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ARTICLE

Obsidian Procurement and Exchange at the Apogee of Empire: Wari Political Economy in Arequipa, Peru

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Abstract

During the Middle Horizon (AD 600–1000), obsidian was transported in greater quantities and distances than ever before identified in the Andes, in part by the expansionary Wari state. Two of the three major obsidian sources used in the south-central Andes are located in the modern department of Arequipa, Peru. Arequipa was a region of intense Wari influence and intrusive presence; however, little is known about regional obsidian use. Portable X-ray fluorescence (pXRF) and laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) were used to analyze 383 obsidian artifacts recovered from 10 archaeological sites in Arequipa. Results highlight diachronic and spatial patterning related to obsidian procurement strategies, state versus bottom-up exchange networks, and local participation within the Wari realm. A wide variety of geological obsidian sources, including nonlocal obsidians originating from Wari's Ayacucho heartland, were used. By the late Middle Horizon, the Wari had consolidated regional resources with the sole use of Alca-1 and Alca-4 bedrock obsidians, the largest-sized and highest-quality sources in the area. We assess related models of obsidian procurement and exchange related to state political economy, long-distance caravan activity, and the role of local ceremonial/waystation centers that facilitated the flow of ideas, goods, and people across Arequipa.

Resumen

Durante el Horizonte Medio (600–1000 dC), la obsidiana fue transportada en cantidades y distancias nunca antes vistas en los Andes Centro Sur, debido en parte, al expansionista estado Wari. Dos de las tres principales fuentes de obsidiana utilizadas están en Arequipa, Perú, región de intensa influencia Wari. Sin embargo, se sabe poco del uso regional de la obsidiana. Se analizan aquí 383 artefactos de obsidiana recuperados de 10 sitios arqueológicos en Arequipa, utilizando fluorescencia de rayos X portátil (pXRF) y espectrometría de masas con plasma de acoplamiento inductivo por ablación láser (LA-ICP-MS). Los resultados destacan los patrones diacrónicos y espaciales del uso de obsidiana, las redes de intercambio y la participación local dentro del reino Wari. También indican una amplia variedad de fuentes geológicas de obsidiana, incluyendo algunas no locales, originarias del corazón de Wari en Ayacucho. A fines del Horizonte Medio, Wari había consolidado el uso exclusivo de obsidianas Alca-1 y Alca-4 (fuentes de mayor tamaño y calidad de la zona). Aquí evaluamos modelos de obtención e intercambio de obsidiana relacionados con la economía política estatal, la actividad caravanera y el papel de los centros ceremoniales/tambos que facilitaron el flujo de ideas, bienes y personas a través de Arequipa.

Keywords: obsidian; pXRF; LA-ICP-MS; geochemical analysis; exchange; frontier; state expansion; Wari

Palabras clave: obsidiana; pXRF; LA-ICP-MS; análisis geoquímico; intercambio; frontera; expansión estatal; Wari

The Middle Horizon (AD 600–1000) was a time of profound socioeconomic change, shaped in part by the Wari state, the most expansive pre-Inka imperial project in the Andes. The Wari are traditionally described as a first-generation empire that established colonies and state-administered sites far beyond their Ayacucho heartland (Isbell and McEwan 1991; Schreiber 2001; Figure 1). Here we examine Wari political economic strategies that financed state projects across such vast geographic distances. Studies suggest that they made special efforts to control key trade routes where access to exotic goods and prestige items was used to maintain class differentiation and legitimize rulership (Earle and Jennings 2012; Isbell 2010; Rosenfeld et al. 2021). At this time, obsidian served as both a precious material and a common domestic item that was transported in greater quantities and distances than ever before identified in the Andes, largely through Wari networks (Burger et al. 2000; Burger and Glascock 2009; Williams et al. 2012). Using obsidian provenance analysis, we investigate both top-down political economic strategies of the Wari and bottom-up processes of regional exchange outside state control.

We report the geochemical analysis of 383 obsidian artifacts from 10 Middle Horizon sites located in the modern department of Arequipa, Peru (Figure 2). The majority of these sites correspond to the late Middle Horizon (ca. AD 800–1000) during the apogee of Wari imperialism when state projects and colonies proliferated (Reid 2023; Schreiber 2001; Williams 2001). Arequipa has traditionally been considered part of Wari's southern periphery (Lumbreras 1974) and served as a crossroads between the state heartland in Ayacucho and Wari's southernmost holdings in Moquegua (Williams 2009). Although the department of Arequipa contains two of the three major Peruvian obsidian sources used in the past, as well as several minor sources (Glascock et al. 2007), little is known about obsidian use in the region and its role in regional political economies. In contrast to viewing the Middle Horizon as a monolithic or homogeneous period, we trace how obsidian use changed during the Middle Horizon with the entrance of Wari state actors into Arequipa (ca. AD 800–1000) and during the subsequent Terminal Middle Horizon (ca. AD 1000–1100) when state centers were abandoned yet communities continued to engage with Wari ideas and material culture.

Wari Political Economy

Political economies are intrinsically tied to various forms of power through which state projects are funded and maintained. Comparative archaeology illustrates the differences between highly centralized state economies and more heterarchical organizations based on collective action (Blanton and Fargher 2008; Smith and Schreiber 2005). Andean political economies are typically assessed in terms of Inka staple and wealth finance as defined in the seminal work of D'Altroy and Earle (1985). Under staple finance, polities intensified the production of everyday stuffs and agricultural goods to support state institutions and activities. Related infrastructure such as roads, storage facilities, and administrative centers enabled the redistribution of surplus resources where needed. In contrast, wealth finance strategies focused on the production and acquisition of prestige and high-value items. These materials were often imbued with ideological power and were distributed to elites in exchange for their collaboration and fulfillment of political duties to the state (DeMarrais et al. 1996).

Wari expressions of power varied on a regional and temporal basis as related to oscillating processes of state development, expansion, consolidation, and ultimate dissolution (Schreiber 1992). Strategies of Wari staple finance were most apparent in regions under direct state control, especially within the Ayacucho heartland where agricultural intensification maintained incipient urban populations. Outlying Wari centers were also transformed by terrace agriculture and canal construction as part of a Wari-built landscape (McEwan and Williams 2012). Given the infrastructural limitations of first-generation empires, the Wari likely used practices of "mediated" or "negotiated" rule, relying on local elites and social institutions, such as *ayllu* or kinship-based corporate groups, to mobilize corvée labor for state projects (Dillehay and Wernke 2019; Sandweiss and Reid 2016). Consequently, staple finance was not an entirely secure or feasible strategy in areas of local resistance or where direct Wari presence was minimal or nonexistent.

In regions where Wari control was indirect or hegemonic, the Wari may have relied on wealth finance strategies (Earle and Jennings 2012). Wealth finance entails the circulation of high-end goods linked to ideological systems of prestige, hierarchy, and religion. State elites may attempt to control the

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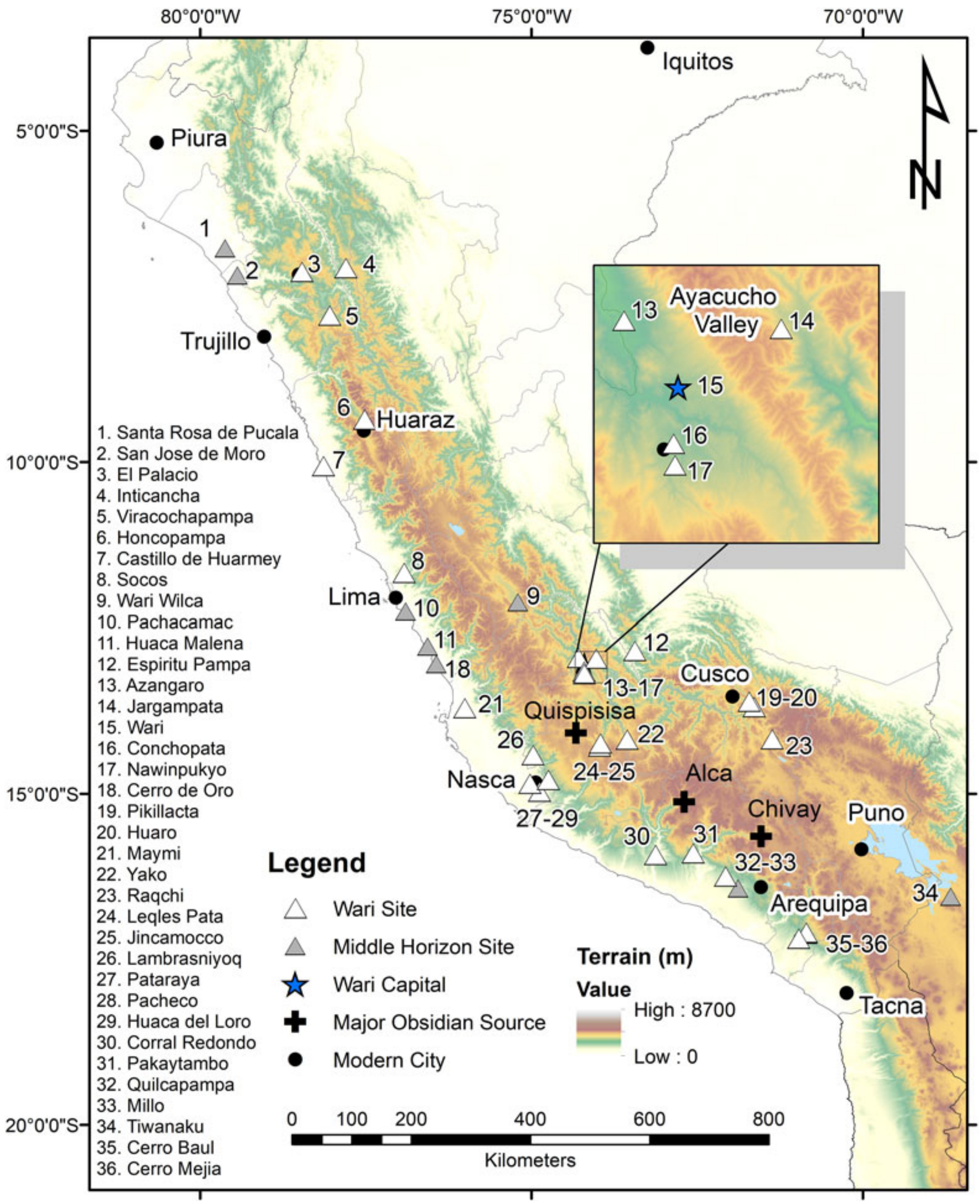

Figure 1. Map of significant Middle Horizon and Wari sites in Peru. (Color online)

chokepoints within commodity chains of high-end items either in the acquisition, production, or distribution stages (Earle and Jennings 2012:214–215). Evidence suggests the Wari attempted to control key trade and mobility routes (Isbell 2010; Reid 2020) and secured access to materials of ideological significance such as *Spondylus* and obsidian (Glowacki and Malpass 2003; Rosenfeld et al. 2021; Topic and Topic 2010). Wari enclaves found within niche ecological zones suggest that colonization efforts were in part aimed at acquiring exotic resources not found within the Ayacucho highlands. For example, the Wari established Espíritu Pampa on the eastern slopes of the Andes where they could acquire Amazonian goods, including fanciful feathers, coca, beeswax, and hallucinogenic plants (Fonseca Santa Cruz and Bauer 2020). Likewise, Wari settlements in the coastal valleys of Nasca and Majes

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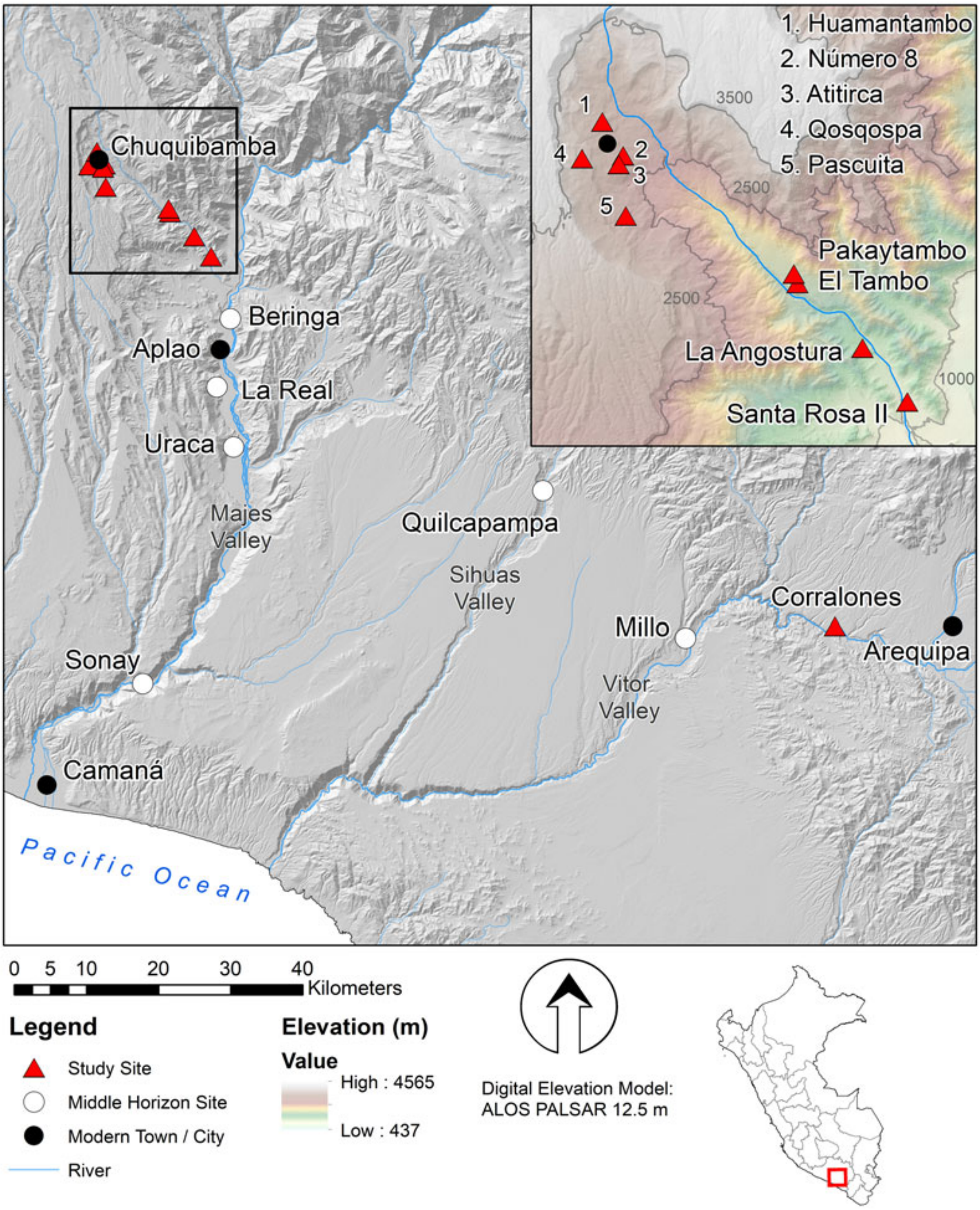

Figure 2. Map of Arequipa study sites. (Color online)

may have facilitated the production of cotton and coca (Conlee et al. 2021; Edwards and Schreiber 2014; Goldstein 2010).

Trade items often extend beyond a polity's political boundaries in ways that complicate models of state power. Wari materials were often "bundled" with "physical items, ritual practices, and the meanings exercised through them" (Lau 2012:30) and included *Spondylus*, greenstone/turquoise figurines, ceramic polychrome vessels, textiles, and obsidian. Such processes relate to bottom-up socioeconomic strategies through which locals may have emulated or co-opted an "international Wari identity" for their own purposes (Isbell 2010:248). Thus, the circulation of wealth items can co-occur under *and* outside Wari control, especially in frontier settings. It is unclear to what

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extent Wari interfered in more traditional realms of exchange such as "down-the-line" trade or reciprocal barter relationships that linked ecological zones and communities. However, it is likely that state-affiliated llama caravans were employed to maintain connections between Wari centers responsible for the transport of exotic goods between distant regions (Edwards 2021; Rosenfeld et al. 2021).

The Role of Obsidian in Wari's Political Economy

Obsidian was a major component of Wari's political economy and is often used as a proxy for Wari–local interaction. Located about 120 km from Wari's capital, Quispisisa was the preferred obsidian source in Ayacucho due to its high-quality and large-sized nodules (Burger and Glascock 2002; Tripcevich and Contreras 2011). Quispisisa obsidian comprised nearly the entire assemblages at the capital and at the secondary center Conchopata (Burger et al. 2000, 2016; Kaplan 2018; Wistuk 2019; Figure 3). The geographically dispersed nature of Andean obsidian sources made it impossible to directly control any singular source (Jennings and Glascock 2002). Instead, Wari obsidian trade items were widely distributed in the form of large or "oversized" lanceolate obsidian bifaces/preforms and Wari "laurel leaf" points.

Lithic tool and ornamental production may have been centralized by the Wari state, given evidence of lithic specialists at the capital as noted by MacNeish and colleagues (1980:14), who described three compounds: one associated with turquoise ornament manufacturing, a second with large quantities of debitage including obsidian, and a third containing hundreds of finished projectile points but no lithic waste debris. Mass production of projectile points and bifaces would have been necessary to support Wari's militaristic campaigns of expansion (see Tantaleán 2013). Obsidian may also have possessed other symbolic qualities, especially as an accoutrement of the warrior class (Goldstein 2010:61). The state may have distributed obsidian raw materials or tool blanks to second-tier centers and non-Wari communities as a form of institutionalized reciprocity, as hypothesized in Moquegua (Nash 2022; Williams et al. 2022).

Arequipa Obsidian

The first Andean obsidian provenance analyses were conducted in the 1970s by Burger and Asaro (1977, 1978). Numerous studies across 12,000 years of the Andean past and using various analytical instrumentation have since identified three major obsidian sources and several minor sources that were predominantly used in Peru and the Bolivian altiplano (Figure 3). Of the three major sources, Alca and Chivay are found in the department of Arequipa (Brooks et al. 1997; Burger, Asaro, Salas, and Stross 1998; Burger, Asaro, Trawick, and Stross 1998; Jennings and Glascock 2002; Rademaker et al. 2013, 2021), and Quispisisa in Ayacucho (Burger and Glascock 2002; Tripcevich and Contreras 2011).

Arequipa's highland zones contain a complex volcanic geology that resulted in several geochemically distinct obsidian sources. Obsidian was initially reported near the modern town of Alca in the Cotahuasi Valley (Burger, Asaro, Trawick, and Stross 1998), and further geological investigations defined six Alca subsources (Rademaker et al. 2013, 2021). Alca-1 was matched to the initial "Cusco Type" defined by Burger and Asaro (1977) and was the dominant Alca subsource used in the past. The minor sources Anillo (Tripcevich 2016) and Sayrosa (Burger et al. 2022) are also found in Alca's immediate region. Of these multiple sources, only Alca-1 and Alca-4 demonstrate extensive bedrock outcrops with large nodules of high-quality volcanic glass up to 30 cm in size.

Middle Horizon obsidian use in Arequipa reflected broader sociopolitical trends as the region became a frontier between the Wari and Tiwanaku states (Cardona Rosas 2002). Alca-1 obsidian was transported across Wari networks as far north as Huamachuco (Burger et al. 2000; Burger and Glascock 2009), to the eastern Amazonian slopes of Vilcabamba (Fonseca Santa Cruz and Bauer 2020), and to Peru's far south in Moquegua (Burger et al. 2000; Reid, Goldstein, and Williams 2022; Williams et al. 2012, 2022; Figure 1). Minimal transfers of Alca-1 were made to the Wari capital in Ayacucho where Quispisisa obsidian remained the dominant source in the state heartland and in

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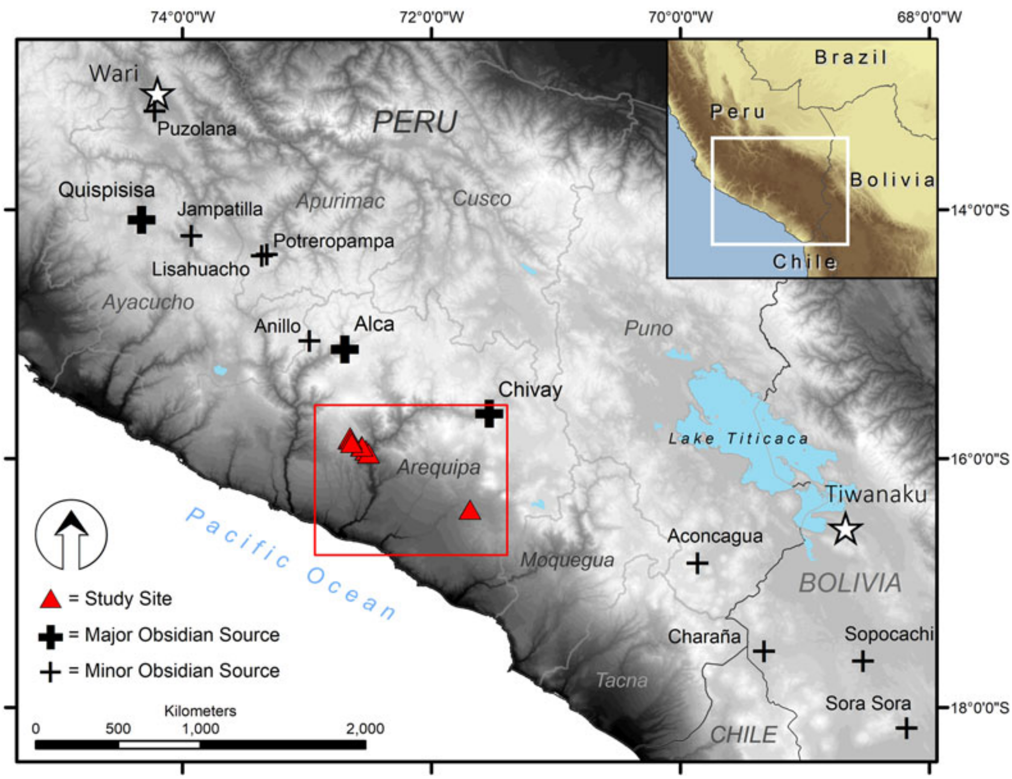

Figure 3. Map of obsidian sources of the south-central Andes in relation to the study region (box) and capitals of the Wari and Tiwanaku states.

northern Peruvian exchange networks (Burger et al. 2000, 2016; Kaplan 2018; Wistuk 2019). In contrast, Chivay obsidian served as the predominant source for Tiwanaku-affiliated settlements in the Titicaca Basin during the Middle Horizon (Burger et al. 2000; Giesso 2003; Glascock and Giesso 2012; Tripcevich 2010).

Obsidian provenance studies from Middle Horizon contexts in Arequipa include both local and intrusive Wari contexts. At Beringa in the mid-Majes Valley, Tung (2012:48) reports the presence of Alca-1 ($N = 1$), Anillo ($N = 1$), and Quispisisa ($N = 2$). At La Real, early mortuary contexts (ca. AD 700–850) included single artifacts composed of Alca-1, Chivay, and Quispisisa, whereas later contexts (ca. AD 900–1050) show the sole use of Alca-1 ($N = 4$; Glascock 2012:179; Jennings et al. 2015:391). At the Wari enclave Quilcapampa in the Sihuas Valley, residents predominantly used Alca-1 (79%, $N = 55$) followed by Quispisisa (20%, $N = 14$) and Chivay ($N = 1$; Rizzuto and Jennings 2021:273). Temporal distinctions show a decline in the use of Quispisisa obsidian in favor of Alca-1 between early and late occupations at La Real, Quilcapampa, and Wari contexts in Moquegua (Williams et al. 2012:84).

Archaeological Site Background and Samples

This study presents provenance data for 383 obsidian artifacts across 10 archaeological sites in Arequipa, Peru. Study sites represent two regional foci: the Chuquibamba–Majes drainage and the Vitor Valley (Figure 2). Notably, all sites are found along the same pre-Inka road network that connected Arequipa's coastal valleys (Cardona Rosas 2002, 2015; Reid 2020; Williams 2009). All sampled sites show evidence of Wari or Wari-affiliated materials such as diagnostic polychrome ceramics. Radiocarbon dates from the study sites largely correspond to the late Middle Horizon (ca. AD 800–1000), and it is possible that most sites were occupied contemporaneously at some point (Supplemental Table 1). A smaller set of samples date to the Terminal Middle Horizon (ca. AD

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1000–1100), a time when Wari influence is still observed in the local material record but interaction with the last vestiges of the Wari state is unclear.

Excavations by Goldstein (2010:222) at five Middle Horizon settlements near the modern town of Chuquibamba (ca. 2,940 m asl) allowed for the analysis of 39 obsidian flakes, more than half of all recovered obsidian from Goldstein's excavations ($N = 69$). The Chuquibamba Tributary forms the upper drainage of the Majes Valley and serves as a major highland–coast corridor. Obsidian was sampled from the agricultural villages of Atitirca ($N = 5$), Huamantambo ($N = 18$), Pascuita ($N = 1$), and Qosqospa ($N = 10$). Five specimens were analyzed from the site Numero 8 (ca. 2,850 m asl). Sector B of Numero 8 is oriented around a small rectilinear compound of double-course stonewalls at least 2 m in height, with internal divisions similar to Wari architectural syntax. Domestic remains indicate that elite residents, possibly tied to the Wari state, once resided there (Goldstein 2010:247).

Wari imperial presence in Arequipa is most conclusively identified at Pakaytambo (ca. 1,700 m asl) at the transition of the Chuquibamba Tributary and the Majes Valley (Reid 2023). Pakaytambo displays imperial-style architecture including patio groups and a D-shaped temple enclosure built atop a monumental platform that measures 35 × 65 m and is up to 3 m in height. Accelerator mass spectrometry (AMS) radiocarbon dates from construction and abandonment events place site occupation between AD 770 and AD 980 (all reported dates are calibrated SHCal20, 95% ranges; Supplemental Table 1). Twenty-three specimens were analyzed comprising 32.9% of all obsidian recovered from Pakaytambo ($N = 70$). Samples include a biface, scraper, and small-sized debitage recovered from wall-fall and floor deposits. Obsidian micro-debitage that was too small to fit over the pXRF aperture were not analyzed. By weight, obsidian comprised almost 30% of all excavated lithic materials from Pakaytambo and 57% by count.

The large administrative center El Tambo (ca. 1,650 m asl) is located 0.5 km south of Pakaytambo and is organized around a central plaza 45 × 50 m in size. Several large orthogonal enclosures with massive stonewalls more than 3 m high are found adjacent to the plaza. AMS radiocarbon dates suggest the site was occupied during the late Middle Horizon, if not earlier (Reid 2023). Surface collections of Inka ceramics suggest that El Tambo was reoccupied during the Late Horizon (AD 1400–1532). Forty-one obsidian artifacts from El Tambo were large enough to be analyzed by pXRF and comprised 35% of all recovered obsidian from the site ($N = 117$). The majority of the samples ($n = 28$) were recovered from excavation contexts, with the remaining corresponding to surface collections ($n = 13$). Because El Tambo is a multicomponent site, surface artifacts may correspond to the later occupation. In addition to obsidian debitage, one drill, one projectile point, and three tool fragments were also analyzed. Obsidian comprised almost 80% of all excavated lithic materials by weight and 86% by count, indicating its importance as a raw material.

Santa Rosa II (ca. 1,060 m asl) is located at the confluence of the Majes Valley and upper tributaries that form the Chuquibamba, Pampacolca, and Colca drainages. The site was first recorded by García Márquez and Bustamente Montoro (1990:32–34) and comprises several sectors with informal structures, llama corrals, and a ceremonial core organized around a plaza 67 × 67 m in size. An attached orthogonal complex is adjacent to the plaza's north end where site managers likely resided. Excavations and material analyses by Reid (2020) indicate that the ceremonial core of the site dates to the late Middle Horizon between AD 770 and AD 1020. At Santa Rosa II, 136 obsidian artifacts were large enough for pXRF analysis, comprising 91.3% of all recovered obsidian ($N = 149$). Of the analyzed obsidian, 16.2% ($n = 22$) correspond to the ceremonial core, and 83.8% ($n = 114$) are from adjacent areas. A variety of projectile points ($n = 15$) exhibiting common Middle Horizon forms were analyzed (Figure 4) alongside tool fragments ($n = 25$), drills ($n = 2$), a single core, preform blank, and lithic debitage ($n = 92$). All point types from Santa Rosa II display typical Middle Horizon forms identical to those recorded at Cerro Baul in Moquegua (Vining 2005:51–56). At Santa Rosa II, obsidian comprised almost 33% of all excavated lithic materials by weight and 36% by count.

La Angostura (ca. 1,130 m asl) is found within the Quebrada Huario, an arid drainage that connects the Majes Valley and the lower Chuquibamba Tributary. Several informal structures, corrals, and the

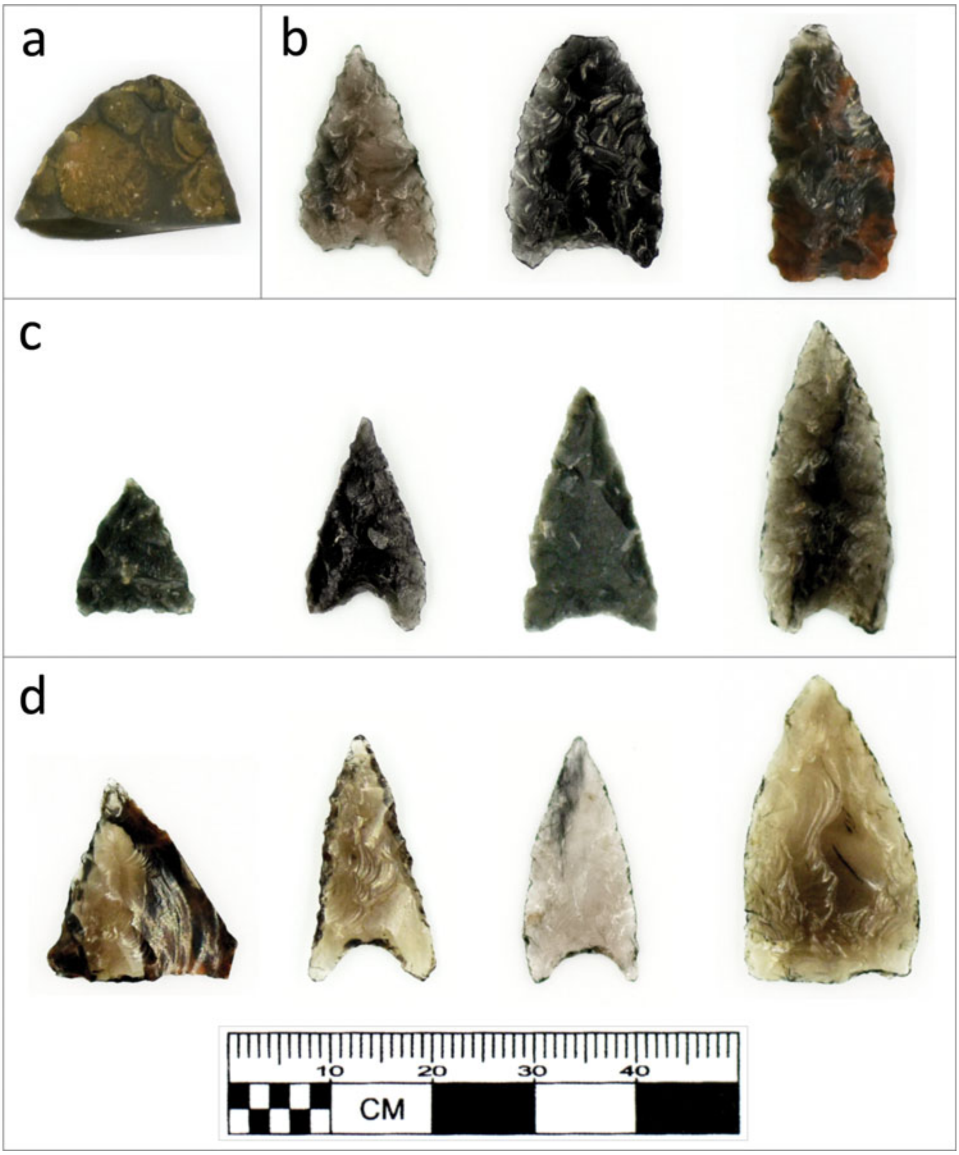

Figure 4. Sample of bifacially worked tools from La Angostura (a) and Santa Rosa II (b–d). Source characterization: a = Alca-4; b = Quispisisa; c = Anillo; and d = Alca-1. (Color online)

presence of geoglyphs at La Angostura indicate the site's use as a waystation along the valley's highland–coastal road. As at Santa Rosa II, a central plaza with an adjoining complex abutting the north wall served as a ceremonial space and was dated to AD 770–1040 (Reid 2020). From La Angostura, 109 obsidian artifacts were large enough for pXRF analysis comprising 83.2% of all recovered obsidian ($N = 131$). Analyzed specimens largely correspond to surface collections, including tool fragments ($n = 8$), blades ($n = 2$), and debitage ($n = 99$). By weight, obsidian comprised almost 6% of all excavated lithic materials from La Angostura and 30% by count.

Thirty-five obsidian artifacts were recovered and analyzed from Corralones (ca. 2,035 m asl), which is strategically located along a transit route at the confluence of the Vitor Valley and the agriculturally productive Arequipa Valley (Cardona Rosas 2002). Corralones exhibits orthogonal architecture, plazas, and patio groups suggestive of Wari lexicons that are notably similar to Wari-affiliated sites in Moquegua such as Cerro Mejia (Nash and Williams 2005). Excavations at the site by Cardona

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Rosas yielded Wari ceramics and two radiocarbon dates between AD 680 and AD 900 (Supplemental Table 1). Analyzed obsidian artifacts from Corralones included projectile points (*n* = 9), point fragments (*n* = 8), one blade, flakes (*n* = 9), and shatter (*n* = 8).

Methodology

We used portable X-ray fluorescence (pXRF) and laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) to investigate obsidian artifact geochemistry. pXRF has increasingly been used to determine obsidian artifact provenance from Peru (Bélisle et al. 2020; Beresford-Jones et al. 2022; Kellett et al. 2013; Matsumoto et al. 2018; Reid, Goldstein, and Williams 2022; Reid, Williams, et al. 2022). It provides a rapid and nondestructive elemental analysis that can be undertaken in the field and produces comparable analytical data to benchtop XRF, INAA, and LA-ICP-MS (Kellett et al. 2013; Rademaker et al. 2013, 2021; Williams et al. 2012). However, pXRF's limitations relate to inadequate specimen size, thickness, and surface irregularity (Davis et al. 2011; Shackley 2010). In contrast, LA-ICP-MS is ideal for small fragments and provides a high-resolution, single-point beam analysis that first ablates the surface of the artifact, removing any potential surface contamination. Investigations have used LA-ICP-MS to accurately distinguish Andean obsidian sources (Eerkens et al. 2010; Kellett et al. 2013; Williams et al. 2012).

All reported pXRF and LA-ICP-MS data were collected using instrumentation maintained by the Elemental Analysis Facility (EAF) at the Field Museum of Natural History in Chicago (see Supplemental Text 1 for instrument specifications). Obsidian artifacts from Corralones were analyzed using an Innov-X Systems Alpha pXRF spectrometer in 2008. Analyses of obsidian artifacts from Pakaytambo, El Tambo, Santa Rosa II, and La Angostura were conducted using a Thermo Scientific Niton XL3t Goldd+ pXRF spectrometer in 2018. LA-ICP-MS analyses of Alca geological materials and obsidian artifacts from Chuquibamba and Majes were conducted in 2005, 2008, and 2019. These analyses used a Varian Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) in 2005 and 2008 and a Thermo ICAP Q ICP-MS in 2019. Both spectrometers were connected to a New Wave UP213 laser for the direct introduction of solid samples.

Elemental data were calibrated using EAF standard methods (Supplemental Tables 2 and 3), and subsequent ppm concentrations were log10 transformed for statistical analyses following Glascock and colleagues (1998) in the program JMP Pro v16.2.0. Obsidian source character groups were first formed using Ward's hierarchical cluster analysis and then compared to reference geological materials. Ratios of elemental concentrations have been shown to mitigate exaggerated elemental values that are sometimes associated with the analysis of small-sized samples by pXRF (Frahm 2016; Reid, Williams, et al. 2022). Ratios of strontium and rubidium compared to other elemental values proved valuable. This is not surprising as both elements are known to best discriminate Andean obsidians by XRF (Glascock et al. 2007; Supplemental Figure 1). pXRF character groups are optimally visualized as ternary graphs by individual instrument using Sr, Rb, and Zr (Figures 5 and 6). LA-ICP-MS results are presented as the ratios between ppm concentrations of Sr/Zr and U/La (Figure 7; Supplemental Figures 2 and 3). A total of 13 obsidian artifacts from La Angostura (*n* = 8) and Pakaytambo (*n* = 5) were analyzed both by pXRF and LA-ICP-MS and showed successful replicability of character groups, verifying source assignments by LA-ICP-MS.

Results

Geochemical characterization by pXRF and LA-ICP-MS allowed us to assign 383 obsidian artifacts from Arequipa to six previously defined obsidian sources—Alca-1, Alca-4, Anillo, Lisahuacho, Jampatilla, Quispisisa—and one unidentified source (Table 1). Obsidians local to Arequipa were unsurprisingly the dominant sources across all study sites. Alca-1 comprised nearly 60% (*n* = 227) of the entire assemblage followed by Alca-4 with 28% (*n* = 108). Four triangular projectile points and several flakes were sourced to Anillo (*n* = 12) from Santa Rosa II, as was a single flake from La Angostura (*n* = 1). Anillo has rarely been identified in the archaeological record, with only a single specimen from Beringa (Tung 2012:48) and three flakes from the Tiwanaku center Omo in the Moquegua Valley (Reid, Goldstein, and Williams 2022). Of note, not a single specimen of Chivay

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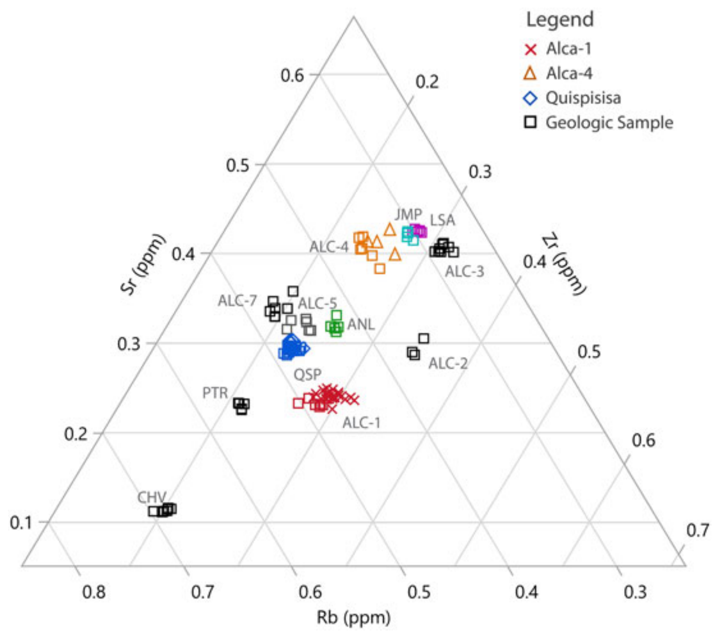

Figure 5. Ternary graph (Sr, Rb, Zr) of obsidian artifacts from Corralones by pXRF.

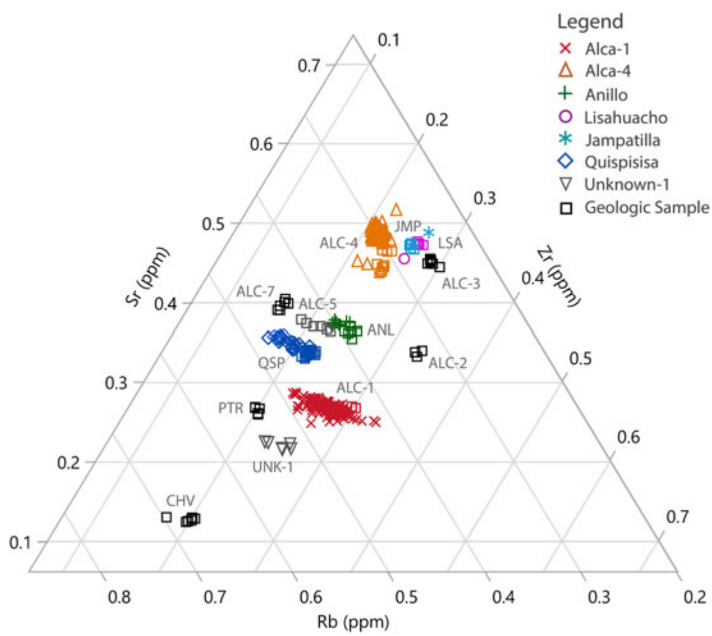

Figure 6. Ternary graph (Sr, Rb, Zr) of obsidian artifacts from the upper Majes–Chuquibamba Drainage by pXRF.

obsidian was detected in this study, although it constitutes one of the three major obsidian sources in Peru and is the proximal obsidian source to Corralones (Figure 3).

Several exotic obsidians whose sources are found outside Arequipa were detected at five of the study sites. Single flakes of Quispisisa were identified at Huamantambo and Qosqospa and greater quantities from Corralones ($n = 5$), Santa Rosa II ($n = 9$), and La Angostura ($n = 11$; Table 1). Quispisisa obsidian was the dominant source used in Ayacucho (Burger et al. 2000, 2016; Kaplan 2018) and Ica/Nasca (Beresford-Jones et al. 2022; Eerkens et al. 2010) and was distributed through Wari networks as far south as Moquegua (Burger et al. 2000; Reid, Goldstein, and Williams 2022; Williams et al. 2012).

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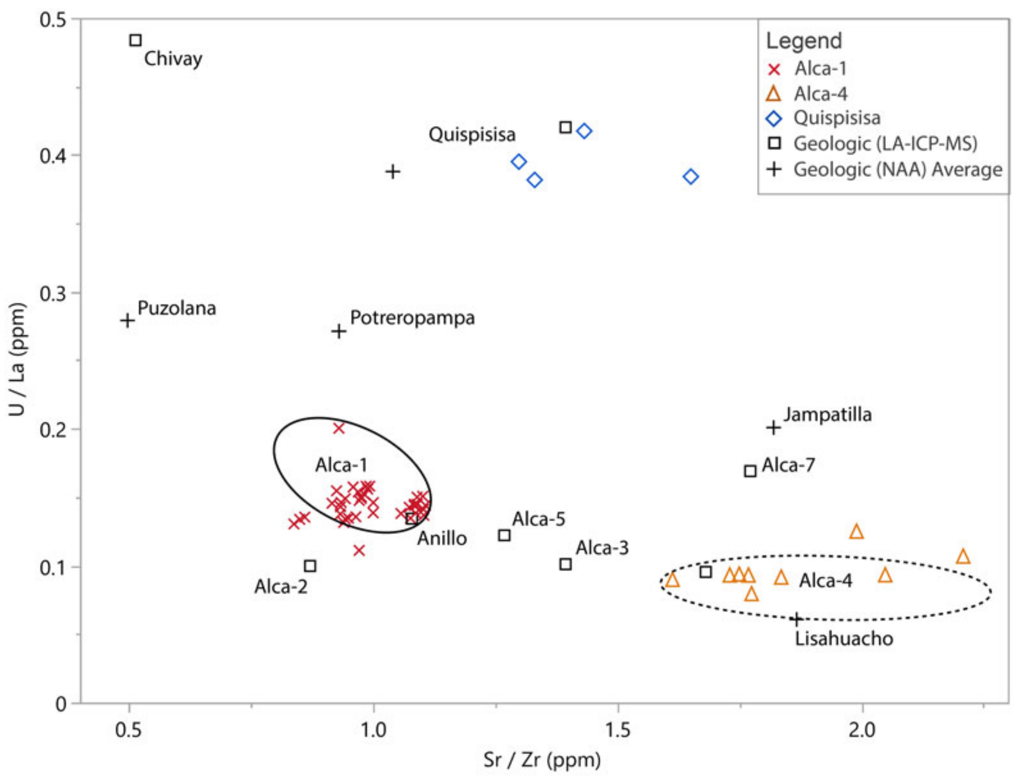

Figure 7. Scatterplot of LA-ICP-MS ppm data of obsidian artifacts. Solid ellipses = 95% confidence interval surrounding LA-ICP-MS values of Alca-1 geological obsidian ($n = 46$). Dashed ellipses = 95% confidence interval surrounding NAA values of Alca-4 geological obsidian ($n = 10$). Square symbols represent single geological samples run by LA-ICP-MS. Plus symbols represent averaged NAA values for major geological obsidian sources as reported by Glascock and colleagues (2007).

A single flake of Lisahuacho obsidian was detected at La Angostura and a single flake of Jampatilla at Santa Rosa II. These findings mark the farthest south that either of these obsidian sources has been archaeologically detected. The Lisahuacho source is found in the province of Aymaraes in the department of Apurimac, and its use was largely restricted to the immediate region (Burger et al. 2006; Kellett et al. 2013; Mendoza Martínez et al. 2020). The Jampatilla source is in Ayacucho in the province of Lucanas (Burger, Schreiber, et al. 1998). Jampatilla obsidian has been detected at archaeological sites in the Sondondo Valley, including the Wari administrative center of Jincamocco (Schreiber 1992). Almost half the obsidian sourced from Jincamocco was attributed to Jampatilla, along with Quispisisa and Alca-1 (Burger et al. 2000:332).

Our study also detected six flakes from the surface of Santa Rosa II categorized as Unknown-1. Strontium and rubidium elemental concentrations suggest they may be related to the Accobangra or Chumbivilcas source areas (see Figure 5 in Burger et al. 2022). Because corresponding geological materials were not available at the time of this analysis, future investigations are needed to determine the source(s) of these six flakes.

In the absence of completed tools, small flake debitage produced through tool maintenance may best indicate source diversity and transport distance (Eerkens et al. 2007). Most of the analyzed obsidian in this study corresponds to late-stage reduction, and only one small core of Alca-1 was recovered from Santa Rosa II. Just over 70% of all Quispisisa artifacts correspond to flakes ($n = 16$) and shatter ($n = 3$; Table 2). Four completed projectile points and four tool fragments were also sourced to Quispisisa. A single flake of Lisahuacho obsidian and a bifacial thinning flake of Jampatilla indicate their parent materials were likely transported as completed tools into the region and discarded off-site.

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Table 1. Character Group Assignment of Obsidian Artifacts from Arequipa Study Sites.

	Alca-1		Alca-4		Anillo		Lisahuacho		Jampatilla		Quispisisa		Unknown-1		Total
Site	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*
Atitirca	4	80.0	1	20.0											5
Corralones	26	74.3	4	11.4							5	14.3			35
El Tambo	40	97.6	1	2.4											41
Huamantambo	16	88.9	1	5.6							1	5.6			18
La Angostura	8	7.3	88	80.7	1	0.9	1	0.9			11	10.1			109
Numero 8	5	100.0													5
Pakaytambo	20	87.0	3	13.0											23
Pascuita	1	100.0													1
Qosqospa	9	90.0									1	10.0			10
Santa Rosa II	98	72.1	10	7.4	12	8.8			1	0.7	9	6.6	6	4.4	136

Table 2. Obsidian Source Characterization by Artifact Form.

Type	Alca-1	Alca-4	Anillo	Lisahuacho	Jampatilla	Quispisisa	Unknown-1
Biface	2						
Projectile point	16	1	4			4	
Tool fragment	37	3				4	
Blade	2						
Core	1						
Preform	1						
Drill	3						
Scraper	1						
Flake	130	87	9	1		15	4
Bifacial thinning flake	8	2			1	1	
Shatter	26	15				3	2
Total	227	108	13	1	1	27	6

The only complete Wari-style biface analyzed in this study was recovered from Santa Rosa II; it was composed of Alca-1 obsidian (Figure 4d).

Discussion

In the Andes, obsidian served both as a highly valued exotic material and as a common everyday good within some domestic economies (Tripcevich 2010). It was an ideal lithic material to produce formal tools, including bifaces and projectile points used in hunting and warfare. Expedient obsidian flakes served utilitarian purposes and were likely sought after by pastoralists for the shearing of camelid wool (Nesbitt et al. 2019). During the Middle Horizon, obsidian was transported to its greatest geographic extent through Wari networks (Burger et al. 2000), often "bundled" with other Wari materials and related practices (Lau 2012). In addition to its utilitarian traits, symbolic qualities of obsidian relating to its many colors, reflection, and ideological attributes may also explain its significant role in Wari's ritual economy and wealth financing. Along with factors of geography and mobility, we argue that obsidian use in Arequipa illustrates resource consolidation by the Wari; it was likely one of several material interests of an intrusive Wari state. Notwithstanding, local obsidian use and bottom-up economic strategies co-occurred in tandem or outside of direct Wari control at centrally located waystations and local ceremonial centers in Arequipa.

Considerations of Chronology and Geography

Across all 10 study sites and related time periods, Alca-1 and Alca-4 were the dominant obsidians used in Arequipa (Table 1). This was followed by minor use of the Ayacucho-sourced Quispisisa identified at five of the sampled sites. Quispisisa obsidian first reached far southern Peru by the mid-seventh century AD in Moquegua along with initial Wari colonization (Burger et al. 2000; Williams et al. 2012). Located along transit routes between the Wari heartland and Moquegua, Corralones is the earliest Wari-affiliated site in Arequipa with a ^{14}C date range of AD 680–960 (Supplemental Table 1), which may explain its considerable amount of Quispisisa obsidian (14.3%). In southern Peru, by the end of the ninth century AD, use of Quispisisa obsidian declines in favor of Alca-1, as identified at La Real, Quilcapampa, and Wari contexts in Moquegua (Jennings et al. 2015:391; Rizzuto and Jennings 2021:273; Williams et al. 2012:84). This study's results also confirm an overwhelming use of Alca obsidian in southern Peru during the late Middle Horizon (ca. AD 800–1000).

Notably, not a single fragment of Chivay obsidian was detected in this study. This is especially surprising for Corralones since Chivay is the closest source and Alca-1 is located twice as far away (Table 3). As noted by Burger and colleagues (2000), a potential cultural and geographic divide

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Table 3. Distance between Study Sites and Obsidian Sources by Least Cost-Path Distance and Estimated Travel Time by Llama Caravan Based on 20 km/day Caravan Speed.

	Alca-1		Alca-4		Anillo		Chivay		Jampatilla		Lisahuacho		Quispisisa	
Site	km	days	km	days	km	days	km	days	km	days	Km	days	km	days
Chuquibamba	86.2	4.3	45.4	2.3	106.4	5.3	152.6	7.6	256.8	12.8	201.3	10.1	298.8	14.9
Pakaytambo / El Tambo	96.8	4.8	56.9	2.8	117.5	5.9	140.2	7.0	268.0	13.4	212.5	10.6	312.1	15.6
La Angostura	102.9	5.1	63.0	3.2	123.6	6.2	134.6	6.7	274.1	13.7	218.6	10.9	318.2	15.9
Santa Rosa II	107.9	5.4	66.7	3.3	127.3	6.4	130.8	6.5	277.8	13.9	222.2	11.1	321.8	16.1
Corralones	200.7	10.0	178.2	8.9	238.8	11.9	95.2	4.8	389.3	19.5	328.3	16.4	444.0	22.2

Note: Caravan speed based on Tripcevich (2007:166).

may have taken place, in which Alca fell under the Wari interaction sphere, and Chivay, located above the Colca Valley, remained the dominant obsidian used by Tiwanaku and Titicaca Basin populations (Giesso 2003; Glascock and Giesso 2012). This pattern is upheld in Moquegua, where Chivay is the proximal source; however, associated trade routes that brought Chivay obsidian eastward appear to have bypassed the coastal plain. Instead, Tiwanaku colonists in frontier contexts crossed highly maintained social boundaries to obtain small amounts of Wari-affiliated Alca-1 and Quispisisa obsidians, along with minor regional sources (Burger et al. 2000, 2022; Reid, Goldstein, and Williams 2022).

Wari Political Economy and Consolidation of Resources

By the late Middle Horizon, obsidian use in southern Peru was defined not by the importation of Quispisisa obsidian from the Wari heartland but by the exploitation of local bedrock Alca-1 and Alca-4 sources (Table 1). In the absence of known Wari influence or presence, this pattern may be explained by a regionalization of local domestic economies or even a rejection of Wari-affiliated trade and waning state influence (e.g., Bélisle et al. 2020; Jennings et al. 2015). However, recent findings in Arequipa of imperial Wari installations at Pakaytambo and possibly El Tambo in the Chuquibamba–Majes drainage (Reid 2023) provide alternative top-down explanations. In contrast to the diversity of obsidian sources identified at regional settlements and waystations, Wari imperial contexts at Pakaytambo and El Tambo show the sole use of Alca-1 and Alca-4 obsidian, the only obsidian bedrock sources in the region with nodules up to 30 cm in size (Rademaker et al. 2013, 2021). From excavated contexts at these two sites, obsidian accounts for over half of all lithic raw materials by count (Supplemental Table 4).

Obsidian was commonly transported by the Wari in two forms: large or "oversized" lanceolate bifaces that also served as preform blanks and smaller laurel leaf points. Reliable access to large-sized obsidian nodules was thus essential to producing Wari-style bifacial points. For Wari agents residing in Arequipa, the import of Quispisisa obsidian would have been costly: travel estimates indicate that a one-way caravan journey took more than two weeks (Table 3). Coinciding with the apogee of state expansionism, Wari residents at Pakaytambo and El Tambo had sufficient local knowledge and infrastructure to provision the highest-quality obsidian resources in the region: Alca-1 and Alca-4. Settlements with strong Wari affiliations, such as Numero 8, also show a sole reliance on Alca-1, which is perhaps related to Wari provisioning of second-tier centers or institutionalized reciprocity as has been proposed in Moquegua (Nash 2022; Williams et al. 2022). An alternative explanation for the absence of nonlocal obsidians is sample size. It is not surprising that the greatest source diversity is identified at the two best-represented sites in the study: Santa Rosa II ($N = 136$) and La Angostura ($N = 109$).

Within models of wealth financing, elites may attempt to restrict access to prestige goods or control the chokepoints within commodity chains in the acquisition, production, or distribution stages (Earle and Jennings 2012:214–215). Due to the expansive extents of Andean obsidian sources, it would have been impossible to directly control obsidian at the geological source (Jennings and Glascock 2002). Instead, Pakaytambo and El Tambo may have been uniquely established to control a major trade and mobility route connecting the south-central highlands to the coastal valleys of far southern Peru, as indicated by GIS least-cost path models (Figure 8). Pakaytambo and El Tambo held strategic positions along the corridor's pre-Inka road at a major constriction in the drainage that also marked the ecological transition between highland and coastal zones and populations (Reid 2023).

We can also question *how* Wari settlers in Arequipa obtained obsidian materials. If residents at Pakaytambo and El Tambo relied on the taxation of local populations or periodic exchange with long-distance caravans, we might expect a greater diversity of local and exotic obsidians, such as those identified at contemporaneous Middle Horizon sites. Instead, Wari agents may have directly procured Alca-1 and Alca-4 obsidian. Pakaytambo is the nearest Wari enclave to the Alca source region, for which direct travel to bedrock outcrops could be made in less than a week (Table 3). Formal lithic analysis of Pakaytambo lithics indicates late-stage bifacial tool production occurred on site (Reid 2020:333). If Wari agents directly procured Alca bedrock obsidians, initial lithic reduction likely occurred at the sources, a pattern observed for Wari exploitation of Quispisisa obsidian (Bencic 2016; Kaplan 2018).

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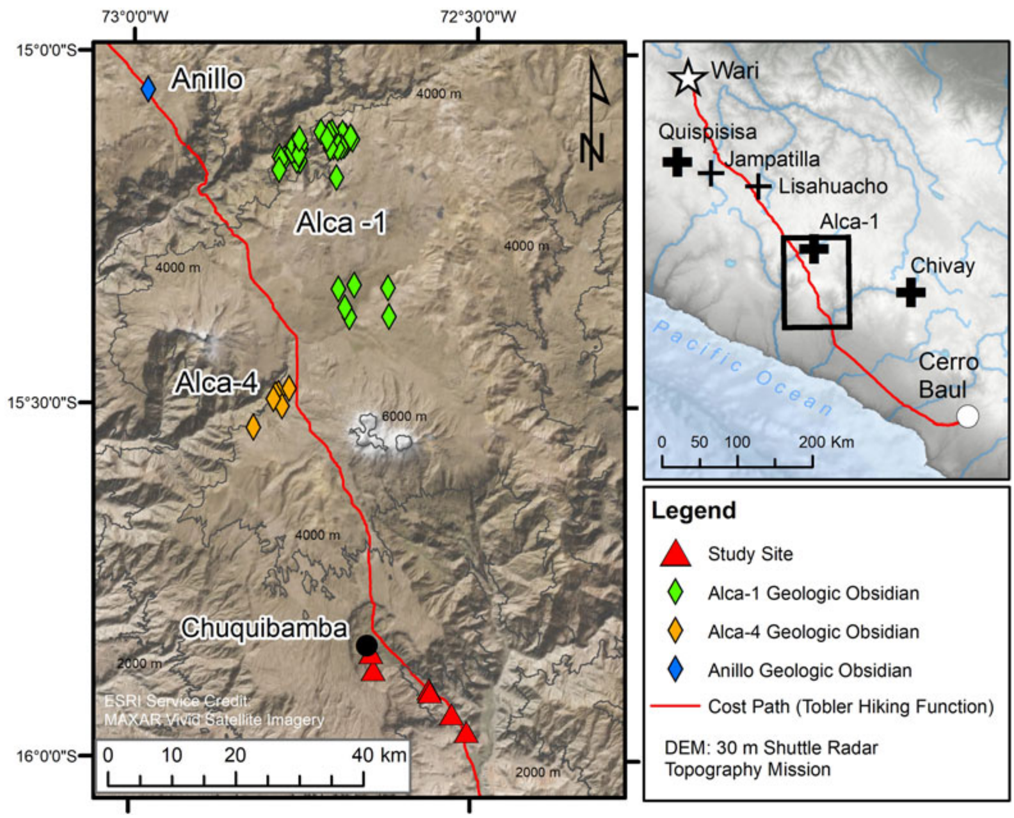

Figure 8. Least cost path (Tobler Hiking Function) between Wari capital and the southernmost colony Cerro Baul. (Color online)

Wari provisioning of Alca obsidian was not strictly for local use but included wider distribution. Skilled lithic knappers shaped Alca-1 obsidian into Wari-style bifaces and laurel leaf points, such as the one recovered from Santa Rosa II (Figure 4d). Wari-style bifaces made of Alca-1 have been identified to the far south at Cerro Baul and Cerro Mejia in Moquegua (Williams et al. 2022:156), at Espiritu Pampa on the eastern slopes of the Andes (Fonseca Santa Cruz and Bauer 2020:193), and as far north as Huamachuco, where they were found as offerings at the shrine Cerro Amaru (Burger and Glascock 2009; Topic and Topic 2010). Minor amounts of Alca-1 debitage have also been identified at the Wari capital (Burger et al. 2000; Kaplan 2018; Wistuk 2019), the administrative center Jincamocco (Burger et al. 2000), and Wari colonial contexts in Cusco at Huaro (Skidmore 2014; Figure 1). The exportation of Alca-1 outside Arequipa, in the form of recognized Wari-style bifaces, shows that resource acquisition in the study region was not solely for local consumption but was also tied to far-reaching Wari networks, perhaps related to wealth financing strategies of easily transported goods.

Bottom-Up Exchange Networks

Obsidian provenance data from local settlements, road waystations, and ceremonial contexts in Arequipa provide a counterpoint to top-down Wari political economic models. Bottom-up processes of interregional exchange proliferated during the Middle Horizon in tandem with or outside direct Wari control (see Bélisle et al. 2020). During the Middle Horizon, new settlements were founded along Arequipa's intervalley roads that show intense engagement with Wari material identity. Road settlements such as Corralones (Cardona Rosas 2002) and Millo (Nigra et al. 2017) show architectural similarities to Wari syntax and ceremonial space; however, their relationship with the Wari state remains unclear. In the Majes Valley, excavations at Santa Rosa II and La Angostura indicate dual waystation and ceremonial functions that centered around local placemaking, rather than Wari

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ideology (Reid 2020). These sites also exhibit the greatest diversity of obsidian sources in the region (Table 1).

Obsidian sourced to Quispisisa, Lisahuacho, and Jampatilla originating in Peru's south-central highlands was likely transported to Arequipa's coastal valleys by long-distance llama caravans. GIS cost-path analysis between Wari's capital and the southernmost colony Cerro Baul models a route that traverses Ayacucho and Apurimac and passes directly through the Anillo and Alca geologic areas before entering the upper Chuquibamba–Majes drainage (Figure 8). Highland caravans could have thus collected incidental obsidian finds without deviating from their original route. Such caravans may have been tied to formal Wari activities (see Edwards 2021); however, even under the auspices of state control, unofficial barter and exchange could occur. The establishment of the waystation/ceremonial centers of Santa Rosa II and La Angostura in a marginal zone between local and Wari settlements may have been a bottom-up strategy to co-opt increased caravan activity at this time.

Large plaza spaces at Santa Rosa II and La Angostura likely facilitated the periodic convergence of locals and nonlocals where exchange was embedded within ceremonial and religious activities (Reid 2020). Visitors would have brought goods from their homeland regions, including obsidian, for use during travel and exchange or barter purposes. Similar social processes have been hypothesized for Formative and Early Horizon temple centers where diverse obsidian assemblages have been identified (Burger et al. 2000; Matsumoto et al. 2018). This study's detection of rare obsidian source materials also provide insight as to how exchange goods flowed into waystations and outward to local residents, exemplified by the presence of Anillo at Santa Rosa II and at the nearest village of Beringa (Tung 2012). Isotopic analysis of camelid remains from Arequipa also indicates that mid-valley *yunga* communities maintained camelid herds (Alaica et al. 2022), illustrating how local communities took an active role in shaping exchange relationships during the Middle Horizon.

Wari centers in Arequipa were abandoned by the end of the tenth century AD (Jennings et al. 2021; Reid 2020). Obsidian from Terminal Middle Horizon (around AD 1000–1100) contexts at several of the study sites correspond to the period when Wari state interaction presumably waned but Wari influence is still archaeologically observed in regional material culture (Supplemental Table 1). Excavated materials from Huamantambo, Numero 8, and Qosqospa in Chuquibamba follow patterns of obsidian consumption established in the late Middle Horizon with a near-complete reliance on Alca-1 and Alca-4 obsidian (Table 1). The breakdown of interregional networks once facilitated by Wari activity may be one explanation for the absence of nonlocal obsidians in later contexts. Regionalization and factionalism occurring around AD 1100 may also account for the abandonment of the dual waystation and ceremonial centers Santa Rosa II and La Angostura. Unfortunately, very little is known about subsequent obsidian use in Arequipa during preceding centuries, largely due to sampling bias.

Conclusions

During the Middle Horizon, Andean obsidian served as both a common domestic good and an exotic material imbued with ideological meaning. At this time, it was transported to its greatest extent and quantity than ever before identified and was transported across Wari networks in the form of large lanceolate bifaces/preforms and laurel leaf points. In contrast to treating the Middle Horizon as a homogeneous and monolithic period, this study's regional perspective highlights changes in obsidian procurement and use related to (1) initial Wari colonization in far southern Peru beginning in the mid-seventh century AD, (2) imperial expansion and political economy at the apogee of empire in the late Middle Horizon (around AD 800–1000), and (3) the Terminal Middle Horizon (around AD 1000–1100) when Wari state centers had been abandoned yet local communities continued to engage in Wari practices and material culture.

Often viewed as a hallmark of Wari interaction, Quispisisa obsidian was first transported to Arequipa by Wari colonists. By the late Middle Horizon, Wari state centers in Arequipa and Moquegua no longer relied on Ayacucho obsidian but solely utilized Alca-1 and Alca-4 bedrock materials. These were the highest-quality proximate sources with nodules 30 cm in size and sufficiently large to manufacture the export product of "oversized" Wari obsidian bifaces. Wari bifaces composed of Alca-1 have been identified from contexts across Peru. We suggest that this demonstrates the

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regional consolidation of key resources in Arequipa, which depended on local knowledge of the landscape and the presence of key infrastructure. However, Wari expansionism in Arequipa was uneven as indicated by the absence of Chivay obsidian across all study sites. This study complicates regional models of obsidian use, whereby the presence of Alca-1 at local settlements may indicate a relationship with Wari networks, rather than a regionalization of domestic economies outside Wari influence.

During the late Middle Horizon in Arequipa, obsidian use did not solely rely on distance to the nearest source but instead was shaped by a combination of sociopolitical and geographic factors. Contemporaneous roads, trails, and waystations were established along routes that linked Arequipa's coastal valleys. Gateway sites such as Corralones, Santa Rosa II, and La Angostura displayed the greatest obsidian source diversity in the study, including the exotic obsidians Quispisisa, Lisahuacho, and Jampatilla from Ayacucho and Apurimac; Arequipa sources of Alca-1, Alca-4, and Anillo; and one unidentified source. The central placement of dual waystation/ceremonial centers attracted a variety of local communities and nonlocals; there, exchange was embedded within ritual practice and periodic gatherings. The adoption and emulation of Wari material identity and customs by Arequipa residents may have been strategies to co-opt or gain entry to Wari networks, of which obsidian was only one of many exchanged materials of both utilitarian and ideological significance. At the dissolution of the Wari state, these long-distance interregional connections also appear to have broken down.

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Data Availability Statement. All archaeological obsidian artifacts analyzed by the authors are curated in the facilities of the Ministerio de Cultura in Arequipa, Peru. Detailed scientific data are available on request to David Reid (dreid5@uic.edu).

Competing Interests. The authors declare none.

Supplemental Material. For supplemental material accompanying this article, visit https://doi.org/10.1017/laq.2023.68.

Supplemental Text 1. Methodology and instrumental specifications.

Supplemental Figure 1. Scatterplot of InnovX pXRF ppm ratioed values of Corralones artifacts (color icons) versus geological obsidians (black square icons). Solid ellipses = 95% confidence interval surrounding geological materials only.

Supplemental Figure 2. Scatterplot of LA-ICP-MS ppm values of Alca-1 obsidian artifacts (color icons) versus geological obsidians (black square icons). Solid ellipses = 95% confidence interval surrounding artifact materials only.

Supplemental Figure 3. Scatterplot of LA-ICP-MS ppm values of Alca-4 obsidian artifacts (color icons) versus geological obsidians (black square icons). Solid ellipses = 95% confidence interval surrounding artifact materials only.

Supplemental Table 1. Radiocarbon Dates from Study Sites.

Supplemental Table 2. pXRF Elemental Concentrations (ppm) of Obsidian Artifacts from Arequipa Study Sites.

Supplemental Table 3. LA-ICP-MS Elemental Concentrations (ppm) of Obsidian Artifacts from Arequipa Study Sites.

Supplemental Table 4. Obsidian vs. Non-Obsidian Lithic Materials from Excavated Contexts.

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