Sayrosa, a Minor Obsidian Source in the Puna of Arequipa

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Abstract

This article reports the identification of the Sayrosa Source, a minor geologic source of volcanic glass referred to Rare Type-3 obsidian in the 1977 pilot study by Burger and Asaro. Located only 25 km northeast of the major Alca-1 deposit, this source was exploited in prehispanic times despite the relatively tiny size of its nodules. Small amounts of Sayrosa obsidian appear at archaeological sites in the puna of Chumbivilcas and the Cusco Valley probably as the by-product of llama caravans carrying other goods such as meat, wool, salt and Alca obsidian from the high grasslands of northern Arequipa to the agricultural communities of Cusco.

Este artículo presenta la identificación geológica y geoquímica de la Fuente Sayrosa, un depósito geológico de obsidiana localizado a 25 km noreste de la cantera de obsidiana Alca-1 en el Valle de Cotahuasi. La Fuente Sayrosa fue utilizada en la prehistoria por mas que un milenio a pesar que se caracteriza por nódulos pequeños de obsidiana. Cantidades menores de obsidiana provenientes de esta fuente se encuentran en sitios arqueológicos de Chumbivilcas y del Valle de Cusco, probablemente como el subproducto de las caravanas que transportaban otros materiales como carne, lana, sal y obsidiana de las canteras de Alca-1 desde la puna al norte de Arequipa a los valles agrícolas de Cusco.

Key words: obsidian exchange, XRF, NAA, obsidian, highland Peru, Cusco archaeology

Introduction

Three major obsidian sources provided the vast majority of volcanic glass mined and exchanged in prehistoric Peru: the Quispisisa Source in southern Ayacucho, the Alca Source in northwest Arequipa and the Chivay Source in northeast Arequipa. Each of these geological deposits cover vast areas and all three feature large nodules of high-quality obsidian that are well-suited for knapping a wide range of tools. There are also minor obsidian sources, most of which are limited in extent and usually include only small obsidian nodules. The Puzolana Source, which is located near the city of Ayacucho, is the northernmost of the minor Peruvian obsidian deposits with a long history of exploitation; another obsidian deposit was exists further to the north at Yanarangra near Castrovirreyna in Huancavelica but there is no known evidence that it was used for tools in prehistoric times (Glascock et al 2007).

In a pilot study carried out at LBNL in the 1970s using neutron activation (NAA) and X-ray fluorescence spectroscopy (XRF), the existence of three major and five minor obsidian sources was inferred based on their trace element composition (Burger and Asaro 1977, 1979). As noted, the three major sources have now been located and of the five minor sources identified in 1977, four have been identified: the Jampatilla Source and the Puzolana Source, both in the Department of Ayacucho, and the Potreropampa Source and the Lisahuacho Source, both in the Department of Apurimac (Glascock et al 2007). Collectively, these minor sources constituted about 15% of the 855 samples analyzed in the pilot study, while the three major sources made up 84% of the sample.

In addition to the eight distinctive geochemical compositions described in 1977, we also identified a small number of obsidian flakes with anomalous compositions. These were referred to as Rare Types 1-8. NAA was used to confirm their distinctive geochemical compositions and it was anticipated that some of them corresponded to additional obsidian sources that were poorly represented in the pilot project's uneven and unsystematic sample (Burger and Asaro (1977:56, 65, Table 1B). Recently, Rare Type 1 was recognized as coming from the Charaña Source, a small obsidian deposit situated in Bolivia near the modern Peruvian and Chilean border (Burger et al., 2021).

The present article describes the discovery and analysis of the Sayrosa Source, an obsidian source in northern Arequipa. In this article we present geochemical evidence indicating that this obsidian deposit produced the volcanic glass used for the artifacts referred to as Rare Type 3 in the 1977 pilot study. While minor deposits such as the Sayrosa Source did not play an important role in provisioning large populations with raw material for stone tool production, these sources were sometimes important locally and small amounts of artifactual obsidian from them reached neighboring areas. Through their geochemical identification, it is possible to gain some idea of the movement and exchange relationships of the groups living near the minor sources with more distant areas.

Discovery

The Sayrosa Source was first documented by Eisei Tsurumi, an archaeologist from the University of Tokyo, Bunyo-ku (Todai) who was exploring this section of Arequipa with ethnographer Tetsuya Inamura. In the 1970s Inamura carried out ethnographic research on agropastoral groups in the Puyca district (Inamura 1986) and during this fieldwork he noticed obsidian nodules scattered on the surface of the Sayrosa River floodplain (Figure 1). In 2010, Tsurumi returned with Inamura to this area and encountered the obsidian nodules utilized in this study.

Tsurumi and Inamura camped next to the Sayrosa River near a village known as La Capilla on August 22, 2010 (Figure 2). Tsurumi also noticed obsidian flakes scattered in the village. Inamura had been told that obsidian flakes were sometimes used to castrate llamas and alpacas (Inamura personal communication 2021). A similar practice was described by herders in the Chivay drainage of southern Peru (Tripcevich 2010) and in south-western Bolivia (Capriles et al 2018:904).

Obsidian nodules were present in abundance nearby in the floodplain along the Sayrosa River at an altitude of 4479 meters above sea level. Tsurumi collected numerous nodules at 14°54'2.80"S, 72°36'26.90"W. They were of differing sizes and were found alongside other kinds of rounded cobbles. A collection was made of obsidian cobbles and eighteen of them were sent to Burger. These were submitted by him on January 29, 2018 to MURR as part of an ongoing collaborative research project on Andean obsidian between Burger and Glascock that has continued for over two decades.

The nodules recovered by Tsurumi from the Sayrosa River floodplain were rounded or ovoid and covered with thin black or dark gray cortex (Figure 3). They varied in size from 2-8 cm in length. The obsidian was of high quality with no indication of phenocrysts or the hydration that leads to the formation of perlite. These vitreous nodules of volcanic glass would have been ideal for chipping small artifacts and flakes. The obsidian was generally black or dark gray in color although some nodules had a reddish brown coloration stemming from iron impurities. Tsurumi assumed that the obsidian nodules had eroded from a nearby geologic deposit.

After examining geological descriptions of this zone (Salas et al 2003), it can be hypothesized that the obsidian nodules came from the adjacent plateau known as Cerro Chinche Orjo, the area marked NQ-Ba1 on the Chulca 30-q geological quadrangle map produced by Peru's

Institute of Geology, Mining, and Metallurgy (INGEMMET) (Salas A. et al. 2001) (Figure 4). Obsidian does not transport very far in Andean highland rivers, and it does not survive in usable clasts far from parent outcrops. On the floodplain outside of the town of Alca, for example, Rademaker found small obsidian clasts, reworked from pyroclastic valley fills. Sampling downstream from the town, he noticed that obsidian clasts were centimeter-sized within a kilometer or two, and beyond that there was no obsidian at all. Similar observations had been made previously at the Chivay Source in the Colca Valley (Burger et al 1998).

The NQ-Ba1 formation is mapped as being located immediately above the Sayrosa River at an elevation of 4600-4992 meters above sea level, and it is only 300 m from the banks where the sampling of obsidian nodules occurred. Thus, Cerro Chinche Orjo is the likely source of the obsidian collected from the river banks of the Sayrosa. However, as obsidian specialist M. Steven Shackley (2005) notes, since prehistoric inhabitants probably collected obsidian nodules from river floodplains, secondary deposits of nodules should be treated as part of the obsidian source.

On the Chulca geologic quadrangle map, the NQ-Ba1 unit is designated as belonging to the Pleistocene Barroso Group, which is described as ignimbrites inter-stratified with cineritic to dacitic tuffs (Salas A. et al. 2001). The accompanying INGEMMET monograph for Chulca and the adjoining quadrangles to the east (Cayarani 30-r), south (Cotahuasi 31-q), and southeast (Orcopampa 31-r) correlates the NQ-Ba1 with the Arma Formation (Np-Ar). The Arma Formation appears primarily on the Cotahuasi quadrangle (Lajo Soto et al. 2001) and it corresponds with ignimbrites containing the Alca obsidian mapped by Rademaker and team (2021 in review).

Thouret et al. (2016, 2017) use different naming conventions in their mapping and absolute dating of the complex ignimbrite sequence in the Cotahuasi region. They designate the southern area of ignimbrites where Rademaker et al. (2021) mapped Alca obsidian as the Upper Sencca

Formation, dated to ~2.2-1.8 mya (Thouret et al. 2016), and the northern area containing Alca obsidian bedrock as the Lomas ignimbrite. The Lomas is dated to ~1.56-1.3 mya elsewhere on the Cotahuasi quadrangle (Thouret et al. 2017). Because Alca-1 obsidian crops out in these ignimbrite units, they should be equivalent. Continued absolute dating and revised geologic mapping in the Cotahuasi and Chulca areas eventually will resolve this complex volcanic history. The Anillo obsidian source (Tripcevich 2016), located west of the Cotahuasi valley and southwest of the Sayrosa Source, also is situated in the INGEMMET-mapped Upper Sencca Formation ignimbrites (Lajo Soto et al. 2001).

Combining these sources of information, it can be inferred that the Sayrosa obsidian source samples come from a layer of Pleistocene ignimbrite and associated secondary deposits reworked locally by the Sayrosa River. The formation containing the obsidian likely dates close in time to other similar Pleistocene ignimbrites to the south and southwest where the Alca and Anillo obsidian sources crop out. These correlations imply a relatively young age of formation (~2.0-1.5 mya) for the Sayrosa Source. This is consistent with lack of devitrification observable and the high quality of the obsidian for tool making.

Geochemical Characterization of Sayrosa Obsidian

The large Alca-1 bedrock outcrop in the upper Cotahuasi Valley is the source of most archaeological obsidian for the Cusco Valley (Burger et al 2000). It is 25 km southwest of the spot where the Sayrosa nodules were collected (Figure 4). At the time of submitting the samples to MURR, Burger assumed that the Sayrosa samples would match the Alca obsidian in composition (Burger et al. 1998). However, when the source samples were analyzed by NAA and

XRF at MURR, they proved to have a distinctive composition (Table 1, Table 2) unrelated to Alca-1 or any of the other sub-groups in the Alca Source (Glascock 2020).

A comprehensive review of the Andean obsidian artifacts analyzed at MURR in the past failed to encounter samples with a composition similar to Sayrosa, thus raising the question of whether this source was exploited in prehistoric times. Fortunately, this question was soon resolved.

As part of ongoing efforts to produce a comprehensive archive of the historic LBNL archaeometry program (Boulanger 2013; 2017), Boulanger digitized some of the 1970s LBNL XRF data that Burger provided to Nico Tripcevich. While comparing these XRF data to the LBNL NAA database and to older (pre-2016) MURR NAA data to establish source assignments, it was observed that three of the samples analyzed by XRF (BUR-353, BUR-529, and BUR-579) were distinctive from all other artifacts in the dataset. The closest match found in the LBNL NAA data was BURG-35—assigned to the Rare Type 3 composition. The LBNL XRF data were provided to Glascock who compared them against the current MURR obsidian database. A direct comparison with the MURR NAA data was somewhat equivocal because of the few elements that were quantified by XRF at LBNL; however, an unequivocal match was made in the comparison of the NAA data for BURG-35 to the Sayrosa composition determined by NAA at MURR (Table 3. Table 4). Thus, the newly determined composition of Sayrosa presented a convincing match with the Rare Type 3 artifacts analyzed from archaeological sites in the Department of Cusco (see below). In addition, some of the Cusco region obsidian artifacts recently analyzed by Véronique Bélisle, whose source was unknown until now, were also found to be a match to the Sayrosa source (Table 5).

Methods

At MURR, the Sayrosa Source samples were analyzed by both X-ray fluorescence (XRF) and neutron activation analysis (NAA) to allow a full comparison to other samples in the MURR obsidian database (Tables 1-4). The Sayrosa samples were thoroughly cleaned before analysis by XRF using a Thermo Scientific Quantx spectrometer operating at 35 kV. The spectrometer measures the following elements: K, Ca, Ti, Mn, Fe, Rb, Sr, Y, Zr, Nb, and Th. The spectrometer was calibrated using a suite of 40 source samples previously analyzed by NAA, ICP-MS, and LA-ICP-MS as described in Glascock (2020).

Later, the portions of the samples were prepared for NAA by crushing between steel plates to create several fragments that would fit inside the irradiation vials used at MURR. For short irradiations, about 100 mg of fragments were placed in high-density polyvials. For long irradiations, about 200 mg of fragments were placed in high-purity quartz vials. Standards made using SRM-278 Obsidian Rock were similarly prepared. Using two irradiations and three measurements on high-resolution gamma-ray spectrometers, a total of 28 elements were measured. The elements include Na, Al, Cl, K, Sc, Mn, Fe, Co, Zn, Rb, Sr, Zr, Sb, Cs, Ba, La, Ce, Nd, Sm, Eu, Tb, Dy, Yb, Lu, Hf, Ta, Th, and U.

In 2017, a sample of more than 450 obsidian artifacts from excavated contexts in Cusco was analyzed by Bélisle using Millsaps College's Bruker Tracer 5i XRF spectrometer. Each sample was scanned for 60 seconds using the obsidian calibration provided by Bruker. An obsidian standard, also provided by Bruker, was scanned regularly over the course of the analysis to control for instrument precision. Recorded elements include Mn, Fe, Zn, Ga, Rb, Sr, Y, Zr, Nb, and Th. The same spectrometer was brought to MURR to scan samples of every known obsidian source in Peru. The artifacts from Cusco were assigned a source by comparing their chemical composition to that of the MURR samples scanned with the same spectrometer (Bélisle et al. 2020).

Results

The analytical results are presented in two tables showing the means and standard deviations for ten Sayrosa Source samples analyzed by XRF (Table 1) and NAA (Table 2), respectively. It is notable that the elements Sr and Ba were below detection by NAA. Comparisons between the XRF and NAA data for the Sayrosa samples and other Peruvian sources with compositions most similar to Sayrosa are shown in Figures 5 and 6, respectively. The most obvious difference between Sayrosa and all other known sources in Peru is the low concentrations for Sr (Figures 7, 8, and 9).

Archaeological Evidence for the Utilization and Distribution of Sayrosa Obsidian

As noted, none of the obsidian artifacts from Peru analyzed at MURR matched the chemical signature of Sayrosa, but four flakes studied at LBNL were recognized as coming from this small source (Figure 10). One of these flakes was recovered by Sergio Chavez (1988) at Choqo Choqo in the high grasslands of Chumbivilcas to the east of Sayrosa and to the south of the Cusco basin. The puna of Chumbivilcas provided a natural route for llama caravans traveling from the Cotahuasi drainage and the Sayrosa River to the lower agricultural lands of the Cusco Valley. Choqo Choqo is one of the open sites encountered by Chavez and it had numerous obsidian points and other tools on the surface, some which resembled Late Preceramic points from Cusco (Burger et al 2000). Unfortunately, the site is multi-component so the date of the Choqo Choqo flake of Sayrosa obsidian cannot be determined.

Single flakes from the Sayrosa Source were also found at three archaeological sites within the Cusco basin. These flakes come from Huasau, to the southeast of Cusco and from Muyu Moqo and Pikicallepata, located to the southwest and southeast of the city respectively (Figure 10). The sample from Pikicallepata came from the excavations of Karen Mohr Chavez and it can be dated to Chanapata-related levels of the late Early Horizon and Early Intermediate Period (c. 100 BC-AD 300) (Burger et al. 2000: Table V). The Huasau sample may date to the Middle Horizon (AD 650-1000) but since the sample comes from the surface, we cannot be certain. The single Sayrosa flake from Muyu Moqo was collected by John Rowe in his survey of Cusco and it could date any time between the late Early Horizon and the early Middle Horizon (Zapata 1997, Bauer 2004). It should be noted at both Choqo Choqo and Pikicallepata, the Alca-1 Source was the dominant obsidian utilized; it constituted 86% of the obsidian in the former site and 56% in the latter. While Sayrosa obsidian was present at the two sites, it made up only a 6-7% of the sampled material (Burger et al 2000:306, Table V).

Apart from these findings, seven additional obsidian artifacts recently recovered in dated contexts in the Cusco region were made from the Sayrosa material. These items were recovered in large-scale excavations at the sites of Yuthu, Minaspata, and Ak'awillay (Figure 10). At these three sites, Alca-1 was the preferred source, representing between 85% and 96% of the sample (Bélisle et al. 2020). In contrast, Sayrosa obsidian was a minor source.

Yuthu was a late Early Horizon village overlooking Lake Huaypo close to the Xaquixaguana Plain northwest of the city of Cusco (Davis 2011; Davis and González 2010). Its occupation spanned 400-100 BCE. Excavations identified a residential sector with the remains of pit houses in addition to a ceremonial sector where a semi-subterranean platform was built. Two Sayrosa obsidian projectile points were recovered in the domestic sector. Sayrosa obsidian, whose source was 173 km to the south, represents 2% (2/101) of the obsidian analyzed from Yuthu.

Minaspata, located in the Lucre Basin close to Lake Muina and the well known Wari center of Pikillaqta, was a large (ca. 35 ha) multi-component site that was occupied from the Early Horizon (starting at around 800 BCE) forward. The obsidian analyzed from Minaspata was recovered in Early Horizon and EIP/Middle Horizon contexts. These contexts were dated with the associated material culture and no radiocarbon dates are available. One Sayrosa flake was recovered in an Early Horizon context, representing 1.2% (1/86) of the obsidian from that period. An additional Sayrosa flake came from an EIP/Middle Horizon context, constituting 1.9% (1/53) of the obsidian from this phase. Sayrosa obsidian thus represents 1.4% (2/139) of all analyzed obsidian from Minaspata. The source was 168 km southwest of the site.

Ak'awillay was a multi-component local center located in the Xaquixaguana Plain. The site was established at 200 BCE as other sites in the area were abandoned. It grew to at least 10 ha in the Middle Horizon, thereby representing the largest known Middle Horizon settlement in the Cusco region outside the Wari-related sites such as Pikillaqta (Bélisle 2015). Excavations yielded several houses, middens, kitchens, a public building, a plaza, and a small cemetery. No Sayrosa obsidian was found in Early Horizon contexts, although this might be due to the small sample size (n=12). Three pieces of Sayrosa obsidian were recovered in Middle Horizon contexts, dated to between 600 and 800 CE. Two flakes were found on the floor of House 11, which was part of a higher-status sector that was associated with several exotic goods. One Sayrosa projectile point was also recovered in the patio near the higher-status houses in the same sector of the site. Together, Sayrosa represents 2.3% (3/131) of the obsidian from Middle Horizon contexts at Ak'awillay, and 2.1% (3/143) of all analyzed obsidian from the site. The source was located 166 km to the south.

Overall, the proportion of Sayrosa obsidian from Early Horizon to Middle Horizon contexts at Yuthu, Minaspata, and Ak'awillay is 1.8% (7/383). The use of Sayrosa obsidian after the Middle Horizon is unknown at this time. The analysis of 54 artifacts from Minaspata recovered in Late Intermediate Period (1000-1400 CE) and Late Horizon (1400-1532 CE) contexts yielded no

Sayrosa obsidian. In earlier studies of artifactual obsidian from Cusco (Burger et al 2000:343-347, Table VII), only seven samples were run from post-Middle Horizon contexts and none of the artifacts were of Sayrosa Source obsidian. However, more sites must be sampled before the late use of the Sayrosa source can be assessed.

It is probably significant that in the very large sample of obsidian artifacts studied at LBNL, MURR, and with the Millsaps Bruker spectrometer, the number of tools made of Sayrosa obsidian was very small. This suggests that the Sayrosa Source was never heavily exploited and that obsidian from this deposit was never widely distributed. At the same time, it is noteworthy that all of the obsidian artifacts confirmed as being from Sayrosa obsidian have been found at archaeological sites in the corridor linking the Alca Source in the puna environment of northern Arequipa with the prosperous and densely occupied valley of Cusco and nearby areas (Figure 10). According to Inamura (in press), llama caravans traveled from the Sayrosa area to Cusco mainly carrying meat (or charki) and salt from Huarhua to exchange for maize and potatoes. The antiquity of these caravans is unconfirmed but it can be hypothesized based on ethnographic accounts that herders involved in prehistoric trading expeditions could have carried obsidian from the Sayrosa Source along with meat and salt, and obsidian from the Alca-1 Source (Tripcevich 2010, 2016). Significantly, Sayrosa Source obsidian has yet to be encountered at archaeological sites in the Titicaca Basin or Apurimac.

One potentially useful approach to complement the archaeological data is to analyze it using ArcGIS 10.7.1 Spatial Analyst tools that are used to model travel time and least-cost paths (TCP). We applied this method to the route from the Alca-1 and Sayrosa sources to Cusco and the archaeological sites with Sayrosa obsidian artifacts. We employed the Tobler (1993) hiking function that computes the minimum travel time from a source location to all other places across complex sloped terrain:

$$W = 6 \exp [-3.5*|S + 0.05|]$$

where W = walking velocity, and S= slope. The term "6" is the maximum walking speed in km/hr, which yields a 5 km/hr walking speed for level terrain on an established trail. Tripcevich (2009) created a vertical factor table based on Tobler's hiking function for use in the ArcGIS 10.7.1 Path Distance and Cost Path functions.

The Path Distance function produces a cost raster by converting a surface layer's values to some other currency. In least-cost modeling the function requires a topographic surface layer (usually a digital elevation model), a source location on the surface, and method for converting topography to the cost of traversing it, usually time or energy (White 2015). The surface layer used here is the Shuttle Radar Topography Mission (SRTM) GL1 global 1 arc-second digital elevation model with ~30-m cell resolution. The cost raster calculates the accumulated time it takes to walk from the Alca-1 source at Cerro Condorsayhua to all other points in every direction across the cost raster. All travel is assumed to be on-path. The Cost Path function calculates the least-cost route between an origin point to a destination point and provides a graphical display of the single least-cost solution (polyline) and its distance in meters.

To determine the number of days of travel along the least-cost route requires a reasonable estimate of daily travel time for the Andean puna. We have consulted the archaeological and ethnographic literature for typical one-day travel distances in the Andes. Recent ethnoarchaeological research by Tripcevich (2016) with Andean llama caravans northwest of the Cotahuasi Canyon suggests daily distances of up to 27 km. The maximum distances Tripcevich documented occur on the high-elevation puna where the landscape is open and topographic relief is minimal relative to the rugged river valleys dissecting the plateau.

In our analysis, the least-coast paths from the Sayrosa source to the sites and to Cuzco produce the following results: Sayrosa to Choqo Choqo=68 km (15.7 hours), Sayrosa to Pikicallepata== 179 km (40.6 hr), Sayrosa to Muyu Moqo = 194 km (43.9 hr), Sayrosa to Huasau = 208 km (49.2 hr), and Sayrosa to Cuzco = 194 km (47.2 hr). These figures suggest that it would take about 4-5 days for a llama caravan to travel from the Sayrosa Source to the Choqo Choqo site in Chumbivilcas and 12-14 days to reach Cuzco and three of the archaeological sites that yielded Sayrosa obsidian. It should be noted that Jorge Flores Ochoa (1968), a distinguished Cuzqueño ethnographer, estimated that llama caravans generally traveled only 10 km a day, which would multiply the estimates made here by 1.5 times. However, because much of the terrain separating Alca-1 from Cuzco is a level plateau (at least in the least-cost path selected by the algorithm), the estimate made using the Tobler function may be applicable in this case. However, any estimate is likely to underestimate the time since llama caravans are social as well as economic endeavors and they often involve off-path visits to friends and family along the way, thereby undermining the assumption of straight unbroken travel.

The LCP connecting the Alca-1 source to Muyu Moqo passes directly to the west of Cerro Chinche Orjo. All other Alca-1 LCPs pass through the Cotahuasi River headwaters or follow the puna to the southeast of the Sayrosa Source. These LCPs pass within 7-20 km of the Sayrosa Source (Figure 10), suggesting that contact between caravans and the groups living in the Sayrosa area could have occurred naturally and led to the acquisition of Sayrosa obsidian nodules. Nearly all Sayrosa LCPs to Cusco and to the archaeological sites use the same routes as the Alca-1 LCPs. Inhabitants of the Sayrosa area could have joined in the caravans traveling through their area and may have carried obsidian tools of Sayrosa obsidian with them to villages in Cusco, where eventually they would have been broken, sharpened, and repaired, thus leaving behind small numbers of discarded flakes.

Concluding Remarks

The research presented in this article establishes that the Sayrosa Source, a minor obsidian source in the puna of northern Arequipa, was exploited for over a millennium in prehistoric times and that small amounts of Sayrosa obsidian reached sites in the Cusco Valley, 194 km to the north. This pattern is probably linked to prehistoric llama caravans traveling from the high grasslands of northern Arequipa through Chumbivilcas to reach the rich agricultural valleys of Cusco, a journey of one to two weeks in each direction. According to Inamura (personal communication 2021), llama caravans between the Alca/Sayrosa area and Cusco continued until very recent times. The archaeological evidence confirms that the exploitation of the Sayrosa Source was underway by the final centuries of the Early Horizon and continued through the Middle Horizon (c.400 BC-800 AD), but it would be premature to exclude the possibility of its use in during the Preceramic, Initial Period and Early Horizon (before 400 BC) or during the Late Intermediate Period and Late Horizon.

An anonymous reviewer has questioned whether the identification of the location of a minor obsidian source such as the Sayrosa Source is a good and useful contribution to furthering our knowledge of Andean archaeology. The authors believe that each new contribution on the use and distribution of obsidian, including obsidian from minor sources, is progressively helping us to understand interaction in the Andean past. The information provided by identifying minor obsidian sources differs from and is complementary to that provided by locating the major obsidian quarries utilized in prehistory. The largest obsidian sources (Alca, Chivay and Quispisisa) accounted for the vast majority of obsidian consumed in the past and their study has shed light on the mining, transport, and provisioning of volcanic glass for household and village economies on a regional and even pan-regional scale. Minor sources, in contrast, have a restricted range but they are still valuable for understanding household economies in the areas immediately around the source.

Preference for obsidian fromn the major sources is easy to explain since these deposits feature nodules 30 cm in diameter or more and thse nodules are better suited for producing large lithic artifacts. The minor obsidian sources, in contrast, while frequently being of high quality, usually feature only small nodules. Some like the Sayrosa Source may reach 8 cm but others such as the Puzolana Source often yield clasts no larger than 4-6 cm. It is therefore not surprising that even in zones close to minor obsidian sources, obsidian from distant major sources may dominate local lithic assemblages (e.g., Burger and Glascock 2021, Burger et al 2016).

Despite this, obsidian from minor sources sometimes appears in small quantities at a considerable distance from their source. In the case of Sayrosa Source, we have documented its presence at seven small sites in Chumbivilcas and the Cusco Valley. As the discussion here of least-cost routes illustrates, it would have been a relatively simple matter for individuals from the Sayrosa River area to organize llama caravans to Cusco or, more likely, to join caravans initiated in the Alca-1 area, since the two routes correspond closely. Indeed, the two obsidians could have been transported along the same caravan routes. On the other hand, should we not assume that the Sayrosa Obsdian, which only constituted about 1.8% at Early Horizon to Middle Horizon contexts at Yuthu, Minaspata and Ak'awillay, was being traded to provision the farming villages of Cusco. It would seem more likely that other types of interaction may have been involved, interaction such as the prestation of gifts to friends, family and even future in-laws. If individuals from the Sayrosa area were traveling to Cusco in caravans focused on wool, textiles, salt, charqui, and perhaps Alca-

1 obsidian, perhaps they carried their locally produced tools of Sayrosa obsidian with them and proceeded to break, lose or give them away in acts of generosity and reciprocity. The senior author has suggested that such occasional occurrences can be referred to as ephemeral interactions (Burger et al. 2016:34). While ephermeral interactions lack the economic importance of trading alliances, they reflect the existence other classes of social interaction rarely considered by archaeologists.

An example of this can be found in a recent study of another minor obsidian source dubbed the Charaña Source (Burger et al 2021). While the Charaña Source is located in a relatively isolated section of the puna in the southern Titicaca Basin, flakes of its obsidian have been identified at Mollo Kontu, a sector of Tiahuanaco. Of 147 samples analyzed at Tiahuanaco, only two (1.4%) come from the Charaña Source; as expected, most obsidian found at Tiwanaku had been brought from the more distant major source of Chivay situated in the Colca Valley. The Charaña Source obsidian at Mollo Kontu may be result of the presence of pilgrims at Tiwanaku from the remote Charaña Source area. The presence of even a small amount of Charaña Source obsidian at Tiwanaku is especially noteworthy given its absence at dozens of sites in central and northern Titicaca Basin.

The Sayrosa Source, like the Charaña Source, is located in lightly occupied and relatively isolated parts of the high puna grasslands. Such areas have rarely been the focus of archaeological study. The identification of obsidian from minor sources provides us with a tool to identify the groups with whom the residents of these zones interacted. As we have seen in of Sayrosa, contact seems to have been primarily with the farming communities of the Cusco Valley. At the present time, no Sayrosa obsidian has been identified at archaeological sites in neighboring Puno or Apurimac.

These are only a few examples of why the identification of minor obsidian sources is worthwhile. It is impossible to predict the impact that locating the Sayrosa Source will have in the future. Nonetheless, we feel confident that when combined with the recent discovery of other minor obsidian sources (Burger et al 2022, Craig et al 2010, Frye et al 1998), the location of the geological deposit of Sayrosa obsidian, formerly referred to as Rare Type 3, should help to facilitate and enrich the fine-grained study of social and economic interaction in the prehistoric southern highlands of Peru.

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Tables

Table 1. Means and standard deviations from XRF for ten source samples from Sayrosa, Peru.

Table 2. Means and standard deviations from NAA for ten source samples from Sayrosa, Peru

Table 3. Comparison of XRF results for three Rare-3 artifacts analyzed at LBNL to Sayrosa source samples analyzed at MURR.

Table 4. Comparison of NAA results for Rare-3 artifact BURG-35 analyzed at LBNL to Sayrosa source samples analyzed at MURR.

Table 5. Comparison of XRF results for seven artifacts analyzed by XRF to Sayrosa source samples analyzed at MURR.

Table 6. **Table 6**. Least-cost path (LCP) results from the foot of the Sayrosa Cerro Chiche Orjo outcrop (4479 masl) to the city of Cusco (*) and to archaeological sites with these obsidians.

Figures

Fig. 1 Residence of pastoralists in Pucya district near the Sayrosa source (Photo by E. Tsurumi)

Fig. 2 Sayrosa River with obsidian and other cobbles and Capilla in the distance (Photo by E. Tsurumi). On the left side of the photo Capilla is situated on an alluvial fan composed of material

eroded from Cerro Chinche Orjo. The fan extends to the floodplain of the Sayrosa River where the obsidian was discovered. One the right side of the photo light-colored volcanic tuff is visible exposed by slope erosion, including a channel dissecting the NQ-Ba1 formation.

Fig.3 Obsidian nodules from Sayrosa Source (Photo by E. Tsurumi)

Fig.4 Location of the Sayrosa and Alca sources in context of local geology (prepared by Kurt Rademaker)

Fig. 5. Scatterplot of XRF data for Rb versus Sr showing groups of sources in Peru most similar to the source at Sayrosa. Groups are surrounded by 90% confidence ellipses.

Fig. 6. Scatterplot of XRF data for Cs versus Hf showing groups of obsidian sources in Peru most similar to the source at Sayrosa. Groups are surrounded by 90% confidence ellipses.

Figure 7. Scatterplot of XRF data for Rb and Sr for three Rare-3 artifacts analyzed at LBNL to sources in Peru analyzed at MURR.

Figure 8. Scatterplot of NAA data for Cs and Hf for Rare-3 artifact BURG-35 analyzed at LBNL to sources in Peru analyzed at MURR.

Figure 9. Scatterplot of XRF data for Rb versus Sr for seven artifacts and Peruvian sources analyzed by Millsaps' Bruker Tracer 5i pXRF spectrometer. Groups are surrounded by 90% confidence ellipses.

Figure 10. Map showing location of Sayrosa Source and archaeological sites with artifacts of Sayrosa obsidian in relation to the least-cost routes between the Sayrosa Source, the Alca-1 Source and the city of Cusco. (prepared by Kurt Rademaker)

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