



Dynamics of obsidian procurement at Pot Creek Pueblo (LA 260), Northern New Mexico

Matthew T. Boulanger¹ · Michael Adler¹ · Evan Sommer² · Ian Jorgeson¹

Received: 4 April 2022 / Accepted: 21 May 2022 / Published online: 13 June 2022
© The Author(s), under exclusive licence to Springer-Verlag GmbH Germany, part of Springer Nature 2022

Abstract

We present obsidian sourcing data from Pot Creek Pueblo (LA 260), one of the northernmost Puebloan settlements in the Northern Rio Grande, occupied from at least 1260 CE until ca. 1320 CE when much of the pueblo was burned and the site was depopulated. Although the occupation of Pot Creek Pueblo was short, it occurred during a pivotal period in the Northern Rio Grande. The population of the region increased rapidly at this time, possibly due to an influx of migrants from the Mesa Verde/San Juan area to the west, and locally people living in relatively small villages comprised of pithouses and above-ground unit pueblos begin to coalesce into fewer, but much larger above-ground pueblos. Obsidian-source choices throughout the region may provide insight into how the proposed migration impacted existing resource-procurement patterns. Our data demonstrate that despite the diverse histories of the settlement's inhabitants, the exchange system supplying obsidian to Pot Creek Pueblo remained stable throughout its occupation. We argue that exchange dynamics of the local community remained the primary means of obtaining obsidian despite potential for new avenues that might have been available through the addition of new community members from outside the region and despite population growth and changing settlement patterns in the broader Northern Rio Grande.

Keywords Ancestral Puebloans · Obsidian · X-ray fluorescence · Sourcing · Lithic procurement

Introduction

Patterns of obsidian exchange feature prominently in recent discussions regarding how best to understand the complexities of population dynamics within the Northern Rio Grande during the tenth through the fourteenth centuries CE. On one hand, Arakawa et al. (2011) and others (e.g., Clark et al. 2019; Ortman 2010, 2012) have suggested that the presence of obsidian sourced to the Jemez Mountains, but recovered from contexts in the Mesa Verde region, provides direct evidence for strong ties between groups emigrating from the Mesa Verde region and ancestral Tewa populations of the Northern Rio Grande. On the other hand, Moore et al. (2020) have pointed out that an increase in Jemez Mountain

obsidian in the San Juan and Mesa Verde regions during the twelfth and thirteenth centuries CE may have more to do with an expansion of village life across the Pajarito Plateau during this time—more people on the landscape making and using tools made on obsidian mean that more obsidian is being introduced into existing trade networks between the Northern Rio Grande and the Mesa Verde/San Juan areas. Expectations laid out by Moore et al. (2020) suggest that variation in the sources of obsidian used by Ancestral Puebloan peoples in the Northern Rio Grande should correlate with proximity to, and therefore cost of acquisition of, those sources.

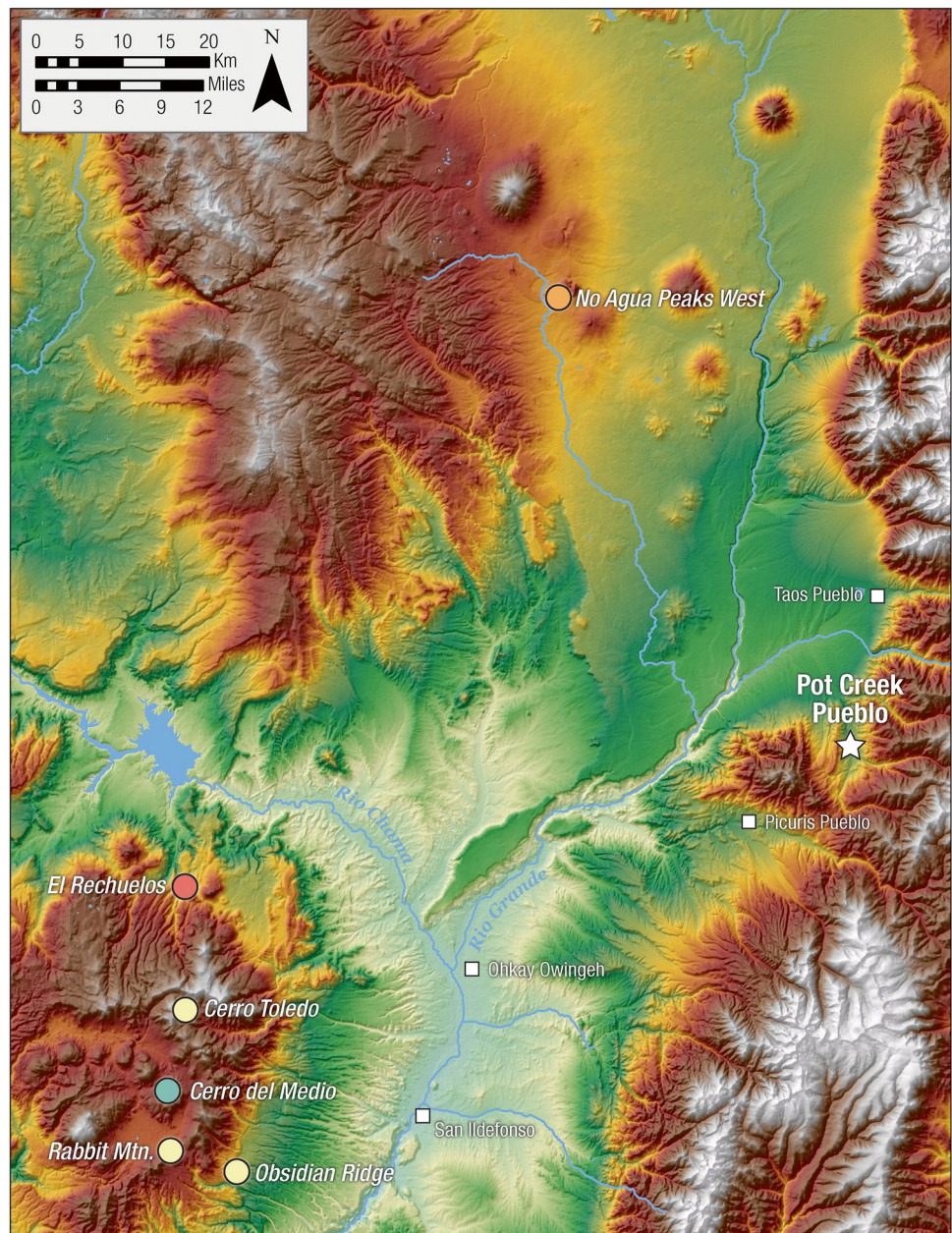
The purpose of our research contribution is not to directly resolve this particular debate; rather, it is to point out, in much the same vein as Moore et al. (2020), that any debate about the scope and scale of population dynamics in the Northern Rio Grande must be informed by data from throughout the areas impacted by the proposed migration into this region. As yet, most of the discussion concerning the movement of people into the Northern Rio Grande from the Mesa Verde/San Juan regions has not included obsidian-provenance data from the northernmost Puebloan communities at Taos, Picuris, and Pot Creek (Fig. 1).

✉ Matthew T. Boulanger
mboulanger@smu.edu

¹ Department of Anthropology, Southern Methodist University, 3225 Daniel Avenue, Heroy Hall, Dallas, TX 75211, USA

² Department of Archaeology, University of Sheffield, Minalloy House, 10-16 Regent Street, Sheffield S1 3NJ, UK

Fig. 1 Location of Pot Creek Pueblo (LA 260) in relation to obsidian sources in the Jemez Mountains and on the Taos Plateau. Historic pueblos of Taos, Picuris, Ohkay Owingeh, and San Ildefonso also shown



We present here results of a large-scale obsidian sourcing study focusing on the site of Pot Creek Pueblo, one of the earliest large pueblos to be constructed on the Taos Plateau. After presenting the site and the archaeological work that has been done there, we discuss how the site's obsidian assemblage suggests continuity in source use through time. Our data strongly suggest that at least within the context of Pot Creek Pueblo and access to major obsidian sources in the region, there was no substantive disruption of access between the twelfth and early fourteenth centuries CE. Moreover, we find that frequencies of different sources in the Pot Creek Pueblo assemblage present a pattern that is

markedly different from those observed at sites along the Rio Grande and on the Pajarito Plateau. If, as Moore et al. (2020) suggest, an increase in Cerro Toledo obsidian during the twelfth and thirteenth centuries reflects increased population on—and exchange from—the Pajarito Plateau, we find no evidence that residents of Pot Creek participated in this exchange sphere. Similarly, if the increase of Cerro Toledo obsidian in the Mesa Verde/San Juan area reflects early scouting of and reverse migration from the Northern Rio Grande (Arakawa et al 2011), these processes do not appear to have involved the ancestral Northern Tiwa of the Northern Pueblos, at least as is represented in obsidian artifacts.

Pot Creek Pueblo

Pot Creek Pueblo (LA 260) is an Ancestral Puebloan settlement located approximately 15 km south of Taos, New Mexico (36° 16' 47" N, 105° 34' 38" W,¹ see Fig. 1). This large multicomponent site was one of three aggregated villages founded in the Taos area during the thirteenth century. The other two villages—Taos and Picuris Pueblos—are still the homes of Northern Tiwa-speaking peoples today. Community members at both Taos and Picuris claim ancestral ties to Pot Creek Pueblo to varying degrees, and there is no consensus on where the majority of the site's population migrated to follow its depopulation.

The earliest documented component of Pot Creek Pueblo consists of a pair of pithouses dating to the Valdez Phase (ca. 950–1190 CE). The later, larger occupation at Pot Creek dates to the Coalition Period (ca. 1200–1325 CE; Wendorf and Reed [1955]). In the local chronology for the Taos area, this is referred to this as the Talpa Phase (1190–1325 CE). The Talpa Phase occupation at Pot Creek Pueblo consists of 10 large multistory roomblocks, central plaza areas, at least one big kiva, and a large midden area (Fig. 2). Dendrochronological dating of architectural wood from the later occupation indicates that pueblo construction primarily occurred between 1260 and 1320 CE. Radiocarbon dating performed at the site supports this chronology (see below). The depopulation of Pot Creek Pueblo, at some point soon after the last phases of construction, involved extensive burning of both domestic and ritual spaces. There is no evidence for conflict or destruction at the site; rather, the pueblo appears to have been burned and vacated by the same people who had built and occupied the settlement. This interpretation is based on the preparation of both domestic and ceremonial spaces for decommissioning, deposition of dedicatory materials in these spaces prior to burning, and computer modeling of burning patterns that point to purposeful ignition of roofing materials and other fuels in the decommissioning of these same spaces (Adler 2010; Adler and Hegmon in press).

Our archaeological knowledge of Pot Creek Pueblo is based on excavations conducted between the late 1950s and the early 2000s (Adler 2021; Arbolino 2001; Crown 1991; Fowles 2004; Wetherington 1968). Despite the wide range of data collection and recordation methods employed at the site over the several decades of fieldwork, we have high resolution in both architectural and temporal datasets from the settlement.

The founding population at Pot Creek Pueblo appears to have come largely from pre-aggregation groups that occupied small, dispersed settlements in the Pot Creek drainage

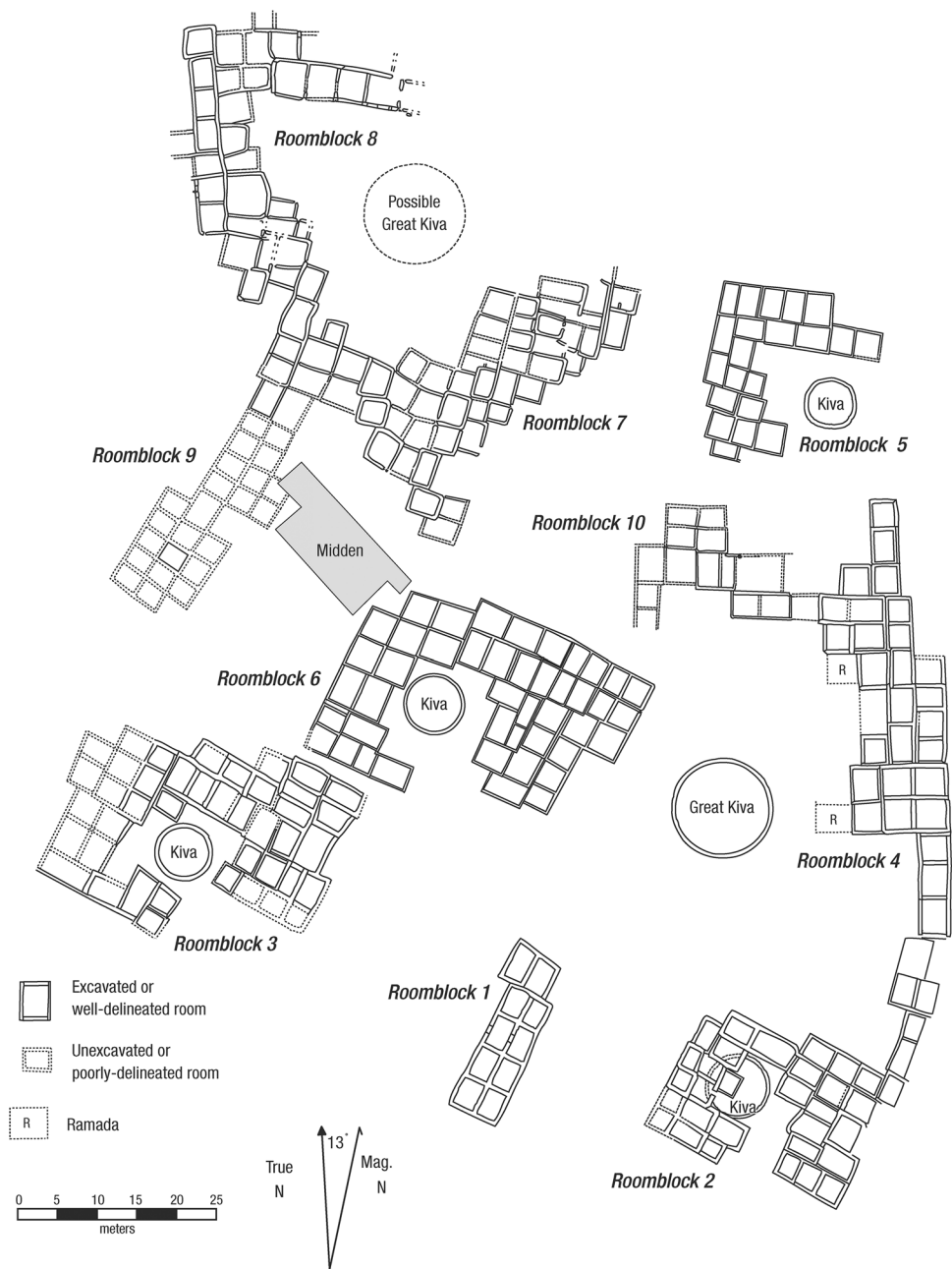
and the larger Taos region. The earliest settlers occupied pithouses, most dug 2 to 3 m below the ground surface, dating to the Valdez Phase. Dispersed pithouse settlements are common across the Taos Plateau (Blumenschein 1958:110; Boyer et al. 1994; Crown 1990; Herold 1968; Woolsley 1986), and this includes the Valdez Phase pithouses excavated at Pot Creek Pueblo in the late 1950s. During the twelfth and thirteenth centuries CE, Taos Plateau residents transitioned from reliance on subterranean domestic spaces to a greater use of surface architecture. At the same time, households began to cluster in larger aggregations in the northern and southern portions of the Taos Plateau. Fowles (2004) details one such cluster in the Pot Creek drainage, a tight scatter of nearly two dozen pithouse, and unit pueblos located within several hundred meters of where the primary occupation of Pot Creek Pueblo would later be built.

As mentioned above, two Valdez Phase pithouses were excavated at Pot Creek Pueblo, both overlain by one or more meters of later architectural materials and fill. Excavations into a stratified midden near the center of the pueblo have documented an occupation sequence beginning in the early-mid eleventh century and continuing through the early fourteenth century. Radiocarbon dates recovered from throughout the midden and from an arroyo surface buried by the midden (Procter 1993) allow us to estimate that the Valdez Phase occupation beneath Pot Creek Pueblo was established by at least ca. 1080 CE. A Bayesian age-depth model of these dates (see Supplementary Information 1) suggests that well over a meter of deposits had accreted in the midden prior to the construction of the pueblo. Although the focus of research at Pot Creek Pueblo has been on the later village occupation (1260–1320 CE), our modeling of ¹⁴C dates from the midden argues for roughly two centuries of occupation on the site prior to the later population amalgamation. This certainly qualifies this location as a “persistent place” (sensu Binford 1982) where ancestral Northern Tiwa peoples resided across a deep history that later was selected as the gathering place of “peoples” with differing histories and, likely, disparate identities.

At roughly the same time Valdez Phase peoples began to aggregate into dense pueblos (e.g., Pot Creek) on the Taos Plateau, portions of the Northern Rio Grande to the south began to see what is argued by some as a major emigration from the Mesa Verde/Northern San Juan region following the splintering of the centralized Chacoan system there (e.g., Ortman 2010). As noted above, most discussions of this migration event have focused on the Tewa Basin to the southwest of the Taos Plateau. Though the scale and scope of this population movement are debated, the movement of a large number of new peoples into the broader region would almost certainly have affected the residents of the Taos area. Fowles (2004) argues, for example, that it was the influx of non-local groups into the Taos area prior to the major population

¹ Coordinates are provided to the public-access Pot Creek Pueblo interpretive site maintained by the United States Forest Service.

Fig. 2 Planview of architectural elements at Pot Creek Pueblo (LA 260)



aggregation at Pot Creek Pueblo that resulted in numerous changes in material culture (e.g., ceramics), and he associates these events with oral tradition compiled at Taos Pueblo by M. C. Stevenson that describe the early arrival of “Winter People” from north of the Taos Plateau and the later immigration of “Summer People” from the south.

The above-ground pueblo at Pot Creek is built of coursed adobe comprising 10 separate roomblocks, each containing between 12 and 35 ground floor rooms (Fig. 2). Of the estimated 284 ground floor rooms that have been mapped, 148 have been tested or fully excavated. While parts of the village architecture reached three stories, most of the

structures were one-to-two stories, leading to an estimated 350–450 rooms constructed during occupation. Population estimates vary depending on which proxy one uses to go from rooms to people. Based on architectural configurations of definable households (Arbolino 2001), 400–500 individuals lived at Pot Creek Pueblo during the height of occupation in the early fourteenth century CE. Roomblocks at Pot Creek Pueblo were built in definable episodes, with the majority of construction episodes containing three or fewer rooms, indicating that most of the site growth was based on the integration of household-level groups into existing architectural complexes.

Hundreds of living spaces were built, used, and ultimately emptied of human occupants at Pot Creek Pueblo over a span of several decades. Dendrochronological dating at the site has identified the first cutting date cluster at 1265 CE, followed by an intense period of construction during the 1270s, and an isolated construction surge in the mid-1280s (Crown 1991). Construction slowed in the last decades of the thirteenth century, followed by a significant increase in construction and renovation during the first 2 decades of the fourteenth century. The final cutting date of 1319 CE from the unfinished great kiva at Pot Creek Pueblo indicates that people left the site in the early 1320s. Midden deposits above the first appearance of diagnostic pottery (e.g., Pot Creek Black-on-White, Talpa Black-on-White) associated with the Talpa Phase are highly turbated, suggesting a rapid accretion and mixing followed by burning and historic disturbance (Procter 1993).

The Talpa Phase occupation of the newly constructed pueblo lasted until approximately 1320 CE, at which time a portion of the site was burned and after which no new construction appears to have taken place. Oral traditions of people living at the modern pueblos of Taos and Picuris suggest continuity with the former residents of Pot Creek Pueblo, and it is likely that some people living at Pot Creek joined both of these communities after the site was depopulated.

In summary, the earliest occupation at Pot Creek Pueblo occurs during the Valdez Phase (ca. 950–1190 CE). Evidence for this early occupation remains scant but comprises at least two defined pithouses and the beginnings of a midden deposit. Beginning in the mid-thirteenth century, these features were partially obliterated and buried as residents of the site began building a dense collection of above-ground roomblocks. The extensive pueblo comprised of these roomblocks appears to have been occupied, in part by descendants of the people who resided at the site during the Valdez Phase and in part by the descendants of other Valdez Phase peoples across the Taos Plateau. Immigration of peoples from the Mesa Verde/San Juan region to the Northern Rio Grande at this time also may have resulted in the changes in pottery, architecture, and social organization suggested by Fowles (2004). Here, we explore whether these dramatic changes in population dynamics—aggregation and coalescence of disparate communities, perhaps with the integration of migrants of different ethnicities—disrupted or otherwise affected change in how and from where residents of Pot Creek Pueblo, and by analogy those of the Taos area, obtained raw materials for stone-tool production.

Obsidian procurement and exchange in the Northern Rio Grande

The central question we tackle here is to what extent, if any, did the integration of geographically, historically, and likely linguistically diverse populations influence the

exchange systems that framed the movement of lithic materials throughout the broader Northern Rio Grande region? We focus here on the use of obsidian at Pot Creek Pueblo as a proxy for these exchange systems for two primary reasons. First, obsidian does not occur locally within the Taos area. The nearest sources of high-quality obsidian are from 80 to 90 km distant, thus any obsidian that was used at the site involved either trade/exchange with people living close to the source(s) or required residents at Pot Creek Pueblo to make the trip themselves, passing through territories occupied by other Ancestral Puebloan groups. Second, unlike chert, obsidian easily lends itself to nondestructive provenance research, and the chemical uniqueness of individual obsidian sources in New Mexico is well documented (e.g., Glascock et al. 1999; Shackley 2005a).

As summarized by Shackley (2005a), Native American stone-tool makers in northern New Mexico obtained obsidian from at least five chemically distinct geological formations within the Jemez Mountains: El Rechuelos Rhyolite (erroneously referred to in earlier literature as Polvadera obsidian), Cerro Toledo Rhyolite (*aka* Obsidian Ridge/Rabbit Mountain obsidian), Valles Rhyolite (*aka* Cerro del Medio/Valles Caldera obsidian), Canovas Canyon Rhyolite (*aka* Bear Springs obsidian), and Bearhead Rhyolite (*aka* Bland Canyon/Paliza Canyon obsidian). In addition to these sources in the Jemez Mountains, people on the Taos Plateau made use of obsidian collected at No Agua Peaks in far northern New Mexico. Here, at least two geochemically distinctive obsidians have been identified, though only one of these (No Agua Peaks West) appears to have been used by indigenous toolmakers (Glascock et al. 1999).

The processes by which Native Americans on the Taos Plateau obtained obsidian from these sources are not yet entirely clear. Obsidian could have been obtained through trade with individuals living close to these sources, or it may have been obtained directly through the staging of logistical forays to acquire raw materials. Whichever the case may be, both El Rechuelos and Cerro Toledo Rhyolite are available as cobbles and nodules within the alluvium of the Rio Grande, south of its confluence with the Chama River (Arakawa et al. 2011; Church 2000; Shackley 2005a, 2021). Small fragments of No Agua Peaks obsidian have been recovered from the Rio Grande gravels but in very low frequencies (Church 2000; Shackley 2021). Thus, the “sources” of these obsidians are relatively widespread, and the obsidian can be found across a vast landscape. Moore et al. (2020) recently used the form of weathering observed on primary and secondary debitage to assess the use of secondary geological sources for obsidian procurement, demonstrating that it may be possible to distinguish from approximately where individuals were gathering their obsidian. Another possible avenue towards this same goal may lie in examining the proportions of both El Rechuelos and Cerro Toledo at a

given site, especially since both Church (2000) and Shackley (2021) have shown that Cerro Toledo obsidian is by far the most common variety found in the Rio Grande alluvium.

In contrast to the other Jemez obsidians, Valles Rhyolite obsidian is not known to have eroded in any significant quantity outside of the caldera proper (Church 2000; Shackley 2005a). This variety of obsidian was most likely obtained by direct forays into the extinct volcano. As Liebman (2017) has noted, the presence of this obsidian at a site may serve as a proxy for access to the caldera for the purpose of obtaining high-quality obsidian in relatively large package sizes.

Previous obsidian sourcing at Pot Creek

Previous obsidian sourcing work by Newman (1997) and Wolfman (1994) at Pot Creek Pueblo has documented only slight evidence for long-distance transportation of obsidian, and their work suggests that a majority of obsidian at the site comes from the Jemez Mountains (Table 1). In a sample of 24 artifacts predominantly from Roomblock #4, Newman (1997) sourced one artifact to East Grants Ridge, roughly 230 km (143 mi) southwest of the site. One artifact assayed by Newman could not be identified as to its geological provenance. The other artifacts in Newman's sample suggest that El Rechuelos Rhyolite was the most commonly used source ($n = 12$, 50%) of obsidian at Pot Creek, with Valles Rhyolite ($n = 4$) and No Agua Peaks West ($n = 4$) obsidian making up a further 33% (Newman 1997; Newman and Nielsen 1985).

Wolfman (1994; see also Glascock et al. 1999) analyzed an equally small sample of 22 obsidian artifacts, all from Roomblock #6, by both X-ray fluorescence spectrometry (XRF) and neutron activation (NAA). Results of his sourcing efforts suggest that a majority of obsidian from the roomblock derives from the Valles Rhyolite ($n = 10$, 45.4%), with El Rechuelos obsidian comprising 36% ($n = 8$). Only one artifact was identified as coming from No Agua Peaks West, and no obsidian from sources other than the Jemez Mountains and the Taos Plateau was identified in his work.

Table 1 Previously reported source assignments for obsidian artifacts from Pot Creek Pueblo (LA 260) as reported by Newman (1997), Wolfman (1994), and Glascock et al. (1999)

Source	Roomblock #4	Roomblock #6	N	Pct
<i>Jemez Mountains</i>				
El Rechuelos	12	8	20	43.5%
Valles	4	10	14	30.4%
Cerro Toledo	1	4	5	10.9%
No Agua Peaks West	4	1	5	10.9%
East Grants Ridge		1	1	2.2%
Unknown	1		1	2.2%
		Σ	46	100%

In the interest of thoroughness, we note that Ridings (1994) also identified El Rechuelos obsidian at Pot Creek. However, her study evaluated obsidian hydration as a dating method, requiring use of obsidian artifacts that all derive from the same geological source. As such, her sampling strategy was specifically aimed at identifying obsidian artifacts that visually and chemically matched her El Rechuelos source samples. No attempts were made to identify the sources of other obsidian at the site or to quantify the proportions of El Rechuelos obsidian relative to other varieties. Given these factors, we will not further discuss Ridings' (1994) results in reference to our present study.

Based on these previous studies, then, it appears as if Valles Rhyolite and El Rechuelos, both within the Jemez Mountains, are the most frequently encountered sources for obsidian used at Pot Creek Pueblo. However, with only 46 pieces of obsidian previously analyzed, we are dealing with a relatively small—and likely not representative—sample. The analyses and data we present here are directed at addressing these deficiencies to begin establishing a large and representative sampling of obsidian from the entire site so that hypotheses concerning obsidian procurement at Pot Creek Pueblo and elsewhere on the Taos Plateau may be better assessed.

Analytical sample

Three-hundred and twenty-three flaked-stone obsidian artifacts from Pot Creek Pueblo were selected for analysis. All of the artifacts discussed here were collected during excavations between 1957 and 2003 and are curated at the Fort Burgwin Archaeology Research Repository at the SMU-in-Taos campus. The sample of artifacts derive from within and around five of the 10 large roomblocks at Pot Creek Pueblo, as well as from middens identified within plaza areas between these roomblocks (Fig. 2). As mentioned above, dendrochronological studies performed at the site establish firm bracketing dates for most of our sample of between 1260 and 1320 CE. Our sample also includes specimens associated with the earlier Valdez Phase pithouses beneath Roomblocks #1 and #2 (Green 1976; Wetherington 1968) and midden contexts dated securely to the Valdez Phase occupation.

In addition to the artifact catalog numbers, artifacts were assigned analytical identification numbers (ANIDs) using the prefix "PCP" and sequential unique numbers 1–327 (i.e., PCP0001–PCP0327).² For convenience we use these ANIDs to reference individual specimens. One hundred of the analyzed specimens are whole or fragmentary projectile

² Four flaked-stone artifacts of materials other than obsidian were included in the analyses and are included in these analytical IDs, but these are not discussed herein.

Table 2 Values for NIST and USGS standard reference materials assayed along with the Pot Creek Pueblo artifact sample, along with recommended values from GeoRem (Jochum et al. 2011) and the USGS. Values in parentheses are reference values. “<LOD” signifies values below the limit of detection

	Ti	Mn	Fe	Zn	Ga	Rb	Sr	Y	Zr	Nb	Ba	Th
NIST 614	<LOD	<LOD	<LOD	7±1	5±1	<LOD	43±1	<LOD	6±1	<LOD	<LOD	<LOD
GeoRem	3.6±.3	1.4±.1	19±6	2.8±.4	1.3±.1	<1	46±1	<1	<1	<1	3±1	<1
NIST 612	<LOD	69±11	<LOD	61±3	37±1	30±1	75±1	35±1	54±1	50±1	<LOD	56±1
GeoRem	44±2	39±1	51±2	39±2	37±2	31±1	78±1	38±2	38±1	40±2	39±1	38±1
NIST 610	600±83	650±6	<LOD	551±5	340±2	429±1	403±1	351±1	449±1	470±1	<LOD	550±1
GeoRem	452±10	444±13	458±9	460±18	433±13	426±1	516±1	462±11	448±9	465±34	452±9	457±1
RGM-1	.126±.02%	318±16	1.245±.033%	37±3	15±1	164±6	108±4	19±1	219±5	6±1	754±70	14±1
USGS	.162±.012%	279±31	1.301±.021%	(32)	15±2	150±8	110±10	(25)	220±20	9±1	810±46	15±1
GeoRem	.159±.004%	300±16	1.309±.021%	33±1	16±1	150±2	105±2	24±1	228±4	9±1	827±6	15±1

points of varying styles generally attributed to the Coalition Period (Wendorf and Reed 1955). These are all likely arrow points and include side-notched ($n = 23$), corner-notched ($n = 20$), unnotched triangle ($n = 6$), and small lanceolate ($n = 3$) forms. Two hundred of the artifacts represent some form of lithic-production debitage, including utilized flakes, bifacial thinning flakes, and early stage (i.e., primary and secondary reduction) flakes. The remainder of the artifacts represents numerous classes of whole and fragmentary tools (gravers, drills, bifaces, and unifaces) and lithic-reduction debris (spent bipolar and generalized cores, blockshatter).

Analytical protocol

Each specimen was analyzed using a Bruker Tracer 5i handheld portable X-ray fluorescence spectrometer. The Tracer 5i uses a Rh-based X-ray tube operating at 50 kV with a tube current of 35 μ a and a silicon drift detector. Spectra collected by the spectrometer are quantified using a custom calibration based on a suite of 43 well-characterized obsidian reference specimens developed by the Archaeometry Laboratory at the University of Missouri (Glascok and Ferguson 2012; Speakman 2012). Artifact specimens are analyzed on the Tracer 5i for at least 3 min each.

This protocol and the obsidian calibration routine permit quantification of the following minor and trace elements: Ti, Mn, Fe, Zn, Ga, Rb, Sr, Y, Zr, Nb, Th, and Ba. The precision and accuracy of our calibration may be evaluated based on the analysis of two certified reference materials distributed by the National Institutes for Standards and Technology (NIST) as well as a solid nodule of Glass Mountain Rhyolite obsidian, the same material used by the United States Geological Survey (USGS) in the production of their certified reference materials RGM-1 and RGM-2 (Table 2). Though our calibration allows for the quantification of Ti, Mn, and Ba, the precision of Ti and Mn values with our calibration is low. Ba is notoriously difficult to measure using a single-assay calibration unless it is present in high abundance ($> \approx 500$ ppm). We report Ba abundances as informational values, but we do not use them in the making of source assignments for these samples. As will be seen below, Ti, Mn, and Ba are not necessary in identifying the sources of obsidian at Pot Creek.

Results

Our analyses of the obsidian from Pot Creek Pueblo reveal seven distinct chemical profiles (Table 3). Greater than 95% of the obsidian from Pot Creek Pueblo derives from sources in the Jemez Mountains. Of these sources in the Jemez, El Rechuelos obsidian accounts for nearly 60% of the artifacts analyzed here. Valles Rhyolite obsidian, available at deposits within the Valles Caldera, is the second most common obsidian at the site ($n = 83$ [25.7%]). A total of 30 artifacts (9.2%) are made on

Cerro Toledo obsidian, available at several primary sources and commonly encountered in Rio Grande alluvium. Two pieces of Canovas Canyon Rhyolite obsidian are present in the assemblage. This obsidian crops out on the southern side of the Jemez Mountains, close to Jemez Pueblo (Shackley 2005a). Canovas Canyon obsidian has been documented in alluvial gravels of the Rio Grande but only south of Albuquerque; thus, its presence at Pot Creek hints at exchange with groups residing on the other side of the Jemez Mountains or Puebloan people living far to the south in the Rio Grande Valley.

Twelve artifacts (3.7%) are made on obsidian from the No Agua Peaks West source. Despite being the geographically closest obsidian source to Pot Creek Pueblo in a straight-line distance, straight-line distances likely do not represent the actual effort required to travel between Pot Creek and No Agua Peaks because of the need to either cross or circumvent the 240+ m (800+ ft) deep Rio Grande Gorge that cuts through the Taos Plateau to the west of the site. Additionally, the low frequency of obsidian from this source probably reflects the generally poor quality of the No Agua Peaks West obsidian when compared to material from the Jemez sources (Shackley 2005a).

Three of the artifacts from Pot Creek exhibit chemical compositions identifying them to sources at great distance from the site. One flake (PCP216) matches the chemical composition of the Mineral Mountains obsidian source located in southwestern Utah, and two flakes (PCP128 and PCP223) appear to match the composition of the Obsidian Cliff source in northwestern Wyoming in modern-day Yellowstone National Park. We were at first skeptical of this result, given that previous identifications of Mineral Mountains obsidian elsewhere in New Mexico have been erroneous and later shown to be from the Cow Canyon source (Duff et al. 2012). Yet, the chemical data for this specimen suggest that it is indeed a best match for this particular source and not Cow Canyon or any other source for which we have data (Table 4). Similarly, the two pieces that appear to match the Obsidian Cliff source are distinct from all other sources in New Mexico, and analyses of source specimens

Table 3 Summary of source assignments for artifacts from Pot Creek Pueblo (LA 260)

Source	N	Pct
<i>Jemez Mountains</i>		
El Rechuelos	193	59.8%
Valles	83	25.7%
Cerro Toledo	30	9.2%
Canovas Canyon	2	0.6%
No Agua Peaks West	12	3.7%
Obsidian Cliff, Wyoming	2	0.6%
Mineral Mountains, Utah	1	0.3%
Σ	323	100%

Table 4 Chemical compositions for exotic obsidian artifacts from Pot Creek Pueblo (LA 260), including comparative source data from SMU, the MURR Archaeometry Laboratory (after Bou-langer et al. 2010), and the Geochemical Research Laboratory (Moore 2009). “<LOD” signifies values below the limit of detection

	Ti	Mn	Fe%	Zn	Ga	Rb	Sr	Y	Zr	Nb	Ba	Th
<i>Mineral Mountains</i>												
PCP216	557	301	.610	30	15	214	35	13	120	23	<LOD	21
MURR NAA		363±5	.543±.007	33±6	185±3	42±13			142±6		184±12	20.9±0.3
MURR XRF	675±98	387±67	.609±.074	40±13	17±3	187±6	34±3	17±3	107±5	23±1	<LOD	21±1
GRL XRF		51±9		17±3	197±11	42±2	25±2	117±6	25±3			
<i>Obsidian Cliff</i>												
PCP0128	<LOD	114	0.936	78	19	287	1	67	175	45	<LOD	32
PCP0223	<LOD	90	0.887	68	20	265	<LOD	61	163	43	<LOD	27
SMU XRF	318±199	160±38	.888±.048	67±6	19±2	257±14	<LOD	60±4	164±8	40±2	<LOD	27±2
MURR NAA		192±7	.868±.026	204±10	237±5	241±5	<LOD	204±10	169±5	45±3	66±9	28±4
MURR XRF	683±80	285±47	.949±.0246	80±12	22±3	241±5	<LOD	72±4	169±5	45±3	66±9	28±3

Fig. 3 Bivariate plot of niobium and rubidium concentrations for obsidian artifacts from Pot Creek Pueblo (LA 260) grouped by source assignments. Ellipses represent the 90% confidence interval for groups where $n \geq 3$

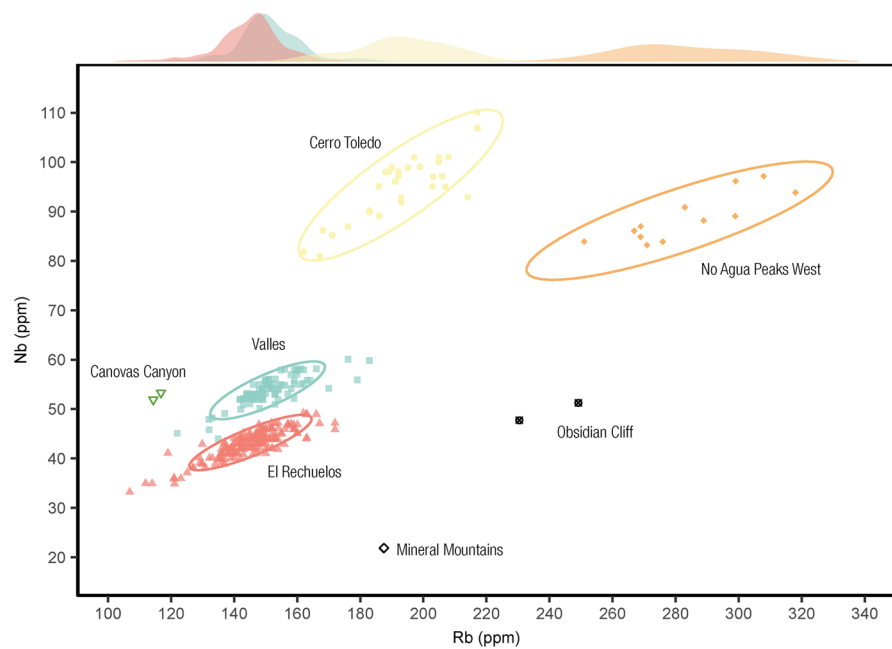
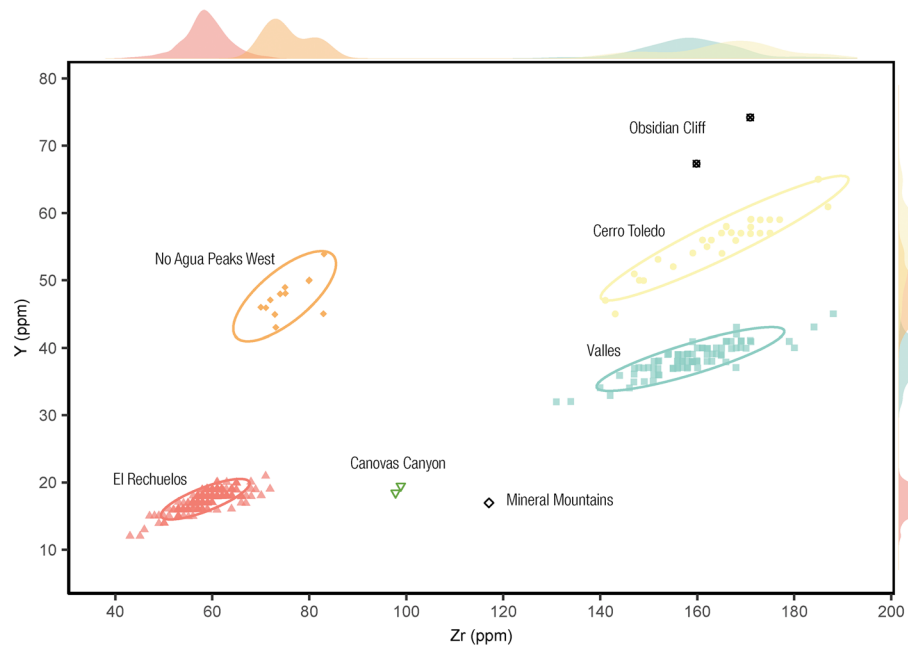


Fig. 4 Bivariate plot of yttrium and zirconium concentrations for obsidian artifacts from Pot Creek Pueblo (LA 260) grouped by source assignments. Ellipses represent the 90% confidence interval for groups where $n \geq 3$



from Obsidian Cliff using the same instrument show that the samples from Pot Creek Pueblo fall within the observed range of elements for this particular source (Table 4).

These three pieces of decidedly “non-local” obsidian come from contexts associated with the Valdez Phase occupation underlying, and thus predating construction of, the pueblo. Both PCP216 and PCP223 were recovered during the 1958 excavations, and both pieces were found in subsurface levels (levels 4 and 2, respectively) within the Valdez Phase pithouse underlying Roomblock #1. Associated artifacts in the same contexts include Valdez Phase ceramics (e.g., Taos/Kwahe’e

Black-on-White, Taos Incised grayware) and flaked-stone debitage and tools made on chert and rhyodacite. PCP128 was recovered in 1983 during excavation into a midden immediately northwest of Roomblock #6 at a depth of between 2.3 and 2.5 m associated with the same types of Valdez Phase ceramics, groundstone tool fragments, and flaked-stone debitage and tools (predominantly chert and rhyodacite). Bracketing radiocarbon dates from the midden and our age-depth model support the assignment of this obsidian flake to the earlier Valdez Phase occupation. Based on their contexts, and the fact that they come from excavations in different portions

of the site conducted 20+ years apart, we believe that the possibility that these three artifacts are recent (i.e., modern) introductions to the site can be ruled out (Figs. 3, 4, and 5).

Discussion

These results agree well with previous sourcing attempts at Pot Creek Pueblo and suggest that the El Rechuelos and Valles Rhyolite were the primary sources of obsidian used by occupants of the site. In contrast to earlier studies, though, the proportion of El Rechuelos obsidian is significantly higher in our sample. With nearly 60% of the obsidian deriving from a single source, we feel justified in suggesting that toolmakers at Pot Creek appear to have preferentially selected this material over other obsidian sources.

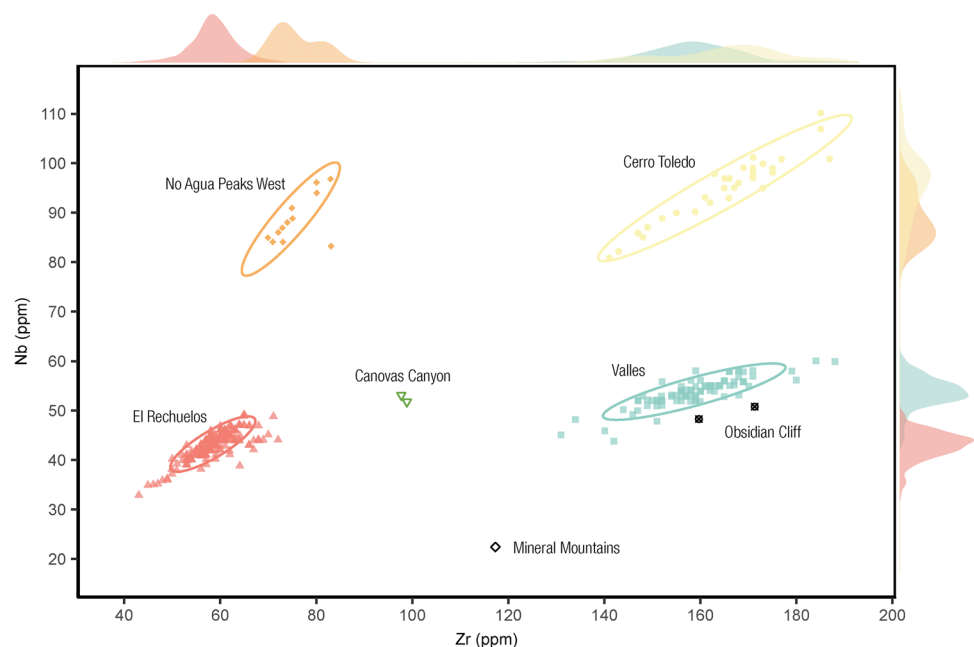
Source localities

The nearest sources of El Rechuelos and Cerro Toledo obsidians are the alluvial gravels of the Rio Grande. However, a comparison of the frequencies of different obsidian sources observed in this alluvium (Church 2000; Shackley 2021) with those observed at Pot Creek clearly reveals that they are dissimilar—even for the northernmost (i.e., closest) sampled localities (Fig. 6). The relatively low frequency of Cerro Toledo obsidian at Pot Creek (9.2%) and its near dominance in alluvial deposits suggests to us that alluvial gravels of the Rio Grande were not a significant source of obsidian for the residents of Pot Creek. Toolmakers at Pot Creek Pueblo were not obtaining their obsidian from the geographically closest “source” of obsidian but rather were seeking out deposits of a specific variety of obsidian. For El Rechuelos obsidian, such

deposits would be within the Chama River and its drainages and from colluvial and alluvial deposits on the northern flanks of the Jemez Mountains. As noted above, the Valles Rhyolite obsidian does not occur in significant quantities outside of the Valles Caldera. Thus, direct forays into the caldera appear to have provided toolmakers with additional raw material.

Modeling the least-cost path distances from Pot Creek to the source areas identified in the study allows us to comment on obsidian preferences at the site. We modeled these paths in ESRI ArcPro (v. 2.8) through a custom Python 3.6 script calling the Path Distance and Cost Path tools through the ArcPy library. Inputs were the locations of Pot Creek Pueblo and the obsidian sources, a 10 m USGS DEM, and a vertical-factor table that considers the energy (kilocalories) required to traverse varying degrees of slope. The path model minimizes the cost in kilocalories to travel between Pot Creek Pueblo and each of the obsidian sources and measures the linear distance along the least cost path. Results of these models, as well as the straight-line distance from Pot Creek Pueblo to the obsidian sources identified there, are presented in Table 5 and in Fig. 7, which shows the modeled least-cost paths from Pot Creek Pueblo to obsidian sources in (A) the northern Jemez Mountains and (B) sources outside the northern Jemez Mountains. The No Agua Peaks West source is certainly the closest obsidian source to the site (60–65 km), but as noted above and elsewhere (e.g., Shackley 2005a), the material from this source is of generally poor quality, and it occurs in very small package sizes. The El Rechuelos source, when calculated to a confirmed source along Polvadera Creek, is 80–90 km distant from Pot Creek Pueblo—closer than any other Jemez Mountains source, though not by much. Both the Valles Rhyolite obsidian and the Cerro Toledo obsidian (calculated to Cerro

Fig. 5 Bivariate plot of niobium and zirconium concentrations for obsidian artifacts from Pot Creek Pueblo (LA 260) grouped by source assignments. Ellipses represent the 90% confidence interval for groups where $n \geq 3$



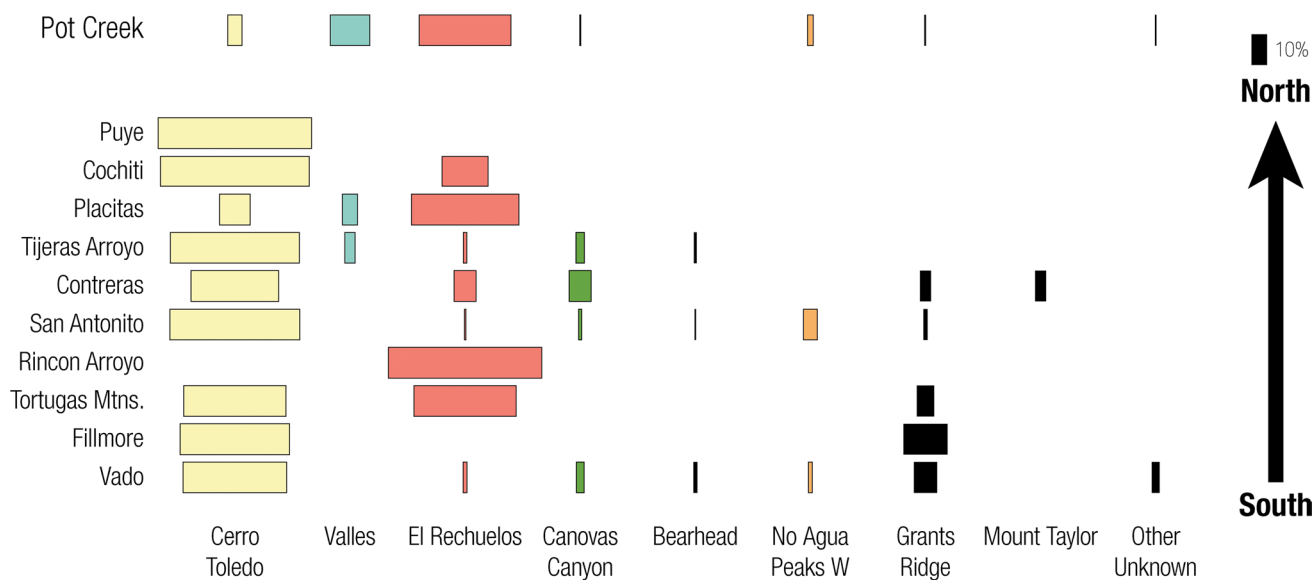


Fig. 6 Frequency-seriation diagram of obsidian sources observed at Pot Creek Pueblo compared to those observed in gravels of the Rio Grande alluvium (after Church 2000 and Shackley 2021)

Toledo proper) are on average only about 10 km (6.2 mi) more distant than El Rechuelos. Thus, in terms of the overall distance travelled from site to source, the differences between the three major Jemez sources are marginal. If El Rechuelos obsidian was being procured from gravels within the Chama River, these differences would be greater: the least-cost path crosses the Chama River at about 68 km distance from Pot Creek Pueblo. However, if the site’s occupants were collecting obsidian from the Rio Grande gravels, this would be the closest possible source to do so, at roughly 56 km distance along the least-cost path. This would, based on surveys by Shackley (2021) and Church (2000), result in a much higher frequency of Cerro Toledo obsidian at Pot Creek. In other words, we see two possibilities: (1) people were obtaining obsidian cobbles directly from the Rio Grande gravels, the closest possible source being near Ohkay Owingeh, and intentionally throwing out the majority of obsidian there (Cerro Toledo) in preference for smaller cobbles of El Rechuelos obsidian; or (2) people were seeking out deposits of El Rechuelos obsidian further up the Chama River and the northern flanks of the Jemez Mountains. For a number of reasons, we believe the second possibility is the simplest and the most likely.

Our point is that Pot Creek Pueblo villagers do not appear to have simply sought out the nearest obsidian source(s). Rather, they appear to have navigated a literal landscape of choices to seek out a preferred material for their use, avoiding poor-quality materials as well as the closest alluvial deposit of obsidian nodules in favor of what at least one flintknapper (Shackley 2005a) considers to be the highest quality obsidian in the Jemez Mountains. Travel from Pot Creek Pueblo through the Chama basin to sources of El Rechuelos obsidian would

have also potentially avoided interaction with other Puebloan groups, as the Chama basin was only sparsely populated (Duwe 2011) until near or after the end of the occupation period at Pot Creek. In contrast, large Ancestral Puebloan populations had begun to coalesce on the Pajarito Plateau before the primary occupation at Pot Creek, and so corridors to the other Jemez Mountain obsidian sources would have involved travel through landscapes already populated by other pueblo groups, specifically Tewa-speaking groups living in the Tewa basin.

Continuity in obsidian source prevalence at Pot Creek Pueblo

To assess the degree to which integration of new populations into the Taos area, and more specifically, Pot Creek Pueblo,

Table 5 Straight-line and least-cost distances (km) from Pot Creek Pueblo (LA 260) to obsidian-source areas identified in this study and in previous studies at the site

Source	Straight-line (km)	Least-Cost (km)
<i>Jemez Mountains</i>		
El Rechuelos	78.8	87.6
Valles	88.7	97.1
Cerro Toledo	84.2	94.6
Canovas Canyon	113.2	123.9
No Agua Peaks West	61.5	64.4
East Grants Ridge	230.7	251.4
Mineral Mountains, Utah	688.3	761.1
Obsidian Cliff, Wyoming	1044.1	1130.1

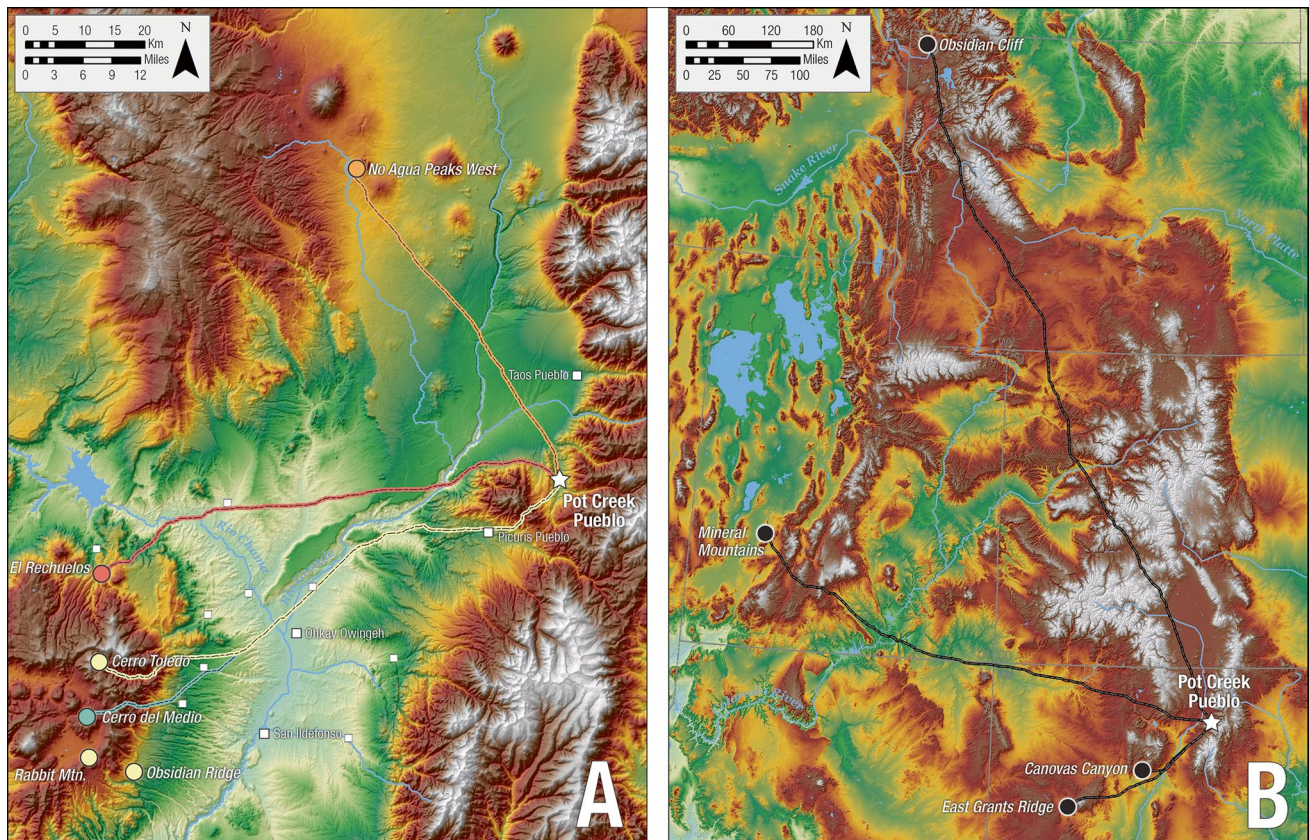


Fig. 7 Modeled least-cost paths from Pot Creek Pueblo to obsidian sources in **A** the northern Jemez Mountains and **B** sources outside the northern Jemez Mountains. White squares in **A** are large Puebloan settlements contemporaneous with Pot Creek

may have impacted obsidian exchange dynamics, we conducted a detailed study of a large midden area located just to the northwest of Roomblock #6 at Pot Creek Pueblo. We know through detailed tree-ring analysis (Crown 1991) and radiocarbon dating that Roomblock #6, located in the center of the village, has one of the longest occupation histories in the settlement. Excavations have uncovered several reconstruction phases, the earliest dating to the late 1260s and early 1270s. Floors and walls from this period indicate that the roomblock began as a set of single-story adobe structures, several of which were constructed using a center-post construction technique, a ubiquitous feature of Pot Creek Pueblo construction by the end of the thirteenth century CE.

We assume that deposition in the proximate midden included, at least in part, refuse from Roomblock #6 and surrounding residences. The midden depth ranges from 2.0 to 2.5 m, comprised primarily of organic-rich stratigraphy with ash, ceramic, lithic, and faunal remains throughout the levels. Our age-depth modeling of ^{14}C dates from the midden suggests that the lower 1–1.5 m of the deposits began during the Valdez Phase and extended into the Pot Creek/Talpa Phases. The upper ca. 1.7 m of the midden appear to have been heavily disturbed during the Pot Creek/Talpa Phases and afterwards.

Analysis of the datable decorated whitewares from the stratified deposits discussed above shows a relatively consistent ratio of mineral-painted Taos Black-on-White to Talpa/Santa Fe Fe organic-painted wares from top to bottom (average 0.22, median 0.16, $n=25$ proveniences). Procter's (1993) analysis of ceramic types from portions of the midden found essentially the same. The presence of the earlier Taos B/W throughout the sequence is due to the presence of this ware across the site, associated with the earlier Valdez phase occupation that underlies the surface architecture. The use and reuse of adobe architecture, much of which was mined from contexts underlying Pot Creek Pueblo, integrated the earlier ceramics—and likely the obsidian—into the architecture, midden, and living surfaces at the site throughout the thirteenth and early fourteenth century occupation of the village.

These same midden contexts contain a significant amount of obsidian ($n=154$). The 1980–1984 excavations in the midden were done in both arbitrary and natural levels, depending on the thickness of the deposit. Based on an analysis of only those obsidian artifacts from excavated levels of 30-cm thickness or less ($n=112$), there is no significant relationship between midden depth and the number of obsidian artifacts from each of the three major sources at

Table 6 Tabulation of obsidian artifacts by source and context at Pot Creek Pueblo (LA 260). Data include those reported here as well as earlier analyses by Newman (1997) and Wolfman (1994)

	General	PH A	RB #1	RB #2	RB #3	RB #4	RB #6	RB #8	Midden	Σ
<i>Jemez Mountains</i>										
El Rechuelos	0	11	3	9	29	27	12	20	102	213
Valles	0	3	2	5	10	6	12	8	51	97
Cerro Toledo	1	3	0	1	5	1	4	1	19	35
Canovas Canyon	0	0	0	0	0	1	1	0	0	2
<i>Taos Plateau</i>										
No Agua Peaks West	0	3	0	0	1	4	1	1	7	17
<i>New Mexico</i>										
East Grants Ridge	0	0	0	0	0	0	1	0	0	1
<i>Non-Local</i>										
Mineral Mountains	0	1	0	0	0	0	0	0	0	1
Obsidian Cliff	0	1	0	0	0	0	0	0	1	2
Σ	1	22	5	15	45	39	31	30	180	368

Pot Creek Pueblo, specifically Cerro Toledo, El Rechuelos, and Valles Rhyolite. Pooling artifact counts into five depth classes; the χ^2 statistic of 9.44 yields a *p* value of 0.306, not significant to either a 0.10 or 0.05 level of significance. This establishes that the relative amounts of obsidian from these three sources showed no significant change throughout the approximately 70 years of occupation at Pot Creek Pueblo.

We also sought to explore whether any significant differences exist in the obsidian-procurement patterns between roomblocks at Pot Creek Pueblo. Merging the data reported here with earlier results from Newman (1997) and Wolfman (1994) results in a total of 368 total artifacts traced to a known obsidian source (Table 6). A chi-squared test of these data shows that obsidian sources are nonrandomly distributed among contexts at the site ($\chi^2=75.487, p=0.042, df=56$); however, these differences are entirely attributable to (1) the presence of a single artifact from an unspecified surface context at the site, (2) the presence of a single artifact from East Grants Ridge in Roomblock #6, and (3) the presence of the Mineral Mountains (*n* = 1) and Obsidian Cliff artifacts (*n* = 1) from the Valdez Phase occupation at the site. If we remove the unprovenienced artifact and three non-local obsidian artifacts from the analysis, a chi-squared test shows that there is no significant difference in obsidian-source representation among roomblocks at the site ($\chi^2=32.374, p=0.260, df=28$). Thus, at least in regards to what can be considered reasonably local obsidian sources—those in the Jemez Mountains and on the Taos Plateau—no statistically significant differences in source use can be detected among the roomblocks at the site.

Similarly, no significant differences are found in the representation of sources and the types of formal tools or debitage at the site. Given that our sample includes tools associated with hunting activities (i.e., projectile points) and domestic-sphere activities (i.e., utilized flakes, scrapers,

gravers), the results of our analyses suggest that no particular variety of obsidian was being selected for specific kinds of tools. Rather, the obsidian-procurement patterns revealed here appear to have been community based, transcending cultural- or gender-based divisions of labor and behavior.

Comparison to regional obsidian-source use

Previous studies of obsidian sources in the Taos area have relied exclusively on distinctive visual characteristics of the El

Table 7 Obsidian-source assignments from sites in the Taos area. Assignments were made based on visual characteristics alone and thus cannot distinguish between the Valles Rhyolite (VR) and Cerro Toledo Rhyolite (CT) obsidians. Data are compiled from Boyer (1990), Boyer and Levine (1991), and Boyer et al. (1994)

	El Rechuelos	Valles/Cerro Toledo	No Agua Peaks West
<i>Valdez Phase</i>			
LA 3570	13	15	
LA 70577	144	44	
LA 70576	1	2	
LA 2742	4	3	
Σ	162	64	
<i>Valdez-Talpa</i>			
LA 69138	12	5	1
LA 77862	1		
Σ	13	5	1
<i>Talpa</i>			
LA 70575	9	10	
LA 71190	22	11	
LA 71189		2	
Σ	31	23	

Rechuelos and No Agua Peaks obsidian. These visual criteria might be diagnostic for these sources, but no similar criteria allow for the identification of Cerro Toledo and Valles Rhyolite obsidian or for the discrimination of other non-local obsidian from them. Nevertheless, previous visual obsidian sourcing in the Taos area by Boyer and colleagues (Boyer 1990; Boyer and Levine 1991; Boyer et al. 1994) suggests that there is a distinct preference for El Rechuelos obsidian, relative to other obsidians, throughout the Valdez and Talpa Phases, thus supporting our findings from Pot Creek Pueblo (Table 7).

The pattern of obsidian-source representation at Pot Creek Pueblo is, however, distinct from what has been documented outside of the Taos area, both within the Northern Rio Grande and farther afield. This seems to be the case both with the early pithouse contexts at Pot Creek as well as with later Coalition Period contexts.

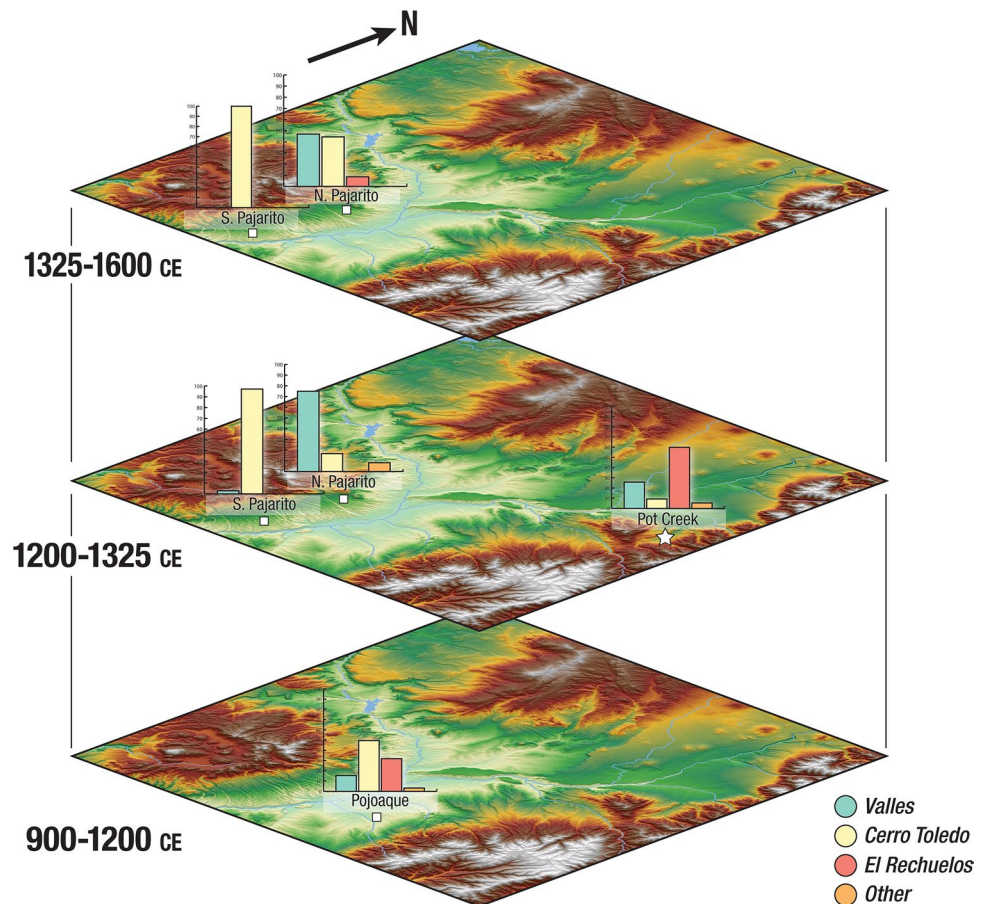
The Early Developmental (600–900 CE) sample between the Tewa and Santo Domingo Basins (adjacent to the Jemez Mountains) reported by Moore and colleagues (2020) is 72.6% Cerro Toledo obsidian, with a further 14.5% from the Valles Rhyolite. El Rechuelos obsidian accounts for only 3.2% of their sample ($n=62$). The same study notes a general decrease in the proportions of El Rechuelos obsidian at sites between the Rio Grande and Santa Fe during the Late Developmental (900–1200 CE) from between 45 and 50% (early and middle Late Development) to 25% (late Late Development). Though the pithouse occupation at Pot Creek has not been directly dated, the ceramic assemblage therein suggests it is more or less contemporaneous with the Early–Middle Developmental Period, and the primary occupation at Pot Creek Pueblo is contemporaneous with the latter portion of the Late Developmental Period.

Moore and colleagues (2020) also note significant differences in obsidian sources from sites occupied during the Developmental Period and those used at Coalition Period (1200–1325 CE) sites in the same area. They report that sites on the northern Pajarito Plateau show obsidian-procurement patterns distinct from those on the southern plateau. Obsidian assemblages from the northern Pajarito Plateau at this time are dominated by Valles Rhyolite (75%) and Cerro Toledo (16.7%) obsidians. No artifacts in their sample were traced to the El Rechuelos source. At the same time on the southern plateau, nearly all (97.2%) of the obsidian derives from the Cerro Toledo Rhyolite. Somewhat further afield in the Gallina region to the west of Pot Creek, Coalition period (ca. 1200–1325 CE) sites tend to have greater than 50% Valles Rhyolite obsidian (Shackley and Moore 2018). In the San Juan Region in western New Mexico, the use of El Rechuelos obsidian appears to decline in frequency through time, from a high of 65% between 1060 and 1140 CE to 22.9% in sites dated between 1225 and 1280 CE (Arakawa et al. 2011; Moore et al. 2020). This latter period is roughly contemporaneous with pueblo occupation at Pot Creek.

Based on these reviews, the predominant use of El Rechuelos obsidian at Pot Creek in contexts dating between early 1200 CE and early 1300 CE appears to distinguish the site's occupants from neighboring groups both within and without the Rio Grande Valley (Fig. 8). Because of the relatively short occupation at Pot Creek, it remains to be seen whether obsidian-procurement patterns of Native peoples on the broader Taos Plateau changed over time, and if so, how these patterns relate to those observed to the south and west. The available sample based on visual classification alone suggests that from Valdez Phase time onward, El Rechuelos obsidian was preferentially obtained and used in the Taos area. Further research is needed to determine whether source determination by geochemistry bears out these findings.

To the best of our knowledge, obsidian from either the Obsidian Cliff or Mineral Mountains sources has not previously been identified in archaeological contexts dating to the period between ca. 900 and 1200 CE within the Northern Rio Grande. We think that the one flake of Mineral Mountains western Utah as well as the two Obsidian Cliff pieces of debitage likely arrived at Pot Creek via interactions with people living on the Northern Plains—not the Great Basin. Obsidian from these two sources, along with obsidian from El Rechuelos has been documented at sites in southwestern Wyoming and northwestern Colorado (e.g., Scheiber and Finley 2011; Smith 1999), providing ephemeral evidence of contact between groups living in these areas over the last 5000 years or more. Elsewhere in northeastern New Mexico, Shackley (2005b) reported that several obsidian assemblages from the southern Park Plateau are composed predominantly of El Rechuelos and Valles Rhyolite obsidian with a single piece attributed to the Yellowstone Volcanic Field. A later study of locally collected artifacts curated at the John W. Rawlings Heritage Center in Las Animas, CO, found that these were produced using Valles Rhyolite, El Rechuelos, No Agua Peaks, Cerro Toledo, and Obsidian Cliff obsidians (Shackley 2011; see also Clark 2016)—roughly the same suite of sources, minus Mineral Mountains, observed at Pot Creek Pueblo. While it is unclear precisely when these particular artifacts date to, it is well documented that later pueblo communities in northern New Mexico (e.g., Taos, Picuris, and Pecos) maintained strong cultural and economic ties with Plains peoples after the mid-1400 s CE. The presence of Northern Plains obsidian in pithouse contexts at Pot Creek suggests that such ties clearly predate the establishment of pueblos during the fifteenth century, though at a smaller scale. The absence of any Plains-related obsidian from pueblo contexts at Pot Creek may suggest a hiatus of these ties, or perhaps a shift in exchange patterns to include less far-flung materials such as Central and Southern Plains cherts (e.g., Alibates) and bison, which have both been recovered from the site.

Fig. 8 Stacked map showing frequencies of main Jemez Mountains obsidian sources present at sites in the Northern Rio Grande between 900 and 1600 CE. Data for sites from the Pajarito Plateau and the Pojoaque area are compiled from Moore et al. (2020). Bar graphs are all scaled to 100%



Conclusion

Geochemical analysis by XRF of a large sample of obsidian artifacts and debitage excavated from Pot Creek Pueblo demonstrates that nearly all of the obsidian artifacts from the site derive from the three major sources in the Jemez Mountains, roughly 70–80 km to the southwest. Significantly, El Rechuelos obsidian comprises nearly 60% of the assemblage. Also importantly, Valles Rhyolite obsidian, which can only be obtained within the Valles Caldera proper, comprises roughly a quarter of the assemblage. The low proportion of Cerro Toledo obsidian at the site suggests to us that obsidian was likely not procured from alluvial deposits of the Rio Grande. These results suggest a pattern of direct procurement from sources in the Chama Valley or on the northern flanks of the Jemez Mountains rather than from alluvial deposits within the Rio Grande.

The presence of three artifacts from sources typically associated with Native peoples residing on the northern Plains suggests to us social and cultural relationships between these people and the early occupants of Pot Creek. With the exception of two pieces of obsidian (one unidentified source, and the other from East Grants Ridge) identified by Newman (1997), no other evidence of long-distance obsidian exchange was identified at the site. The absence of

any northern Plains obsidian within the Puebloan occupation at Pot Creek may signify a hiatus of these relationships, though other artifact classes at the site demonstrate trade and exchange with Native peoples living on the Great Plains.

The current sample is significantly larger than what has been analyzed previously, and it allows for testing whether there are any differences in source use across the site. With the exception of a paltry few non-local pieces, our data do not show any significant difference between the abundances of obsidian from different sources through time at Pot Creek. Rather, we see what appears to be continuity in the reliance on El Rechuelos and Valles Rhyolite obsidian throughout the entirety of the occupation. Thus, if the occupants of Pot Creek utilized a dual organizational approach as part of their social organizational strategy, and the dual organizational strategy influenced the overall layout of the distinct room-blocks at the site as has been suggested by Fowles (2005), the dual organizational strategy does not appear to have been reflected in obsidian-procurement patterns. Of course, this does not necessarily dismiss the proposition of a socially segmented population; rather, it simply fails to reveal any meaningful distinctions based on one aspect of the economy and presumed social networks if obsidian was being procured through trade and exchange.

Perhaps most significantly, our data demonstrate quite clearly (Fig. 8) that obsidian procurement at Pot Creek Pueblo was focused on different sources than those used by groups living on the Pajarito Plateau and adjacent to the Rio Grande. This appears true for the time periods before, during, and after the Pot Creek occupation. We suspect, though cannot prove at the moment, that this points towards a pattern of direct procurement of obsidian rather than a pattern of procuring it through trade/exchange with populations living close to the major Jemez Mountains obsidian sources. This finding has significance to the various models of trade and migration currently being discussed using data from sites located to the south and west of Pot Creek (e.g., Arakawa et al. 2011; Moore et al. 2020). Insofar as the increase in Cerro Toledo obsidian at sites in the Mesa Verde and San Juan region may reflect direct social ties or exchange with people living in the Northern Rio Grande, the people living at Pot Creek Pueblo do not appear to have been part of this network.

The well-dated occupation at Pot Creek Pueblo provides us with a glimpse of perhaps no more than a century of obsidian-procurement on the Taos Plateau. In order to better understand whether the observed patterns are unique to the village at Pot Creek, or whether they characterize a pattern of obsidian-source use with significant time depth, we must obtain datapoints that precede and follow the Pot Creek occupation. For now, however, the available data from Pot Creek Pueblo suggest two things. First, if there was a massive influx of immigrants into the Northern Rio Grande from the Mesa Verde region ca. 1280 CE, this migration does not appear to have disrupted the obsidian-procurement patterns of residents at Pot Creek Pueblo. Second, the obsidian-procurement at Pot Creek Pueblo—and potentially the broader Taos area—appears focused on sources different than those preferred by contemporary residents on the Pajarito Plateau and elsewhere in the Northern Rio Grande. Thus, indigenous peoples of the far northern pueblos in the Rio Grande Valley had limited participation in the obsidian-exchange networks of Pajarito area pueblos that emphasized acquiring and trading Cerro Toledo obsidian.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s12520-022-01590-7>.

Acknowledgements The senior author would like to dedicate this paper to his eldest brother, Jon Wilson Boulanger. This research was conducted and the manuscript written during the COVID-19 pandemic, the same pandemic that ended Jon's life. And, while there is nothing in this paper that relates specifically to Jon, the senior author will forever associate this research with his death and with his memory. We thank our departmental colleague Chris Roos as well as several anonymous reviewers for very constructive and helpful comments on an earlier draft of this paper. M. Steven Shackley, in particular, provided feedback on an earlier draft that greatly improved the quality and content of this paper. We also thank Michael D. Glascock at the University of

Missouri Research Reactor Archaeometry Laboratory for providing calibration specimens that aided in this study. Funding for the XRF spectrometer used here was provided by the QUEST Fund, the Institute for the Study of Earth and Man (ISEM) at SMU, and members of the departments of engineering and anthropology at SMU.

Declarations

Competing interests The authors declare no competing interests.

References

- Adler M (2010) Annual Meeting of the Society for American Archaeology. St. Louis, Missouri
- Adler M, Hegmon M In Press Leaving town: similarities and differences in ancestral pueblo community dissolution practices in the Mesa Verde and Northern Rio Grande Regions. In: *Research, Education, and American Indian Partnerships at the Crow Canyon Archaeological Center*, edited by S. Ryan. University Press of Colorado, Boulder, CO.
- Arakawa F, Ortman SG, Shackley MS, Duff AI (2011) Obsidian evidence of interaction and migration from the Mesa Verde region, southwest Colorado. *Am Antiq* 76(4):773–795
- Arbolino RD (2001) Agricultural strategies and labor organization: an ethnohistoric approach to the study of prehistoric farming systems in the Taos area of northern New Mexico. Ph.D. dissertation, Southern Methodist University, Dallas.
- Binford L (1982) The archaeology of place. *J Anthropol Archaeol* 1:5–31
- Boulanger MT, Glascock MD, Steven Shackley M, Skinner C, Thatcher JJ (2010) Likely source attribution for a possible Paleoindian obsidian tool from northwest Louisiana. *Louisiana Archaeol* 37:81–88
- Boyer JL (1990) The Tres Piedras Project: archaeological testing at LA 71740, Taos County, New Mexico. *Archaeology Notes* 19. Museum of New Mexico, Office of Archaeological Studies, Santa Fe.
- Boyer JL, Levine DF (1991) The Talpa Testing Project: archaeological testing excavations along state road 518 and a data recovery plan for LA 77861, Taos County, New Mexico. *Archaeology Notes* 27. Museum of New Mexico, Office of Archaeological Studies, Santa Fe.
- Boyer JL, Moore JL, Levine DF, Mick-O'Hara L, Toll MS (1994) Studying the Taos Frontier: the Pot Creek Data Recovery Project, Volumes I and II. *Archaeology Notes* 68. Museum of New Mexico, Office of Archaeological Studies, Santa Fe.
- Clark BJ (2016) Freshman sourcing obsidian? Using pXRF in the introductory archaeology classroom. *SAA Archaeol Record* 16(3):13–16
- Church T (2000) Distribution and sources of obsidian in the Rio Grande gravels of New Mexico. *Geoarchaeology* 15:649–678
- Clark JJ, Birch JA, Hegmon M, Mills BJ, Glowacki DM, Ortman SG, Dean JS, Gauthier R, Lyons PD, Peeples MA, Borck L, Ware JA (2019) Resolving the migrant paradox: two pathways to coalescence in the late precontact U.S. *Southwest J Anthropol Archaeol* 53:262–287
- Crown PL (1991) Evaluating the construction sequence and population of Pot Creek Pueblo, northern New Mexico. *Am Antiq* 56:291–314
- Duwe S (2011) The prehispanic Tewa world: space, time, and becoming in the Pueblo Southwest. Ph.D. dissertation, The University of Arizona, Tempe.
- Fowles SM (2004) The making of made people: the prehistoric evolution of hierarchy among the Northern Tiwa of New Mexico. Unpublished Ph.D. dissertation, University of Michigan, Ann

- Arbor. (2005) Historical contingency and the prehistoric foundations of eastern Pueblo moiety organization. *J Anthropol Res* 61(1):25–52
- Gluscock MD, Ferguson JR (2012) Report on the analysis of obsidian source samples by multiple analytical methods. Prepared by: Archaeometry Laboratory, University of Missouri Research Reactor. Prepared for: Bruker, Kennewick, Washington.
- Gluscock MD, Kunselman R, Wolfman D (1999) Intrasource chemical differentiation of obsidian in the Jemez Mountains and Taos Plateau, New Mexico. *J Archaeol Sci* 26:861–868
- Green EL (1976) *Valdez Phase Occupation Near Taos, New Mexico*. Fort Burgwin Research Center no. 10. Southern Methodist University, Dallas, Texas.
- Liebman MJ (2017) From landscapes of meaning to landscapes of signification in the American Southwest. *Am Antiq* 82(4):642–661
- Moore J (2009) Great basin tool-stone sources; the NDOT obsidian and tool-stone sourcing project: 2002 progress report. Prepared for the Nevada Department of Transportation, Prepared by the Cultural Resources Section, Environmental Services Division
- Moore JL, Blinman E, Shackley MS (2020) Temporal variation in obsidian procurement in the northern Rio Grande and its implications for obsidian movement into the San Juan area. *Am Antiq* 85(1):152–170
- Newman JR (1997) Patterns of lithic procurement and utility in the Rio Grande del Rancho Valley of the Northern Rio Grande Region, New Mexico. Unpublished Ph.D. dissertation, Department of Anthropology, Southern Methodist University.
- Newman JR, Nielsen RL (1985) Initial notes on the X-ray fluorescence sourcing of northern New Mexico obsidians. *J Field Archaeol* 12:377–383
- Ortman SG (2010) Evidence of a Mesa Verde homeland for the Tewa Pueblos. In: *Leaving Mesa Verde: Peril and change in the thirteenth-century Southwest*, edited by T. A. Kohler, M. D. Varien, and A. M. Wright, pp. 222–261. Amerind Studies in Archaeology 5. University of Arizona Press, Tucson.
- Ortman SG (2012) *Winds from the North: Tewa Origins and Historical Anthropology*. University of Utah Press, Salt Lake City
- Procter, RS (1993) Social and economic implications of design structure in prehistoric ceramics of the Taos district. Unpublished Ph.D. dissertation. Department of Anthropology, Washington University, St. Louis.
- Ridings, RI (1994) Study of obsidian hydration and climatic change at Pot Creek Pueblo. Unpublished Ph.D. dissertation, Department of Anthropology, Southern Methodist University.
- Scheiber LL, Finley JB (2011) Obsidian source use in the greater Yellowstone area, Wyoming Basin, and Central Rocky Mountains. *Am Antiq* 76:372–394
- Shackley MS (2005a) *Obsidian: geology and archaeology in the North American Southwest*. University of Arizona Press, Tucson
- Shackley MS (2005b) Source provenance of obsidian artifacts from prehistoric sites on the Southern Park Plateau, Northeast New Mexico Geoarchaeological XRF Laboratory. Prepared for Southwest Archaeological Consultants Prepared by
- Shackley MS (2011) Source Provenance of Obsidian Artifacts from Two Sites in Southern Colorado Geoarchaeological XRF Laboratory. Prepared for B. Clark, University of Denver Prepared by
- Shackley MS (2021) Distribution and sources of secondary deposit archaeological obsidian in Rio Grande alluvium New Mexico. Geoarchaeology, USA. <https://doi.org/10.1002/gea.21877>
- Shackley MS, Moore JL (2018) More than just Jemez Pueblo obsidian: comment on Liebmann's "...Landscapes of Signification in the American Southwest." *American Antiquity* 83(4): 753–755.
- Smith CS (1999) Obsidian use in Wyoming and the concept of curation. *Plains Anthropol* 44:271–291
- Speakman RJ (2012) Evaluation of Bruker's tracer family factory obsidian calibration for handheld portable XRF studies of obsidian. Prepared by: Center for Applied Isotope Studies, University of Georgia. Prepared for Bruker, Kennewick, Washington.
- Wetherington RK (1968) *Excavations at Pot Creek Pueblo*. Fort Burgwin Research Center no. 6. Taos, New Mexico.
- Wolfman D (1994) *Jemez Mountains Chronology Study*. Contract 53–8379–9–14. Prepared by Office of Archaeological Studies, Museum of New Mexico, Santa Fe. Prepared for USDA Forest Service.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.