typically relied on identifying non-local raw materials in the analysis of lithic artifacts, or non-local ceramic types. There is a rich history within Southwestern archaeology of using ceramic types to infer patterns of population movement, as well as the geography and magnitude of social, cultural, and economic interaction among pre-contact communities and culture regions such as the NRG. Much of the previous work to either define ceramic types in the NRG (e.g. Mera 1935), or use ceramic types to infer culture areas or cultural interaction have relied largely on visual assessments of variation in surface treatment, design elements, paste, and temper (e.g. Wendorf and Reed 1955; McNutt 1969; Ford et al. 1972; and more recently Wilson 2005). Recent research on this subject has included analysis of the chemical composition of sourced clay samples and pottery sherds, often of typed wares, to investigate regional patterns of ceramic production, trade and social interaction (e.g. Wiseman and Olinger 1991; Thomas et al. 1992; Fowles 2004; Eiselt and Ford 2007; Fowles et al. 2007; Duwe 2011; Eckert et al. 2015; Agostini 2018; also see Curewitz and Foit 2018).

Investigating the nature and magnitude of cultural, economic, and demographic interaction with communities outside the NRG, as well as identifying the regional sources of that interaction, is critically important for our understanding of the culture history of the area, and continues to be of considerable research interest. Much of the recent research on this topic cited above has focused on chemical compositional analysis of ceramic types found in Coalition (AD 1200-1350) and Classic (AD 1350-1540) period site assemblages. To date, very few compositional studies have focused on Developmental period (AD 600-1200) ceramic types from the NRG (see Fowles 2004; Fowles et al. 2007). Addressing this dearth of research is sorely needed if we are to better understand the culture history of the NRG before the development of larger aggregated communities during the Coalition Period. The purpose of the present research is to investigate the chemical composition of typed pottery sherds, primarily white wares, from Late Developmental period (AD 900-1200) communities in the southern Tewa Basin. Situated within the NRG north of the Santa Fe River, the Tewa Basin is home to present day Tewa and Northern Tiwa pueblos. Our study focuses on identifying compositional groups, and determining the potential geographic origins of non-local Cibola white ware sherds commonly found at Late Developmental period sites. Although we focus our study on white wares, it is important to point out that they normally make up only a small percentage (5–15%) of the ceramic assemblages at Late Developmental sites in the Tewa Basin, including those in the present study. Many of the sherds that make up the white ware assemblages at Late Developmental sites are from locally produced Kwahe'e B/w vessels (Figure 1). Defined and named by H. P. Mera in 1935, Kwahe'e B/w is the first type in the region's locally produced white ware ceramic series, which in the past has been referred to as the Rio Grande, or Tewa ceramic series (Stubbs and Stallings 1953). The Tewa series represents a very long-lived tradition of white ware pottery production (Wilson 2005:101) that comprises a well-established and coherent progression of ceramic types that were produced within the Tewa Basin using local clays and tempers (Wilson 2013; but see Washburn 2014). It has been suggested that Kwahe'e B/w was produced between about A.D. 1000 and A.D. 1200, and likely developed directly from a locally produced variant of the non-local Cibola white ware type Red Mesa B/w[1] (Mera 1935; Wendorf and Reed 1955; Wilson 2013; Wiseman 2014; but see discussion in McNutt 1969). It is important to note that there was a gradual and significant increase in Kwahe'e B/w during the latter part of the Late Developmental period. Earlier assemblages were dominated by white wares assigned to the Cibola tradition, primarily Red Mesa B/w. The locally made variant of Red Mesa B/w was presumably produced in the southern Tewa Basin just prior to, and perhaps also contemporaneous with, the earliest production of Kwahe'e B/w, which began sometime between about AD 975 and AD 1023 (Schillaci and Lakatos 2017). Red Mesa B/w (Figure 2) is one among at least 15 white ware types within the Cibola, or Chaco-Cibola, white ware series with a large production area located principally in the San Juan Basin (http://ceramics.nmarchaeology.org/typology/ware?p=15). A number of Cibola white ware types, including Red Mesa B/w, Gallup B/w, and Escavada B/w, are often associated with the geographically large regional polity centered in Chaco Canyon that included the eastern Red Mesa Valley and upper Rio Puerco (east) valley, among other areas. As such, the geographic distribution of these types by way of trade within the Chaco regional system is wide.

Given their association with Chaco culture, the presence of Cibola white ware types at sites outside the Chaco regional system, such as those in the NRG and Middle Rio Grande (MRG) regions, has often been used as a relative indicator of social interaction, including trade, with the regional system, or emigration from Chaco communities to the west. This approach has been reflected in much of the research on extra-regional interaction or population movement during the Developmental, or Pueblo I and Pueblo II periods in the NRG and MRG regions (e.g. Wendorf and Reed 1955; McNutt 1969; Ford et al. 1972; Fowles 2004; Wilson 2005). Although it has been generally understood that the presence of Cibola white wares at NRG and MRG sites indicates interaction of some sort with the

FIGURE 1. Early Kwahe'e Black-on-white olla from site LA 391, recovered during the Santa Fe to Pojoaque Corridor Project. Courtesy of the New Mexico Department of Transportation and the Office of Archaeological Studies. Photo by Carol Price.

Chaco regional system, specific communities or sub-regions within that geographically expansive regional system have not been identified in the literature as sources of that interaction. A comparative study of the chemical composition of pottery sherds offers a unique opportunity to address this question. If ceramic compositional profiles from NRG communities can be matched with similar profiles from specific communities within the Chaco regional system, then the sources of interaction or immigration could be potentially identified.

Previous Compositional Work in the Northern Rio Grande Region

Initial compositional studies of NRG ceramics were conducted using x-ray fluorescence (XRF), and focused mainly on historic or late prehistoric (Coalition and Classic periods) pottery types (Bower and Snow 1984; Bower et al. 1986; Olinger 1988; Wiseman and Olinger 1991; Thomas et al. 1992; Habicht-Mauche 1993). Relevant to the present study, Wiseman and Olinger (1991) used XRF to examine the compositional profiles of white ware sherds found at the Pojoaque Grant Site

FIGURE 2. Red Mesa B/w bowl found during the excavation of LA 80934 in McKinley County, New Mexico. MIAC Cat. #56501 /11, site LA 80934. Collections of the Navajo Nation at the Museum of Indian Arts & Culture/Laboratory of Anthropology. Photo by Carol Price.

(LA 835), a Late Developmental site in the southern Tewa Basin also included in the present study. That study identified two compositional groups, one local and one non-local. The local group was composed primarily of Kwahe'e B/w sherds. The non-local group, composed primarily of Red Mesa B/w sherds, was presumed to largely represent ceramic vessels manufactured in areas to the west, possibly in the Rio Puerco (east) valley (Wiseman and Olinger 1991:215). Interestingly, their compositional results indicated that a small proportion of the sherds identified visually as Cibola white ware types fell within the local group (14/247, 5.7%), suggesting they originated from vessels manufactured in the Tewa Basin using locally available clay.

More recent compositional studies have utilized other techniques such as NAA and laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) (e.g. Fowles 2004; Eiselt and Ford 2007; Fowles et al. 2007; Duwe 2011; Eckert et al. 2015). A study by Eiselt and Ford (2007) examined historic micaceous pottery and raw clays using NAA, and matched Northern Tiwa, Tewa, and Jicarilla Apache pottery sherds with specific regional clay sources within the NRG. Fowles (2004), and Fowles et al. (2007), compared the chemical composition of Late Developmental and Coalition period (ca. AD 1050-1320) pottery sherds with the composition of local clay sources and "waster sherds"[2] associated with pottery production in the Taos Valley. That study identified multiple local and non-local compositional groups. Local clay sources generally corresponded with the local compositional groups, including wasters. Relevant to the present study, Fowles et al. (2007), concluded that one of their non-local groups, which was composed almost entirely of Kwahe'e B/w, likely originated from an unidentified production area in the Española Basin (Tewa Basin). That study also concluded that the village aggregation corresponding with the emergence of the Coalition period from the Developmental period was associated with a curtailment of clay procurement, perhaps in response to threats of inter-village hostility (Fowles et al. 2007:146–147). In a study using a type of LA-ICP-MS, Duwe (2011) identified two compositional groups in his analysis of locally sourced clay samples and pottery sherds from Coalition and Classic period Tewa series wares including Santa Fe B/w, Wiyo B/w, Abiquiu Black-on-gray, Bandelier Black-on-gray, and Sankawi Black-on-cream—all originating from sub-regions within the Tewa Basin. In their study of ceramic production and circulation during the transition from the Late Coalition to the Early Classic periods (AD 1250-1350) in the NRG, Eckert et al. (2015) conducted a compositional analysis of Santa Fe B/w sherds using NAA. The results of their study revealed at least three broad production provenances (Santa Fe vicinity, Pajarito Plateau, Arroyo Hondo). Combined with the results of petrography and assessment of design style, the authors identified three different communities of practice within a single community of identity established through a long residency within the region (Eckert et al. 2015:1).

The chemical compositional studies discussed above have advanced our knowledge regarding pottery production and trade in the NRG by demonstrating that pottery produced within different communities are typically identifiable as compositional groups that can often be linked to local clay sources. These previous studies have also provided the basis for identifying sherds derived from non-local vessels produced outside the NRG, something that is essential to our study. With the exception of Wiseman and Olinger (1991) and Fowles et al. (2007; also see Fowles 2004), none of these previous compositional studies focusing on the NRG examined Developmental period sites, Cibola white wares, or Kwahe'e B/w. The purpose of the research presented here was to investigate the chemical composition of typed pottery sherds, predominantly local and non-local white wares, from Late Developmental period (AD 900-1200) communities in the southern Tewa Basin. We define "local" as the southern Tewa Basin, while "non-local" is presumed to be from locations outside the NRG (see Druc 2013 for discussion). We were primarily interested in identifying source communities within the Chaco regional system associated with the production of the non-local Cibola white wares found on Late Developmental period sites.

Methods

Ninety-nine pottery sherds were selected from assemblages excavated from three Late Developmental period (AD 900-1200) settlements (LA 835, LA 388, LA

6579) in the Tewa Basin (Appendix I; Figure 3). In addition to these sherds, 6 fired ceramic tiles made from four local Tewa Basin clay sources were included in the analysis.

Clay samples for analysis were taken from Tertiary period sedimentary deposits of the Tesuque Formation (Miocene-Pliocene) near present-day Santa Fe (Bishop's Lodge and Santa Fe Ranch samples), Quaternary period (late Pleistocene) lacustrine sediments on the east side of the Rio Grande near the mouth of Cañada Ancha just south of the former town of Buckman ("Culebra Lake" samples[3]) (see Galusha and Blick 1971; Reneau and Dethier 1996), and Tertiary period (latest Pliocene) lacustrine Culebra Lake sediments directly underlying the Guaje Pumice Bed of the Otowi member of the Banderlier Tuff (Crowe et al. 1978:9–10; also see Turbeville et al. 1989; Waresback and Turbeville 1990; Dethier and Fagenholz 2007) along NM State Road 502 west of Totavi (Totavi sample[4]). The Otowi member at this location was deposited approximately 1.6 mya and unconformably overlies the Culebra Lake deposits (see Dethier and Fagenholz 2007:388, 390). It is important to note that these Tewa Basin clays are derived from geological formations not found elsewhere in the southwest, and are not geologically, or geomorphologically

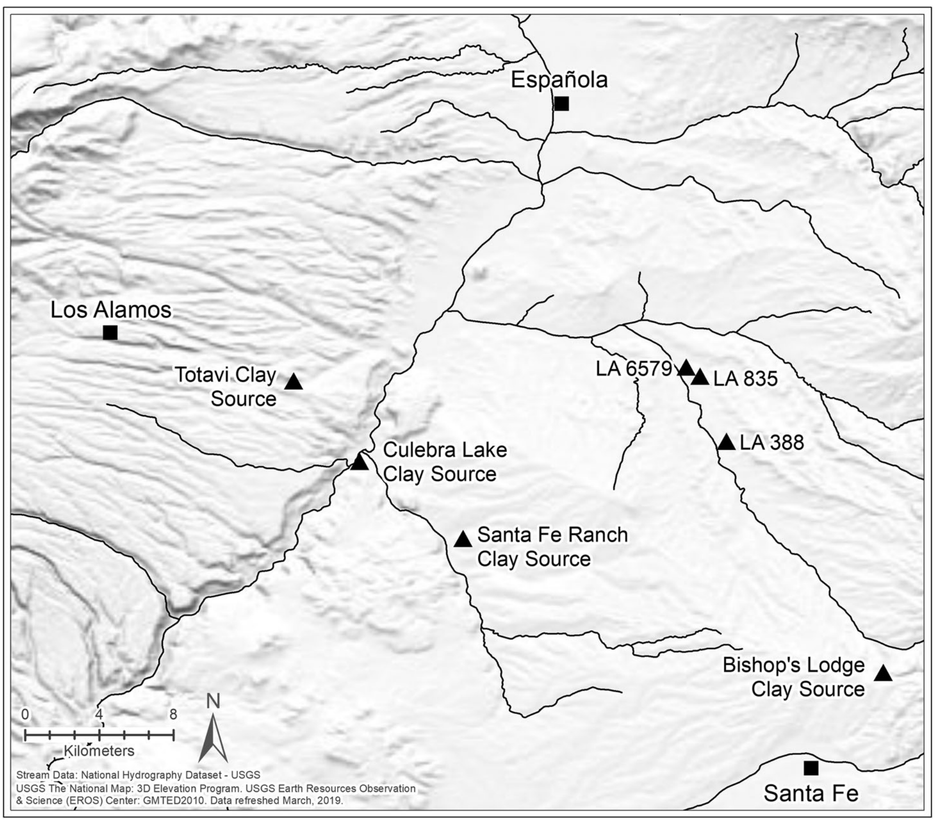

FIGURE 3. Map of the study area showing the locations of archaeological settlements and clay samples used in the study.

associated with the Jurassic, Cretaceous, and Tertiary sedimentary formations that yield clays or temper materials used for ceramic production by Chaco communities in the San Juan Basin (see Neitzel et al. 2002), or clays from the Jurassic and Cretaceous, or Eocene-Oligocene formations of the Galisteo Basin south of the Santa Fe River (see Eckert et al. 2018). Results from previous ceramic re-firing experiments have revealed similarities in paste color and texture between clays from these local Tewa Basin sources and the local white ware type Kwahe'e B/w (Wilson 2005). Re-firing of Kwahe'e B/w sherds yielded yellow-red colors and paste texture similar to those noted for local clays with high volcanic ash content (Wilson 2005:126). Unlike Kwahe'e B/w, sherds assigned to the non-local Cibola white ware types (e.g. Red Mesa B/w) tended to have blocky pastes and fired to lighter buff and pink colors in oxidizing atmospheres, reflecting use of low-iron shale clays found in the Jurassic, Cretaceous, and Tertiary sedimentary formations available in the San Juan Basin (Wilson 2005:126). In other words, the clays included in the present study can be considered geologically endemic to the Tewa Basin, and differ from other clay sources used in the manufacture of contemporaneous ceramics types in the San Juan Basin and elsewhere in the Southwest.

The chemical composition of the sherds, as well as the fired ceramic tiles, was measured using NAA. Elemental analysis involved standard ceramic NAA routinely undertaken at MURR (Glascock 1992; Neff 2000, 2002). Fragments of approximately 1 square centimeter were burred using a silicon carbide bit to remove potential surface contamination as well as slips and paints. They were then washed in deionized water, dried, and then ground to a fine powder using a high purity mortar and pestle. The samples were further dried in an oven at 90 degrees Celsius prior to weighing. We used a two sample, three count irradiation procedure to produce ppm data for 32 elements for each specimen.

Determinations of temper from broken sherds (i.e. not from thin sections) were made using a binocular microscope. While not as comprehensive as temper determinations based on thin-section, determination based on microscopy of broken sherds was appropriate given the aims and scope of the study, and the significant visual differences between Cibola white wares and the local ceramic type Kwahe'e B/w in paste and temper. Type determinations were made based on paste characteristics, temper, surface treatment, decoration (design elements), and execution of design elements. All ceramic type and temper determinations were made by C. Dean Wilson. Sampling of sherds focused on ceramic types and sherd size. The primary objective of the study was to assess if any interregional trade and interaction with the Chaco regional system could be confirmed. We therefore selected sherds from Cibola white ware types commonly found at Chaco culture sites in the San Juan Basin and elsewhere to the west of the NRG. These types included Red Mesa Black-on-white (Red Mesa B/w; N = 32), Gallup B/w (N = 9), and Escavada B/w (N = 5). The production period for these ceramic types range from AD 875-1050 for Red Mesa B/w to AD 980-1150 for Gallup B/w (see http://ceramics.nmarchaeology.org/typology/ware?p=15). Because we needed to establish which sherds were locally produced and which might have been produced at centers within the Chaco regional system, we also selected sherds from ceramic types that make up the local Rio Grande, or Tewa, ceramic series. These local types included

Kwahe'e B/w (N = 37), Santa Fe B/w (N = 1), indented corrugated (N = 6), smeared neckbanded (N = 1), smeared corrugated utility ware (N = 2), as well as wide-neck banded (N = 5) and clapboard (N = 1) utility wares.

Statistical Analyses

Data from NAA of Late Developmental pottery sherds and wood-fired local clay samples from the southern Tewa Basin were combined with data (Appendix II) from a study of Chaco culture ceramics from sites located in the San Juan Basin and elsewhere in the northern southwest (Neitzel et al. 2002). The data were analyzed using principal components analysis (PCA), as well as cluster analysis using k-means and UPGMA methods. We used PCA as a multivariate ordination technique to reveal compositional groups, and to explore how such groups may differ from each other in terms of their chemical (elemental) composition. Principal components analysis was conducted using a correlation matrix (raw data), which is equivalent to an analysis using a covariance matrix of standardized (z-score) data. Using a correlation matrix prevents differences in higher magnitude elements from disproportionately impacting the analysis. Plots of principal component scores were interpreted visually. In principle, compositional groups would be represented by discrete clusters of data points in multivariate space defined by the principal components. We conducted three principal components analyses with various combinations of identified local and non-local groups, including those comprising sherds collected from Chacoan sites outside the Tewa Basin. Elements were identified as being important contributors to multivariate compositional space by evaluating eigenvector loadings from PCA. These variables were then used in bivariate analyses. We used k-means clustering to evaluate the legitimacy of visually identified compositional groups determined from PCA. K-means clustering is a non-hierarchical clustering method that assigns *n* observations into *k* clusters, where *k* is a predetermined number of hypothetical clusters (Jain 2010). For the present study, the number of clusters (*k*), or compositional groups, was determined visually from plots of principal component scores. We used UPGMA cluster analysis of Euclidian distances derived from the log-transformed data as a second way to identify compositional groups. UPGMA (unweighted pair group method with arithmetic mean) is an agglomerative hierarchical clustering method that groups similar observations into nested clusters (Manly 2005).

Results

Analysis 1

The initial PCA was conducted on the compositional data from fired clay tiles and the sherds collected from Late Developmental period sites in the Tewa Basin (N = 105). A visual assessment of the plot of the first two principal components describing 63% of the total variation across 32 elements indicated three groups (Table 1, Figure 4A). These groups were also identified by k-means clustering of scores from the first two principal components. Corresponding 95% confidence ellipses

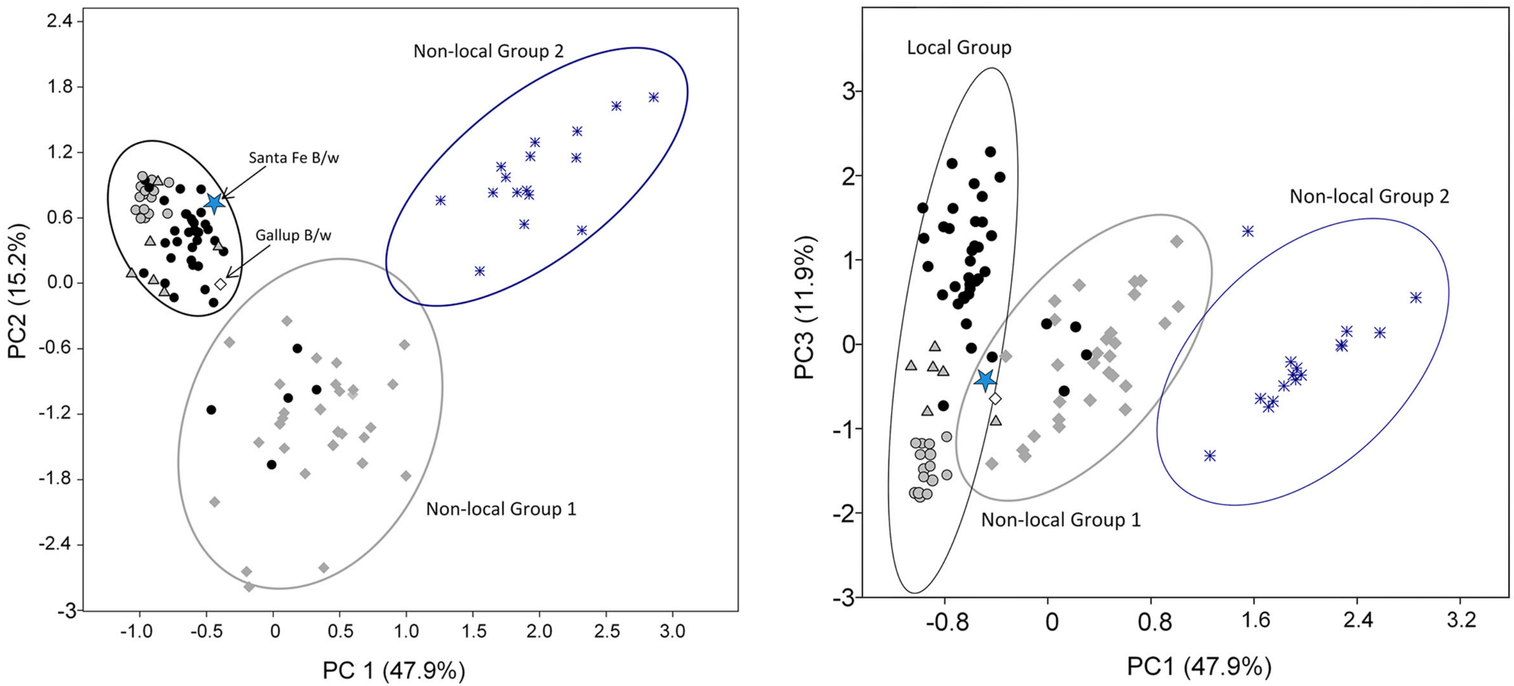

FIGURE 4. A. Plot of the first two principal components describing multivariate compositional space for one local and two non-local sherd groups. B. Plot of the first and third principal components describing multivariate compositional space. 95% confidence ellipses are shown. Principal components were based on a correlation matrix of elemental concentration values (ppm) for 32 elements. Plot symbols include black circles, Kwahe'e B/w; gray triangles, fired clay tiles; gray circles, gray wares; gray diamonds, Non-local Group 1; asterisks, Non-local Group 2.

TABLE 1.

RESULTS FROM A PRINCIPAL COMPONENTS ANALYSIS BASED ON A CORRELATION MATRIX OF PPM CONCENTRATIONS FOR 32 ELEMENTS MEASURED IN FIRED CLAY TILES AND 99 POTTERY SHERDS COLLECTED FROM 3 ARCHAEOLOGICAL SITES IN THE TEWA BASIN.

PC	Eigenvalue	% variance	Cumulative % variance
1	15.3287	47.902	47.902
2	4.85984	15.187	63.089
3	3.77271	11.790	74.879
		Eigenvector loadings	
Element	PC 1	PC 2	PC 3
As	−0.04317	−0.14007	0.02843
La	0.23667	0.06057	0.11254
Lu	0.22418	0.10966	0.11835
Nd	0.21076	0.16375	0.15249
Sm	0.21279	0.19936	0.15009
U	0.16868	0.00699	0.15942
Yb	0.22350	0.15591	0.09622
Ce	0.22818	0.08363	0.14544
Co	−0.18301	0.14680	0.27457
Cr	−0.05309	−0.13378	0.43129
Cs	−0.06654	−0.30402	0.01358
Eu	0.19088	0.24012	0.13145
Fe	−0.16257	0.09831	0.32159
Hf	0.20593	−0.03577	−0.14574
Rb	−0.15339	−0.05859	0.25742
Sb	0.05446	−0.30471	0.10654
Sc	0.02387	−0.21934	0.41831
Sr	−0.15721	0.16751	0.07177
Ta	0.19805	−0.00451	−0.01678
Tb	0.17855	0.27093	0.09876
Th	0.23275	−0.12816	0.03113
Zn	−0.17768	0.07111	0.28237
Zr	0.21299	−0.00386	−0.06724
Al	0.22553	−0.11747	0.046419
Ba	−0.14377	0.09351	−0.08360
Ca	−0.16784	0.23969	0.09290
Dy	0.20189	0.22964	0.07170
K	−0.14538	−0.00242	0.12733
Mn	−0.19970	0.23419	0.08214
Na	−0.20393	0.16616	−0.06600
Ti	0.16881	−0.27940	0.05233
V	0.01140	−0.32508	0.24784

Note: Only the results for the first three principal components are shown.

were subsequently fit to these groups. The first group included 55 sherds, almost entirely of local types including Kwahe'e B/w (N = 33, 60% of sherds in group), Santa Fe B/w (N = 1, 1.8%), indented or smeared indented corrugated (N = 8, 14.5%), wide neck-banded (N = 5, 9%), and clapboard neck-banded (N = 1, 1.8%). Also included within this group were a single sherd of Gallup B/w, and the 6 fired tiles of local clay samples. Given the prevalence of local types and the inclusion of the fired tiles from local clay sources, we identified this as a local group (Local Group) reflecting local manufacture of ceramic vessels using locally-available clays. The lone non-local white ware sherd of Gallup B/w (OAS044) identified based on stylistic attributes is unlikely to be a misidentified local type (i.e. Kwahe'e B/w) because it exhibited sherd temper, which is common for Cibola white wares such as Gallup B/w, but not typically, if ever, observed in the local white wares from the NRG. The second group (Non-local Group 1) comprised principal component scores from 34 sherds, mostly non-local Cibola white ware types including Red Mesa B/w (N = 20, 59%), Escavada B/w (N = 5, 15%), and Gallup B/w (N = 4, 12%). Also included in this group were five sherds (15%) of the local type Kwahe'e B/w (OAS076, OAS104, OAS118, OAS119, OAS124).[5] All five Kwahe'e B/w sherds in the group exhibited tuff and sand temper normally indicative of locally manufactured white wares. None exhibited sherd temper. Based on the prevalence of Cibola white wares in the group (85%), we identified this group as non-local (Non-local Group 1). The third group (Non-local group 2) consisted of 16 sherds of non-local types, including Red Mesa B/w (N = 12, 75%), and Gallup B/w (N = 4, 25%). We designated this third grouping as non-local (Non-local Group 2).

A comparative assessment of eigenvector loadings for the first principal component describing 48% of the total variation (Table 1) revealed a number of elements with high positive loadings (La, Lu, Nd, Sn, Yb, Ce, Hf, Th, Zr, Al, Dy), as well as low negative loadings (Na, Mn, Zn, Co, Ca), indicating these elements are important drivers of variation along this multivariate compositional vector which separates the three groups. The second principal component separates Non-local Group 1 from the Local Group and Non-local Group 2. For the second principal component Tb, Eu, Ca, and Mn exhibit comparatively high loadings, while V, Cs, Sb, and Ti exhibit comparatively low loadings. A plot of scores for the first and third principal components revealed the same three groups, albeit along the first principal component only. Although the three groups are not separated along the third principal component (Figure 4B), there is separation of utility wares and Kwahe'e B/w white sherds within the local group. The fired clay tiles from local sources, as well as the lone sherd of Santa Fe B/w, are positioned between these two local subgroups. Based on the eigenvector loadings, variation along the third principal component is being driven primarily by Co, Cr, and Zn (high positive loadings), and Hf (low negative loading).

The results from the UPGMA cluster analysis (Figure 5) supported the compositional groups identified by PCA, with the exception of OAS131 (Escavada B/w), which was positioned within Non-local Group 1 in the PCA analysis, and OAS121 (Escavada B/w), which did not cluster in either of two non-local groups. The same five Kwahe'e B/w sherds (OAS076, OAS104, OAS118, OAS119,

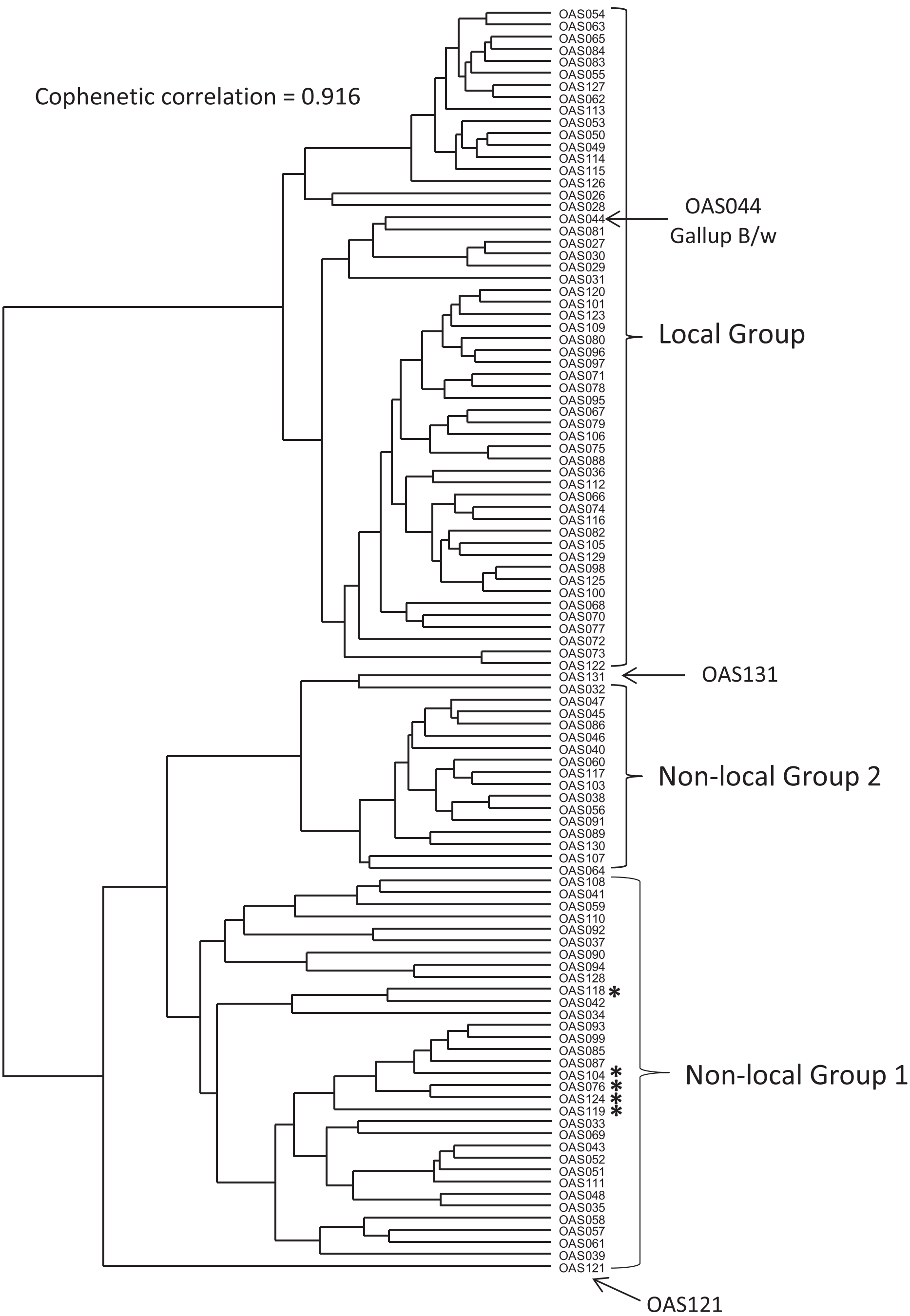

FIGURE 5. Dendrogram from UPGMA cluster analysis of Euclidian distances derived from the log-transformed elemental concentration values (ppm) for 32 elements. Asterisks denote the five sherds of Kwahe'e B/w manufactured with nonlocal clay (OAS076, OAS104, OAS118, OAS119, OAS124).

OAS124) that fell within Non-local Group 1 in the PCA analysis also clustered with this non-local group in the UPGMA analysis. The single sherd of Gallup B/w (OAS044) manufactured with sherd temper also clustered with the Local Group in the UPGMA results.

Analysis 2

The second PCA focused on sherds from the non-local groups. The objective of this analysis was to identify possible sources for the non-local Cibola white wares found on the Late Developmental period sites from the southern Tewa Basin. Data from the two non-local ceramic groups (Non-local Group 1 and 2) were included in this analysis. Because the non-local sherds were Cibola white ware types associated with Chaco culture, we pooled our data with data from Chacoan sites analyzed by Neitzel et al. (2002) for comparison. Specifically, we used their compositional groups representing ceramic production areas or zones within the Chaco regional system. These compositional groups for the most part comprised sherds collected from multiple great houses. Results from this PCA are presented in Table 2. We plotted the scores from the two non-local Tewa Basin groups on the convex hulls describing the distributions of principal component scores for Neitzel and colleagues' compositional groups. Figure 6 shows that the principal component scores for the Non-local Group 1 from the Tewa Basin—including the 5 sherds of Kwahe'e B/w made with non-local clay and tuff and sand temper identified in Analysis 1—plot within the convex hulls of Neitzel and colleagues' Chaco Reference, Guadalupe, Kin Ya'a, and Chimney Rock compositional groups, but not within the convex hulls of the Tocito and Chimney Rock A groups. The Non-local Group 2 from the Tewa Basin is separated from all Chaco groups in multivariate compositional space. Plots of subsequent principal components were uninformative, revealing largely overlapping groups.

Analysis 3

The third PCA included compositional data from select Chaco communities included in the study by Neitzel et al. (2002) rather than compositional groups representing broad production zones. The Chaco Reference Group (MURR data only) identified by that study is an aggregate grouping of sherds from multiple sites within the Chaco regional system. Based on the provenience of the sherds included in the Chaco Reference Group, Neitzel et al. (2002:53) interpret this group as representing a broad production zone for Dogoszhi style Cibola white wares (e.g. Gallup B/w) that lies between the Chuska Mountains and Chaco Canyon. Because the Chaco Reference group was an aggregate of multiple production centers, and we were interested in estimating where more specifically within this broad production zone the non-local sherds at Late Developmental sites in the Tewa Basin may have originated from, we selected data from individual Chacoan communities provided by Neitzel et al.'s study. For the most part we did not include data from the Neitzel et al. (2002) Chaco Reference, Tocito, or Chimney Rock A groups representing larger production zones. Based on the results of analysis 2, we included only those data

TABLE 2.

RESULTS FROM A PRINCIPAL COMPONENTS ANALYSIS BASED ON A CORRELATION MATRIX OF PPM CONCENTRATIONS FOR 32 ELEMENTS MEASURED IN 184 POTTERY SHERDS FROM ARCHAEOLOGICAL SITES WITHIN THE CHACO REGIONAL SYSTEM (DATA FROM NIETZEL ET AL [2002]) AND FROM THE TEWA BASIN.

PC	Eigenvalue	% variance	Cumulative % variance
1	11.1212	34.754	34.754
2	7.13995	22.312	57.066
3	3.46315	10.822	67.888
		Eigenvector loadings	
Element	PC 1	PC 2	PC 3
As	0.07949	−0.06071	0.006917
La	0.28526	0.07778	0.025446
Lu	0.08719	0.32945	0.027867
Nd	0.27739	0.07311	0.038327
Sm	0.27273	0.11996	0.034646
U	0.11083	0.20899	0.092201
Yb	0.08767	0.32963	0.082849
Ce	0.28060	0.10308	0.030847
Co	0.07875	−0.06625	0.14499
Cr	0.21253	−0.19324	−0.13172
Cs	−0.04237	−0.03356	0.48161
Eu	0.28037	0.05645	0.04421
Fe	0.18096	−0.19506	−0.14854
Hf	0.09508	0.20680	−0.24485
Rb	0.16258	−0.11035	0.32621
Sb	−0.09034	−0.08875	0.25531
Sc	0.09973	−0.05558	0.38201
Sr	0.22249	−0.18538	−0.09890
Ta	0.16840	0.10240	−0.12757
Tb	0.18724	0.21198	0.070371
Th	0.23653	0.08739	−0.00723
Zn	0.12934	−0.21108	0.21666
Zr	0.12557	0.22533	−0.14534
Al	−0.06874	0.24257	0.24007
Ba	0.17735	−0.20530	0.01924
Ca	0.18283	−0.15035	−0.15485
Dy	0.16577	0.26267	0.11237
K	0.21987	−0.11084	0.16995
Mn	0.19665	−0.22326	−0.09918
Na	0.15215	−0.19258	−0.15481
Ti	0.14020	0.00319	−0.11866
V	0.09109	−0.25388	0.19294

Note: Only the results for the first three principal components are shown.

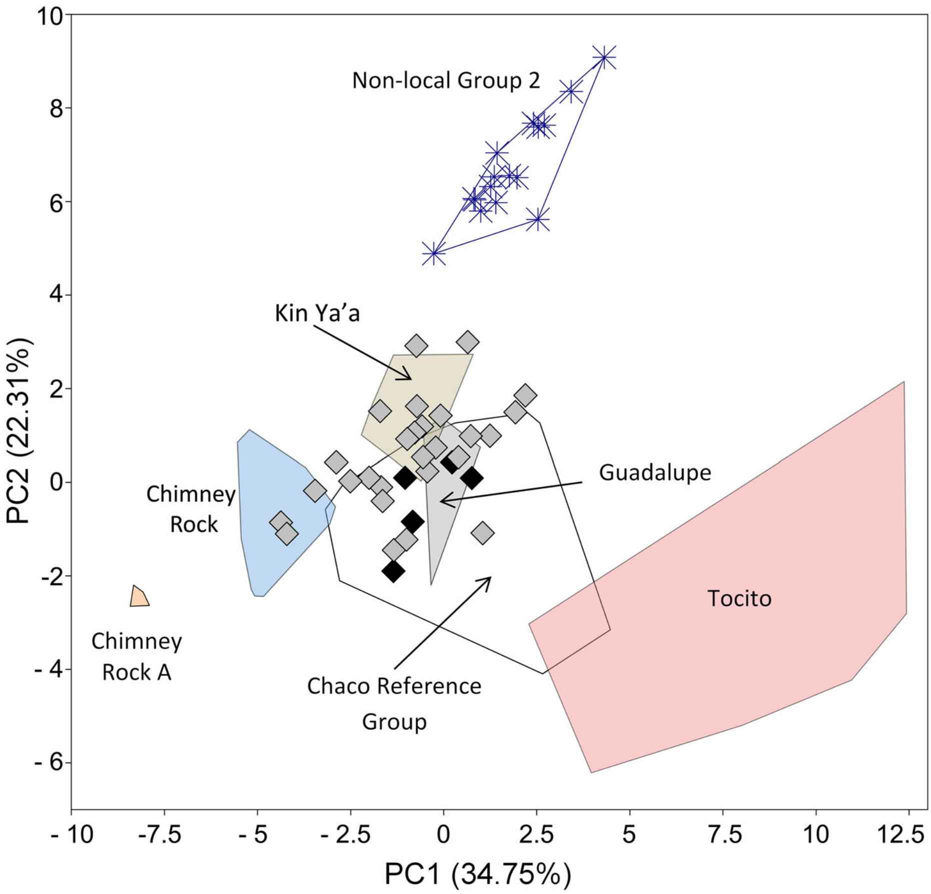

FIGURE 6. Plot of the first two principal components describing multivariate compositional space for the two non-local sherd groups from the Tewa Basin, and Chaco compositional groups representing production zones (data from Neitzel et al. 2002). Compositional groups are represented by convex hulls. Non-local Group 1 sherd values are represented by grey diamond symbols. Black diamond symbols represent the five Kwahe'e B/w sherds manufactured with non-local clay. Principal components were based on a correlation matrix of elemental concentration values (ppm) for 32 elements.

from the great house communities of Guadalupe, Kin Ya'a, and Chimney Rock that were also part of the compositional groups assigned to those sites by Nietzel et al. For example, we only included sherds from the Chimney Rock compositional group that were collected from the Chimney Rock great house. We also included data from Pueblo Pintado, as a representative of the regional system's core at Chaco Canyon. We interpret these data as representing community level production centers.

The results of this third PCA (Table 3, Figure 7) revealed that all of the sherds from Guadalupe, Kin Ya'a, and Pueblo Pintado fall within the 95% confidence ellipse of Non-local Group 1. In addition, 2 of 5 sherds from Chimney Rock also fall with this

TABLE 3.

RESULTS FROM A PRINCIPAL COMPONENTS ANALYSIS BASED ON A CORRELATION MATRIX OF PPM CONCENTRATIONS FOR 32 ELEMENTS MEASURED IN 138 POTTERY SHERDS FROM ARCHAEOLOGICAL SITES WITHIN THE CHACO REGIONAL SYSTEM (DATA FROM NIETZEL ET AL [2002]) AND FROM THE TEWA BASIN.

PC	Eigenvalue	% variance	Cumulative % variance
1	12.1695	38.030	38.030
2	5.85431	18.295	56.325
3	3.93624	12.301	68.626

	Eigenvector loadings		
Element	PC 1	PC 2	PC 3
As	−0.03686	−0.01016	0.1291
La	0.24722	0.15391	0.10604
Lu	0.23329	0.17531	−0.00628
Nd	0.21306	0.21886	0.12236
Sm	0.21656	0.25770	0.05927
U	0.18439	0.05668	0.07349
Yb	0.23528	0.19164	−0.00531
Ce	0.23552	0.18218	0.11671
Co	−0.02347	−0.05127	0.20081
Cr	−0.03620	0.01874	0.36251
Cs	−0.00935	−0.14689	0.30264
Eu	0.19394	0.26801	0.06483
Fe	−0.15685	0.20908	0.17793
Hf	0.19549	−0.08989	−0.14616
Rb	−0.10264	0.12943	0.35752
Sb	0.04894	−0.29517	0.12878
Sc	0.05281	−0.09431	0.43042
Sr	−0.15631	0.19541	0.029521
Ta	0.20520	−0.04521	−0.06071
Tb	0.18264	0.25806	−0.02415
Th	0.25530	−0.12143	0.06375
Zn	−0.17375	0.1323	0.24078
Zr	0.21438	−0.05303	−0.09262
Al	0.23786	−0.13721	0.08899
Ba	−0.13727	0.04696	0.03988
Ca	−0.17846	0.23232	−0.03140
Dy	0.21747	0.21844	−0.02674
K	−0.10890	0.18505	0.24669
Mn	−0.21086	0.23696	−0.03044
Na	−0.21024	0.19916	−0.08897
Ti	0.17465	−0.23337	0.08797
V	0.03277	−0.21898	0.34625

Note: Only the results for the first three principal components are shown.

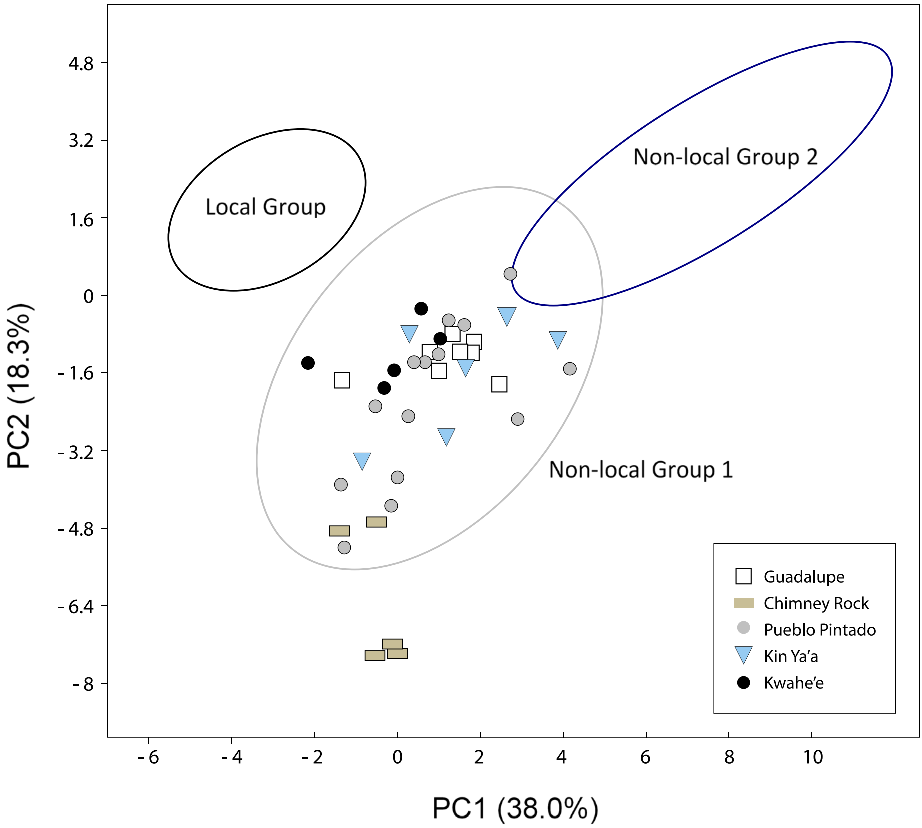

FIGURE 7. Plot of the first two principal components describing multivariate compositional space for one local and two non-local sherd groups, as well as Chaco sherd values (data from Neitzel et al. 2002). 95% confidence ellipses are shown for Tewa Basin groups only. Principal components were based on a correlation matrix of elemental concentration values (ppm) for 32 elements. Sherd values from various Chaco great house communities are individually plotted: squares, Guadalupe; rectangle, Chimney Rock; gray circle; Pueblo Pintado; gray triangle, Kin Ya'a; black circles, Kwahe'e B/w sherds manufactured with non-local clay.

same confidence ellipse. The same five sherds of Kwahe'e B/w with local temper that fell within the confidence ellipse of Non-local Group 1 in analysis 1, were similarly positioned in analysis 3. As expected based on the results of analysis 2, none of the sherds from these Chaco groups fell within the 95% confidence ellipse of Non-local Group 2.

Bivariate Analysis

A comparison of eigenvector loadings from analysis 1 and 3 (cf. Tables 1 and 3) revealed a very similar pattern of elements with high positive loadings and low negative loadings for the first principal component, along which most of the separation among the three compositional groups is observed. The comparatively high positive loadings in common between analysis 1 and 3 include La, Lu, Nd, Sm, Yb, Ce, Th, Zr, Al, and Dy. The shared low negative loadings include Na, Mn, Zn, and Sr. Among these elements lanthanum (La) and manganese (Mn) had the highest (or near highest) and lowest (or near highest) loadings respectively in analysis 3, which included data from Chaco great house ceramic assemblages representing community level production centers. After examining other elemental pairings, these two elements provided the best bivariate separation of the compositional groups determined by PCA. Using the analysis 3 data set, a bivariate plot of lanthanum and manganese values (Figure 8) indicates that the local sherds from the Tewa Basin exhibit higher concentrations of manganese compared to the non-local Cibola white wares. The Non-local Group 2 is marginally separated from Non-local Group 1 and the Chaco groups by exhibiting higher concentrations of lanthanum. The same five sherds of Kwahe'e B/w with local temper that fell within the confidence ellipse of Non-local Group 1 in PCA analysis 1 and 3, also fell well within the

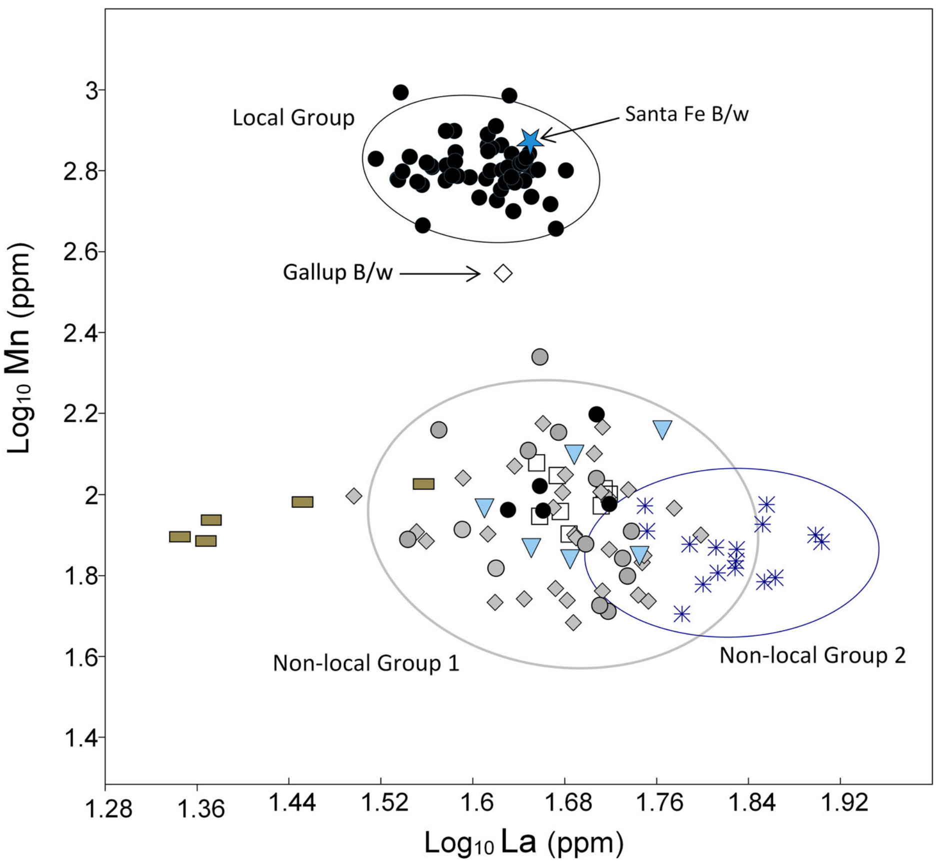

FIGURE 8. Bivariate plot of log-transformed ($\log_{10}$) lanthanum (La) and manganese (Mn) values (ppm). 95% confidence ellipses are shown for Tewa Basin groups only. Sherd values from various Chaco great house communities (data from Neitzel et al. 2002) are individually plotted: squares, Guadalupe; rectangle, Chimney Rock; gray circle; Pueblo Pintado; gray triangle, Kin Ya'a; black circles, Kwahe'e B/w sherds manufactured with non-local clay.

TABLE 4.

COMPOSITIONAL GROUP MEANS AND STANDARD DEVIATIONS FOR THE 32 ELEMENTS INCLUDED IN THE NAA OF POT SHERDS FROM LATE DEVELOPMENTAL PERIOD SITES IN THE TEWA BASIN.

	Local (N = 55)[n]		Non-local 1 (N = 34)		Non-local 2 (N = 16)	
	Mean (ppm)	SD	Mean (ppm)	SD	Mean (ppm)	SD
As	3.829	1.229	5.128	3.201	2.586	0.506
La	40.639	3.723	48.222	6.886	67.296	7.009
Lu	0.528	0.069	0.589	0.103	0.917	0.116
Nd	36.279	3.934	38.016	6.354	55.777	6.094
Sm	7.496	0.750	7.503	1.196	11.778	1.197
U	5.538	1.570	6.790	2.559	10.135	2.781
Yb	3.422	0.374	3.599	0.484	5.541	0.486
Ce	86.905	9.027	98.849	15.397	137.521	13.795
Co	13.226	3.183	5.090	2.140	3.121	0.841
Cr	60.959	17.753	62.782	12.405	43.497	8.711
Cs	9.816	1.409	12.158	2.681	7.152	1.572
Eu	1.393	0.109	1.325	0.228	2.055	0.219
Fe	36092.150	7315.593	23362.140	6900.571	16885.220	1327.489
Hf	5.763	0.758	7.894	1.617	9.758	0.606
Rb	133.252	14.433	125.170	17.016	94.469	13.419
Sb	0.661	0.207	1.013	0.304	0.741	0.104
Sc	13.708	2.757	15.390	1.806	13.081	1.384
Sr	257.730	58.757	169.021	63.751	144.860	30.635
Ta	1.397	0.166	1.604	0.288	1.970	0.190
Tb	0.981	0.098	0.876	0.150	1.498	0.173
Th	12.537	1.321	19.273	3.066	23.743	2.393
Zn	93.887	17.235	62.669	20.489	42.613	6.374
Zr	163.652	24.603	211.189	40.510	273.869	27.200
Al	80118.070	6728.646	105028.100	12727.100	126885.400	12710.250
Ba	642.104	202.805	496.494	128.900	382.669	54.549
Ca	29649.360	7736.534	8379.247	7490.582	8956.631	2600.222
Dy	5.250	0.514	4.948	0.699	8.713	0.984
K	26435.050	2684.300	24363.010	4360.258	19819.640	2842.814
Mn	649.316	105.905	90.824	28.496	74.746	12.431
Na	9943.307	2145.089	4526.503	1902.361	2086.269	489.275
Ti	4087.905	472.240	5962.900	767.022	5570.800	255.474
V	85.489	23.585	116.938	17.062	74.333	15.033

[1]N = 55 includes six fired tiles made from local Tewa Basin clays.

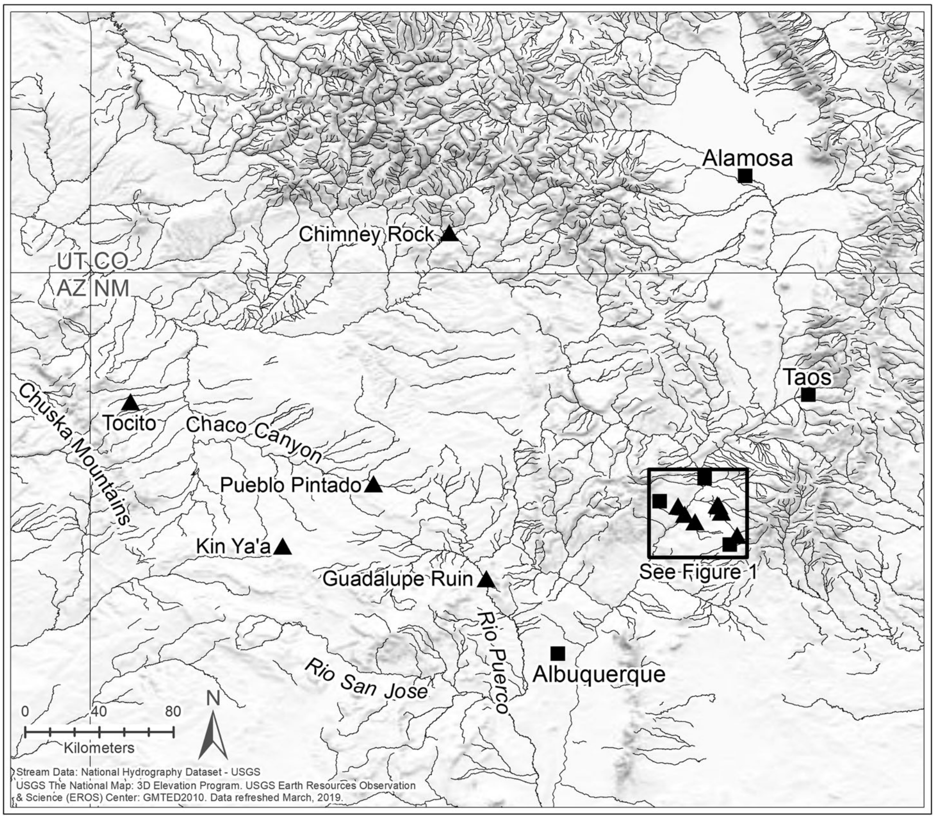

FIGURE 9. Map showing Chaco great house communities included in the study. Inset box denotes area represented by the regional map (cf. Figure 3).

bivariate distribution for Non-local Group 1 in this comparison of lanthanum and manganese concentrations. The results of this bivariate analysis are supported by a comparison of mean values among the three compositional groupings (Table 4), which also shows a higher mean concentration of lanthanum for Non-local Group 2, as well as higher mean concentration of manganese for the Local Group from the Tewa Basin.

Discussion

We draw three primary conclusions from the results of our study of compositional data derived from NAA of ceramic sherds and fired clay tiles. First, the sherds from the Tewa Basin sites included in the study formed three major compositional groups, one local and two non-local. The local group is made up of two sub-groups, one comprising local white ware sherds exhibiting primarily tuff, or tuff and sand temper, and another comprising utility gray wares exhibiting mica and granite temper. Second, based on the overlap of Non-local Group 1 and various Chaco compositional groups in multivariate compositional space, as well as overlap in bivariate space describing variation in lanthanum and manganese concentrations, we infer that sherds from Non-local Group 1 likely originated from Cibola white ware vessels produced within the Chaco regional system more than 100 km to the west of the Tewa Basin. From analysis 3 we further infer that many of these vessels originated from community level production centers including great house communities within Chaco Canyon (Pueblo Pintado), as well as south (Kin Ya'a), north (Chimney Rock), and east (Guadalupe) of Chaco Canyon, but not communities in the greater Chuska region (Tocito)(Figure 9). Third, not all of the Cibola white ware vessels were brought in from the great house communities listed above, or from the broad production zone for Cibola white wares that lies between the Chuska Mountains and Chaco Canyon, because none of the comparative compositional groups included in our study overlapped with Non-local Group 2, leaving the geographic origin of production for this compositional group unknown. The Rio Puerco (east) valley and Rio San Jose valley regions are possible sources of production for this non-local group. Previously, we suggested that the sudden population increase in the Tewa Basin beginning around A.D. 900 could represent an influx of Proto-Tewa-Tiwa-speakers from the Rio San Jose valley, the Rio Puerco (east) valley, and/or the MRG, including the Santo Domingo Basin and Albuquerque Valley (Lakatos and Wilson 2012; Schillaci and Lakatos 2017). The movement of these Proto-Tewa-Tiwa groups north through the Santo Domingo Basin to the Tewa Basin during the A.D. 800s, therefore, could have resulted in the introduction to the Tewa Basin of both the Proto-Tewa-Tiwa language and Cibola white wares including Red Mesa B/w. Similar scenarios, either in part or in whole, have been presented by others (cf. Mera 1935; Wendorf 1954; Wendorf and Reed 1955; McNutt 1969; Ford et al. 1972; Boyer et al. 2010; but see Ortman 2012 for alternative view). Additional chemical compositional research with provenienced sherds and sourced clay samples from the Rio San Jose valley, the Rio Puerco (east) valley, and the Santo Domingo Basin are needed to assess this proposed scenario.

Our results yielded unexpected and interesting secondary findings. Originating from a vessel manufactured with local clay, the single sherd of the non-local type Gallup B/w (OAS044) was likely typed correctly given it exhibited sherd temper, which is uncharacteristic of local production. This suggests that at least a small number of Cibola white ware vessels were manufactured in the southern Tewa Basin, possibly by re-located Chaco community potters using local materials (clay) with Cibola tradition manufacturing techniques (sherd temper, Dogoszhi style design elements) This finding compliments those presented by Wiseman and Olinger (1991, Table 1) who identified 14 Cibola white ware sherds from LA 835 (*K'u:yemuge ˀówîŋge*) that fell into their local group composed primarily of Kwahe'e B/w. Surprisingly, our results also identified five sherds of Kwahe'e B/w originating from two sites (*K'u:yemuge ˀówîŋge* [LA 835] and LA 6579) with compositional profiles placing them firmly within Non-local Group 1, which as we have shown, comprises Cibola white ware sherds produced at various Chaco great house communities in the San Juan Basin, including one from Chaco Canyon. Parenthetically, one of these sites, *K'u:yemuge ˀówîŋge* (LA 835), has been identified by multiple Tewa consultants[6] as being an ancestral Tewa settlement (see Schillaci et al. 2017). The fact that these five Kwahe'e B/w sherds exhibit tuff temper typical of local production means that a local pottery type, Kwahe'e B/w, was made with non-local clay (Non-local Group 1) from the Chaco regional system to the west, and tempered with local materials (tuff, or sand and tuff), indicating that both finished ceramic vessels and raw untempered clay were brought, or traded, from Chaco communities to ancestral Tewa communities in the NRG. Our findings again compliment those presented by Wiseman and Olinger (1991, Table 1) who identified 6 of 61 Kwahe'e B/w sherds with non-local compositional profiles, presumably reflecting production areas to the west. We can only speculate as to why non-local clay would be brought in from a considerable distance when suitable clay from local sources was available. Ethnographic data suggests an upper threshold limit of about 7–9 km for raw clay procurement (Arnold 1985; Druc 2013:502). Such a threshold is largely consistent with the results of our compositional analysis indicating use of Tewa Basin clays in the production of Kwahe'e B/w.

Recently Eckert et al. (2015) employed communities of practice and identity (see discussions in Eckert 2008, 2012; Cordell and Habicht-Mauche 2012; Joyce 2012) as a conceptual framework in their study of the production of Santa Fe B/w in the NRG. They defined communities of practice as social networks in which potters share a technological tradition (Eckert et al. 2015:8). The authors explained that the selection of clay and temper are early steps in the production process, and that these choices are affected by a potter's community of practice, as are choices made later during construction of a vessel, including choices regarding decoration style and the use of particular design elements (Eckert et al. 2015:8). Eckert et al. (2015:2) defined communities of identity as social networks in which potters share a group identity, and explained that as individuals move between different social contexts, they will emphasize membership in the community of identity (e.g. ethnicity, language, class, lineage) that most benefits them within a particular social context. We suggest that the use of local temper, local clay—as revealed by our compositional analysis—and a distinctive decoration style in the production of Kwahe'e B/w is consistent with a communities of practice and identity framework.

We propose that the enigmatic Kwahe'e B/w vessels constructed from non-local clay from Chaco regional sources might *also* reflect local Tewa Basin communities of identity and practice. Druc (2013:487), drawing on Shepard (1968) and others, outlines a number of possible scenarios that can obscure the identification of local and nonlocal ceramic production. Of these scenarios, we see two that could apply to a community of practice framework for interpreting the production of Kwahe'e B/w using non-local clay. For the first scenario, migrants from Chaco communities to the west brought clay with them to the Tewa Basin that they obtained from their local clay sources in the San Juan Basin. These re-located or migrant potters then used their transported non-local clay to produce a local Tewa Basin ceramic type in the local Tewa ceramic tradition to establish membership in a new social network (community of practice) with a new shared group identity (community of identity). We have no way of knowing for certain, however, if clay was transported by Chaco migrants when relocating to the Tewa Basin, or if migrant potters made return trips to obtain clay from San Juan Basin sources, or even if they continued their participation in a Chacoan procurement network (Huntley et al. 2012), thus implying a preference for non-local (i.e, outside the Tewa Basin) materials for ceramic production. The ethnographic data mentioned earlier indicates return trips to the San Juan Basin to collect clay were unlikely. A preference for non-local materials also seems unlikely given the fact that the Kwahe'e B/w vessels in question were produced using local temper materials (tuff), which we view as indicative of a local community of practice. A reviewer of this manuscript suggested that use of non-local clay might reflect a potter's effort to remain symbolically connected to their Chaco homeland, or perhaps a blending of communities of practice. Both suggestions are possible. Here it is important to reiterate that because at least one of the settlements included in the present study, *K'u:yemuge ˀówîŋge*, is ancestral Tewa, communities of identity and practice engaged in the production of Kwahe'e B/w comprised primarily, but perhaps not entirely, local ancestral Tewa potters. Non-local potters—likely females from Chaco communities who married into local ancestral Tewa communities[7]—would have participated in the social network producing ceramic vessels in the local Tewa tradition as a means for integrating themselves into a new local community.

For the second scenario, non-local clay was obtained by way of trade and used by local ancestral Tewa potters to produce the local ceramic type Kwahe'e B/w consistent with the local community of practice to assert or reflect a shared group identity (community of identity). This scenario would require that the potter's choice of clay not be an essential component to the local ceramic tradition and community of practice. Trade of non-local clays associated with Chaco ceramic production suggests ancestral communities in the Tewa Basin may have participated in a large extra-regional procurement network associated with the Chaco regional system. This notion is supported by the presence of obsidian and turquoise originating from the NRG at Chaco communities (see Moore et al. 2020).

We believe that the production of Kwahe'e B/w embodied communities of identity and practice that were directly ancestral to those described by Eckert et al. (2015) for Santa Fe B/w, and that the local Tewa ceramic series, to which Kwahe'e B/w and Santa Fe B/w belong, reflects enduring cultural cohesion and continuity. It is interesting to note that communities of identity and practice are also reflected in the vernacular pit-house architecture of the Late Developmental period in the NRG. As we have discussed elsewhere (Lakatos and Wilson 2012; Schillaci and Lakatos 2017), the continuity and conservatism reflected by the Tewa ceramic series is homologous to the continuity and conservatism reflected in pit-house architecture described by Lakatos (2003, 2006, 2007). This continuity in ceramic tradition and vernacular architecture both stem from the same communities of identity and practice, and embody the same conservative cultural habitus.

Conclusion

Despite representing only a small percentage of overall ceramic assemblages, the Cibola white wares present at Late Developmental sites in the Tewa Basin, and elsewhere in the NRG, have been regarded as evidence for interaction with Chaco communities in the San Juan Basin. The present study offers additional empirical evidence that such interaction occurred. In addition to a larger production zone within the Chaco regional system, we identified individual Chaco great house communities, including one within the Chaco core, as likely sources of this interaction. As pointed out by an anonymous reviewer of this paper, our results not only establish that there was significant interaction between Late Developmental period communities in the Tewa Basin and Chaco communities, they also challenge the ways archaeologists identify local and non-local ceramics. Our study identified a single sherd of a non-local type (Gallup B/w), exhibiting a local clay compositional profile, but manufactured using a non-local technique (sherd temper). We also uncovered evidence of raw untempered clay being traded or brought into Tewa communities from Chaco sources, and adapted to local manufacture techniques. These secondary findings suggest that there may have been flexibility in the use of raw materials in the construction of ware types within regional ceramic traditions, and that such flexibility can be accommodated within local communities of practice and identity. Future research exploring ceramic trade to the NRG should include comparative compositional data from Chaco communities in the Rio San Jose and Rio Puerco (east) valleys, as well as from fired clay samples originating from these potential production areas.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1 We would include late Kiatuthlana B/w and the early Red Mesa B/w variants.

2 Wasters are protective covering sherds used during pottery firings.

3 Kelley (1948, 6) referred to these deposits as "Culebra Lake clay". Strictly speaking, deposition of these Late Pleistocene lacustrine clays was not associated with the Late Pliocene Culebra Lake (see Dethier and Fagenholz 2007). Previous pottery replication experiments have demonstrated that the Late Pleistocene "Culebra Lake" clays from Cañada Ancha are suitable for construction of coiled vessels (Lakatos 1995).

4 Figure 5 in in Crowe et al. (1978) depicts the actual sampling location of the Totavi clay used in the present study. A description of the geology of this location is presented on pages 9 and 10, where Crowe et al. describe the lacustrine sediments as "tuffaceous siltstone" rather than tuffaceous clay.

5 It is important to note that these sherds exhibited mineral paint, thus distinguishing them from the local white ware type Santa Fe B/w which exhibits organic paint.

6 The Late Developmental period site LA 835 (aka "Pojoaque Grant Site" also includes LA 833 and LA 834) has been identified by *at least* two different Tewa consultants on separate occasions as the ancestral Tewa settlement *K'u:yemuge ˀówîŋge* (see Schillaci et al. 2017). This site is listed on the National Register of Historic Places in large part because Pojoaque Pueblo oral tradition maintains that *K'u:yemuge ˀówîŋge* was an ancestral Tewa village that continues to have spiritual importance to the pueblo, which maintains traditional connections to the site (U.S. Department of Interior, August 3, 2015).

7 The notion of female migrants from Chaco communities is particularly interesting considering recent research (Kennett et al. 2017) indicating matrilocality at the great house community of Pueblo Bonito (contra Schillaci and Stojanowski 2002, 2003; Stojanowski and Schillaci 2006; also see discussions in Ensor et al. 2017; Schillaci and Stojanowski 2017).

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Appendix I. Descriptive information for sherds from the Tewa Basin used in the analysis.

ID	Site	Type	Group	Vessel	Temper
OAS026	Totavi	NRGtile	Local Group	Tile	self-tempered
OAS027	Culebra Lake	NRGtile	Local Group	Tile	self-tempered, sand
OAS028	Culebra Lake	NRGtile	Local Group	Tile	self-tempered
OAS029	Culebra Lake	NRGtile	Local Group	Tile	self-tempered
OAS030	Bishop's Lodge	NRGtile	Local Group	Tile	volcanic ash
OAS031	Santa Fe Ranch	NRGtile	Local Group	Tile	volcanic ash
OAS036	LA 388	Kwahe'e B/w	Local Group	Bowl body	tuff, sand
OAS044	LA 388	Gallup B/w	Local Group	Jar body	sherd, sand
OAS049	LA 388	Wide Neckbanded	Local Group	Jar rim	mica, granite
OAS050	LA 388	Wide Neckbanded	Local Group	Jar body	mica, granite
OAS053	LA 388	Indented Corrugated	Local Group	Jar neck	mica, granite
OAS054	LA 388	Clapboard Neck	Local Group	Jar body	mica, granite
OAS055	LA 388	Wide Neckbanded	Local Group	Jar neck	mica, granite
OAS062	LA 6579	Smeared Neckbanded	Local Group	Jar neck	mica, granite
OAS063	LA 6579	Smeared Indented	Local Group	Jar body	mica, granite
OAS065	LA 6579	Indented Corrugated	Local Group	Jar body	mica, granite
OAS066	LA 6579	Kwahe'e B/w	Local Group	Bowl body	tuff, sand
OAS067	LA 6579	Kwahe'e B/w	Local Group	Bowl body	tuff, sand
OAS068	LA 6579	Kwahe'e B/w	Local Group	Bowl rim	tuff
OAS070	LA 6579	Kwahe'e B/w	Local Group	Jar body	tuff
OAS071	LA 6579	Kwahe'e B/w	Local Group	Bowl body	tuff, sand
OAS072	LA 6579	Santa Fe B/w	Local Group	Bowl body	tuff
OAS073	LA 6579	Kwahe'e B/w	Local Group	Indet. rim	tuff
OAS074	LA 6579	Kwahe'e B/w	Local Group	Jar body	tuff, sand
OAS075	LA 6579	Kwahe'e B/w	Local Group	Jar neck	tuff
OAS077	LA 6579	Kwahe'e B/w	Local Group	Bowl body	tuff, sand
OAS078	LA 6579	Kwahe'e B/w	Local Group	Bowl body	tuff
OAS079	LA 6579	Kwahe'e B/w	Local Group	Bowl body	tuff
OAS080	LA 6579	Kwahe'e B/w	Local Group	Jar body	tuff
OAS081	LA 6579	Kwahe'e B/w	Local Group	Jar body	tuff
OAS082	LA 6579	Kwahe'e B/w	Local Group	Bowl body	tuff
OAS083	LA 6579	Indented Corrugated	Local Group	Jar body	mica, granite
OAS084	LA 6579	Indented Corrugated	Local Group	Jar rim	mica, granite
OAS088	LA 835	Kwahe'e B/w	Local Group	Bowl rim	fine silt

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ID	Site	Type	Group	Vessel	Temper
OAS095	LA 835	Kwahe'e B/w	Local Group	Bowl body	tuff, sand
OAS096	LA 835	Kwahe'e B/w	Local Group	Bowl rim	tuff
OAS097	LA 835	Kwahe'e B/w	Local Group	Bowl rim	tuff
OAS098	LA 835	Kwahe'e B/w	Local Group	Bowl rim	fine sand, silt
OAS100	LA 835	Kwahe'e B/w	Local Group	Bowl rim	fine silt, sand
OAS101	LA 835	Kwahe'e B/w	Local Group	Bowl rim	fine silt, sand
OAS105	LA 835	Kwahe'e B/w	Local Group	Bowl rim	tuff, sand
OAS106	LA 835	Kwahe'e B/w	Local Group	Bowl body	tuff, sand
OAS109	LA 835	Kwahe'e B/w	Local Group	Bowl rim	tuff, sand
OAS112	LA 835	Kwahe'e B/w	Local Group	Bowl body	tuff, sand
OAS113	LA 835	Wide Neckbanded	Local Group	Jar rim	granite, mica
OAS114	LA 835	Wide Neckbanded	Local Group	Jar neck	granite, mica
OAS115	LA 835	Indented Corrugated	Local Group	Jar neck	granite, mica
OAS116	LA 835	Kwahe'e B/w	Local Group	Jar body	tuff, sand
OAS120	LA 835	Kwahe'e B/w	Local Group	Bowl body	tuff, sand
OAS122	LA 835	Kwahe'e B/w	Local Group	Bowl rim	tuff, sand
OAS123	LA 835	Kwahe'e B/w	Local Group	Bowl body	tuff, sand
OAS125	LA 835	Kwahe'e B/w	Local Group	Bowl body	tuff, sand
OAS126	LA 835	Smeared Corrugated	Local Group	Jar body	granite, mica
OAS127	LA 835	Indented Corrugated	Local Group	Jar body	granite, mica
OAS129	LA 835	Kwahe'e B/w	Local Group	Bowl rim	tuff
OAS033	LA 388	Red Mesa B/w	Non-local Group 1	Bowl body	fine sandstone
OAS034	LA 388	Red Mesa B/w	Non-local Group 1	Bowl body	sherd, sand
OAS035	LA 388	Red Mesa B/w	Non-local Group 1	Jar body	tuff, sand
OAS037	LA 388	Red Mesa B/w	Non-local Group 1	Jar body	sherd, sand
OAS039	LA 388	Red Mesa B/w	Non-local Group 1	Bowl rim	fine sandstone
OAS041	LA 388	Red Mesa B/w	Non-local Group 1	Bowl body	sherd, sand
OAS042	LA 388	Red Mesa B/w	Non-local Group 1	Jar body	sherd, sand
OAS043	LA 388	Red Mesa B/w	Non-local Group 1	Bowl body	sherd, sand
OAS048	LA 388	Red Mesa B/w	Non-local Group 1	Jar body	sherd, sand
OAS051	LA 388	Red Mesa B/w	Non-local Group 1	Bowl body	fine sandstone
OAS052	LA 388	Red Mesa B/w	Non-local Group 1	Jar neck	fine sandstone
OAS057	LA 388	Red Mesa B/w	Non-local Group 1	Bowl rim	sherd, sand
OAS058	LA 388	Gallup B/w	Non-local Group 1	Bowl rim	sherd
OAS059	LA 388	Red Mesa B/w	Non-local Group 1	Bowl rim	sherd, sand
OAS061	LA 388	Red Mesa B/w	Non-local Group 1	Jar body	sherd, sand

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ID	Site	Type	Group	Vessel	Temper
OAS069	LA 6579	Red Mesa B/w	Non-local Group 1	Bowl body	sand
OAS076	LA 6579	Kwahe'e B/w	Non-local Group 1	Bowl body	tuff, sand
OAS085	LA 835	Gallup B/w	Non-local Group 1	Jar body	fine sandstone
OAS087	LA 835	Escavada B/w	Non-local Group 1	Bowl rim	fine sandstone
OAS090	LA 835	Red Mesa B/w	Non-local Group 1	Bowl body	sherd, sand
OAS092	LA 835	Escavada B/w	Non-local Group 1	Bowl rim	sherd, sand
OAS093	LA 835	Escavada B/w	Non-local Group 1	Bowl rim	sherd, sand
OAS094	LA 835	Red Mesa B/w	Non-local Group 1	Bowl rim	sherd, sand
OAS099	LA 835	Red Mesa B/w	Non-local Group 1	Bowl rim	fine sandstone
OAS104	LA 835	Kwahe'e B/w	Non-local Group 1	Bowl body	tuff, sand
OAS108	LA 835	Gallup B/w	Non-local Group 1	Bowl body	sherd, sand
OAS110	LA 835	Gallup B/w	Non-local Group 1	Bowl rim	sand
OAS111	LA 835	Red Mesa B/w	Non-local Group 1	Bowl rim	sand, sherd
OAS118	LA 835	Kwahe'e B/w	Non-local Group 1	Bowl body	tuff, sand
OAS119	LA 835	Kwahe'e B/w	Non-local Group 1	Bowl body	tuff, sand
OAS121	LA 835	Escavada B/w	Non-local Group 1	Bowl rim	sherd, sand
OAS124	LA 835	Kwahe'e B/w	Non-local Group 1	Bowl body	tuff, sand
OAS128	LA 835	Red Mesa B/w	Non-local Group 1	Bowl rim	sherd, sand
OAS131	LA 835	Escavada B/w	Non-local Group 1	Jar body	fine sandstone
OAS032	LA 388	Gallup B/w	Non-local Group 2	Jar body	sherd, sand
OAS038	LA 388	Red Mesa B/w	Non-local Group 2	Bowl rim	sherd, sand
OAS040	LA 388	Red Mesa B/w	Non-local Group 2	Bowl body	shale
OAS045	LA 388	Red Mesa B/w	Non-local Group 2	Bowl body	sherd
OAS046	LA 388	Red Mesa B/w	Non-local Group 2	Jar neck	sherd, sand
OAS047	LA 388	Red Mesa B/w	Non-local Group 2	Bowl body	sherd, sand
OAS056	LA 388	Red Mesa B/w	Non-local Group 2	Bowl rim	sherd, sand
OAS060	LA 388	Gallup B/w	Non-local Group 2	Jar body	sherd, sand
OAS064	LA 6579	Red Mesa B/w	Non-local Group 2	Jar body	sand
OAS086	LA 835	Red Mesa B/w	Non-local Group 2	Bowl body	sherd, sand
OAS089	LA 835	Red Mesa B/w	Non-local Group 2	Bowl rim	sherd, sand
OAS091	LA 835	Red Mesa B/w	Non-local Group 2	Bowl body	sherd, sand
OAS103	LA 835	Red Mesa B/w	Non-local Group 2	Bowl body	sherd, sand
OAS107	LA 835	Gallup B/w	Non-local Group 2	Bowl body	sand, sherd
OAS117	LA 835	Gallup B/w	Non-local Group 2	Bowl rim	sherd, sand
OAS130	LA 835	Red Mesa B/w	Non-local Group 2	Jar body	fine sandstone

Appendix II: Descriptive information for sherds from Neitzel et al. (2002) used in the present study.

ID	Site	Compositional Group
Analysis 2		
JNE003	Wallace Ruin	Chaco Reference
JNE004	Wallace Ruin	Chaco Reference
JNE007	Wallace Ruin	Chaco Reference
JNE011	Wallace Ruin	Chaco Reference
JNE017	Chimney Rock	Chaco Reference
JNE018	Chimney Rock	Chaco Reference
JNE022	Chimney Rock	Chaco Reference
JNE031	Morris 41	Chaco Reference
JNE036	Morris 41	Chaco Reference
JNE037	Morris 41	Chaco Reference
JNE038	Morris 41	Chaco Reference
JNE041	Morris 41	Chaco Reference
JNE043	Morris 41	Chaco Reference
JNE046	Salmon Ruin	Chaco Reference
JNE048	Salmon Ruin	Chaco Reference
JNE049	Salmon Ruin	Chaco Reference
JNE052	Salmon Ruin	Chaco Reference
JNE055	Salmon Ruin	Chaco Reference
JNE058	Salmon Ruin	Chaco Reference
JNE061	Four Clowns	Chaco Reference
JNE062	Four Clowns	Chaco Reference
JNE063	Four Clowns	Chaco Reference
JNE064	Four Clowns	Chaco Reference
JNE065	Four Clowns	Chaco Reference
JNE068	Four Clowns	Chaco Reference
JNE069	Four Clowns	Chaco Reference
JNE072	Four Clowns	Chaco Reference
JNE073	Four Clowns	Chaco Reference
JNE092	Indian Creek	Chaco Reference
JNE094	Indian Creek	Chaco Reference
JNE095	Indian Creek	Chaco Reference
JNE096	Indian Creek	Chaco Reference
JNE098	Indian Creek	Chaco Reference
JNE099	Indian Creek	Chaco Reference

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ID	Site	Compositional Group
JNE100	Indian Creek	Chaco Reference
JNE101	Indian Creek	Chaco Reference
JNE102	Indian Creek	Chaco Reference
JNE103	Indian Creek	Chaco Reference
JNE108	Aztec West	Chaco Reference
JNE109	Aztec West	Chaco Reference
JNE111	Aztec West	Chaco Reference
JNE113	Aztec West	Chaco Reference
JNE114	Aztec West	Chaco Reference
JNE115	Aztec West	Chaco Reference
JNE116	Aztec West	Chaco Reference
JNE120	Aztec West	Chaco Reference
JNE121	Pueblo Pintado	Chaco Reference
JNE123	Pueblo Pintado	Chaco Reference
JNE127	Pueblo Pintado	Chaco Reference
JNE131	Pueblo Pintado	Chaco Reference
JNE132	Pueblo Pintado	Chaco Reference
JNE136	Kin Ya'a	Chaco Reference
JNE139	Kin Ya'a	Chaco Reference
JNE142	Kin Ya'a	Chaco Reference
JNE144	Skunk Springs	Chaco Reference
JNE146	Skunk Springs	Chaco Reference
JNE147	Skunk Springs	Chaco Reference
JNE148	Skunk Springs	Chaco Reference
JNE149	Skunk Springs	Chaco Reference
JNE150	Skunk Springs	Chaco Reference
JNE151	Skunk Springs	Chaco Reference
JNE152	Skunk Springs	Chaco Reference
JNE154	Skunk Springs	Chaco Reference
JNE155	Skunk Springs	Chaco Reference
JNE156	Skunk Springs	Chaco Reference
JNE157	Skunk Springs	Chaco Reference
JNE158	Skunk Springs	Chaco Reference
JNE160	Tocito	Chaco Reference
JNE162	Tocito	Chaco Reference
JNE173	Tocito	Chaco Reference

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ID	Site	Compositional Group
JNE176	Peach Springs	Chaco Reference
JNE177	Peach Springs	Chaco Reference
JNE178	Peach Springs	Chaco Reference
JNE181	Peach Springs	Chaco Reference
JNE183	Peach Springs	Chaco Reference
JNE184	Peach Springs	Chaco Reference
JNE188	Peach Springs	Chaco Reference
JNE008	Wallace Ruin	Chimney Rock
JNE016	Chimney Rock	Chimney Rock
JNE019	Chimney Rock	Chimney Rock
JNE027	Chimney Rock	Chimney Rock
JNE028	Chimney Rock	Chimney Rock
JNE030	Chimney Rock	Chimney Rock
JNE033	Morris 41	Chimney Rock
JNE039	Morris 41	Chimney Rock
JNE050	Salmon Ruin	Chimney Rock
JNE051	Salmon Ruin	Chimney Rock
JNE053	Salmon Ruin	Chimney Rock
JNE075	Four Clowns	Chimney Rock
JNE110	Aztec West	Chimney Rock
JNE122	Pueblo Pintado	Chimney Rock
JNE124	Pueblo Pintado	Chimney Rock
JNE145	Skunk Springs	Chimney Rock
JNE175	Peach Springs	Chimney Rock
JNE185	Peach Springs	Chimney Rock
JNE186	Peach Springs	Chimney Rock
JNE020	Chimney Rock	Chimney Rock A
JNE021	Chimney Rock	Chimney Rock A
JNE023	Chimney Rock	Chimney Rock A
JNE024	Chimney Rock	Chimney Rock A
JNE029	Chimney Rock	Chimney Rock A
JNE078	Guadalupe	Guadalupe
JNE079	Guadalupe	Guadalupe
JNE083	Guadalupe	Guadalupe
JNE084	Guadalupe	Guadalupe
JNE085	Guadalupe	Guadalupe

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ID	Site	Compositional Group
JNE087	Guadalupe	Guadalupe
JNE088	Guadalupe	Guadalupe
JNE089	Guadalupe	Guadalupe
JNE066	Four Clowns	Kin Ya'a
JNE093	Indian Creek	Kin Ya'a
JNE097	Indian Creek	Kin Ya'a
JNE125	Pueblo Pintado	Kin Ya'a
JNE129	Pueblo Pintado	Kin Ya'a
JNE130	Pueblo Pintado	Kin Ya'a
JNE134	Pueblo Pintado	Kin Ya'a
JNE137	Kin Ya'a	Kin Ya'a
JNE140	Kin Ya'a	Kin Ya'a
JNE141	Kin Ya'a	Kin Ya'a
JNE026	Chimney Rock	Tocito
JNE059	Salmon Ruin	Tocito
JNE060	Salmon Ruin	Tocito
JNE159	Tocito	Tocito
JNE161	Tocito	Tocito
JNE163	Tocito	Tocito
JNE164	Tocito	Tocito
JNE165	Tocito	Tocito
JNE166	Tocito	Tocito
JNE167	Tocito	Tocito
JNE168	Tocito	Tocito
JNE169	Tocito	Tocito
JNE170	Tocito	Tocito
JNE171	Tocito	Tocito
JNE172	Tocito	Tocito
Analysis 3		
JNE016	Chimney Rock	Chimney Rock
JNE019	Chimney Rock	Chimney Rock
JNE027	Chimney Rock	Chimney Rock
JNE028	Chimney Rock	Chimney Rock
JNE030	Chimney Rock	Chimney Rock
JNE078	Guadalupe	Guadalupe
JNE079	Guadalupe	Guadalupe

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ID	Site	Compositional Group
JNE083	Guadalupe	Guadalupe
JNE084	Guadalupe	Guadalupe
JNE085	Guadalupe	Guadalupe
JNE087	Guadalupe	Guadalupe
JNE088	Guadalupe	Guadalupe
JNE089	Guadalupe	Guadalupe
JNE121	Pueblo Pintado	Chaco Core
JNE122	Pueblo Pintado	Chaco Core
JNE123	Pueblo Pintado	Chaco Core
JNE124	Pueblo Pintado	Chaco Core
JNE125	Pueblo Pintado	Chaco Core
JNE126	Pueblo Pintado	Chaco Core
JNE127	Pueblo Pintado	Chaco Core
JNE129	Pueblo Pintado	Chaco Core
JNE130	Pueblo Pintado	Chaco Core
JNE131	Pueblo Pintado	Chaco Core
JNE132	Pueblo Pintado	Chaco Core
JNE133	Pueblo Pintado	Chaco Core
JNE134	Pueblo Pintado	Chaco Core
JNE135	Pueblo Pintado	Chaco Core
JNE136	Kin Ya'a	Kin Ya'a
JNE137	Kin Ya'a	Kin Ya'a
JNE139	Kin Ya'a	Kin Ya'a
JNE140	Kin Ya'a	Kin Ya'a
JNE141	Kin Ya'a	Kin Ya'a
JNE142	Kin Ya'a	Kin Ya'a