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Spatio-temporal patterns in obsidian consumption in the Southern Nasca Region, Peru

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ABSTRACT

Geochemical data from 426 obsidian artifacts collected from a range of sites in the Southern Nasca Region (SNR), Peru highlight spatial and diachronic patterns in obsidian consumption. We compare source ascription data against different models of obsidian acquisition, and find that, for the most part, people adhered to a simple economic model where the most proximate source was exclusively used. Slight departures from this model during the Archaic, Early Nasca, and Tiza periods suggest obsidian was in some cases acquired through alternative means. For the Archaic period we attribute this to higher degrees of mobility where obsidian acquisition was embedded within other activities. For the Early Nasca and Tiza periods we attribute this to the development of alternative exchange relations within the south-central Peruvian region. We also examine differences in obsidian acquisition across SNR river valleys and by elevation, with greater source diversity occurring in the central valleys and at lower elevations.

1. Introduction

Obsidian studies in Peru have been gaining popularity since the first studies published in 1970s. A major thrust of these studies has focused on sources of obsidian, especially documenting the location (e.g., Brooks, 1997; Burger and Glascock, 2000; Burger et al., 1998a,b, Burger, 1998), chemical composition (Glascock et al., 2007), and the nature of exploitation at (e.g., Jennings and Glascock, 2002; Tripcevich, 2007) sources. Fewer studies have examined consumption of obsidian away from sources (for recent exceptions see Burger, 1978; Burger et al., 2000; Craig et al., 2007; Stanish et al., 2002; Vaughn and Glascock, 2005).

This exploratory study examines geochemical data on over 400 obsidian artifacts from the Southern Nasca Region (SNR), Peru. The closest documented obsidian source lies approximately 100 km to the northeast, thus, these items were transported into the region and provide insights into prehispanic regional interaction and obsidian consumption away from sources. Artifacts were collected from a range of sites in the Tierras Blancas ($n = 248$), Aja ($n = 107$), Trancas ($n = 45$), and Taruga ($n = 21$) valleys and on the adjacent pampa ($n = 5$), and almost every item was dated independently by hydration means (see Eerkens et al., 2008a). This sampling strategy allows us to track patterns in source distributions over time and space in the SNR.

2. Background

The Nasca region is located in the Department of Ica, south coast of Peru. The Ica and Grande drainages are generally recognized as the heartland of Nasca development. Our focus in this study is the Southern Nasca Region (SNR), which comprises the Aja, Tierras Blancas, Taruga, and Las Trancas drainages (Fig. 1). The region is very dry and characterized by intermittent streams that fill with waters from annual rains in the highlands. Nasca society flourished in this region during the Early Intermediate Period (hereafter EIP; circa. A.D. 1–750), and while some archaeologists use a slightly

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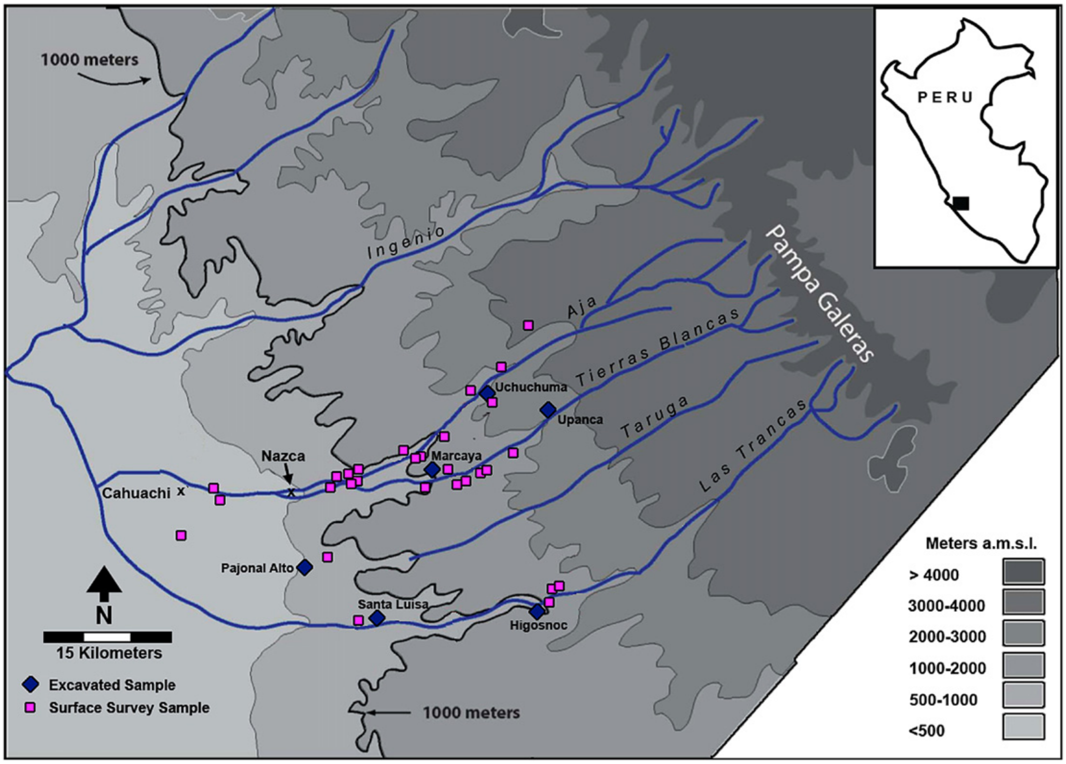

Fig. 1. The Southern Nasca Region (SNR) with the sites sampled in this study. The contour interval is shown in the inset, and the 1000-m contour line is highlighted.

different scheme (e.g., Isla and Reindel, 2006; Silverman, 1997), the EIP is generally divided into the Early (phases 2–4, A.D. 1–450), Middle (phase 5, A.D. 450–550), and Late Nasca (phases 6 and 7, A.D. 550–750) (Schreiber and Lancho Rojas, 2003; Table 1). These divisions are based on a seriation undertaken by Lawrence Dawson (see Proulx, 2006 for a recent summary; referred to generally as the "Dawson Seriation") and changes that occur in settlement patterns in the SNR.

A number of obsidian sources have been located within 250 km of the SNR (Glascock et al., 2007). Seven of these contain artifact-quality obsidian that was quarried and used in prehispanic times (Burger et al., 1998a,b, 2006; Burger and Glascock, 2000, 2001), including two major sources, Quispisisa and Alca, and several minor sources, Anillo, Jampatilla, Lisahuacho, Potreropampa, and Puzolana. Other sources of volcanic glass also exist, such as at Cerro Ticllago (Burger et al., 2006) and Yanarangra (Glascock et al., 2007), but these sources do not appear to have been used prehispanically due to the poor quality of obsidian. Geochemical data indicate that additional obsidian types were exploited in the region (Burger and Asaro, 1977), though the geographic sources of these types have not yet been reported or described in the archaeological literature.

Table 1
Chronology of the SNR.

Horizons/ periods	Local period	Culture	Phases	Approximate calendar years
Late Horizon	*–Inca–*	Inca	n/a	A.D. 1476–1532
LIP	*–Tiza–*	Tiza	n/a	A.D. 1000–1476
Middle Horizon	*–Loro–*	Loro, Wari	MH 1–2 N 8	A.D. 750–1000
EIP	*–Nasca–*	Late Nasca	N 6–7	A.D. 550–750
		Middle Nasca	N 5	A.D. 450–550
		Early Nasca	N 2–4	A.D. 1–450
Early Horizon	*–Formative–*	Proto Nasca	N 1	100 B.C.–A.D. 1
		Paracas	–	800–100 B.C.
Late Archaic				1550–800 B.C.
Middle Archaic				5000–1550 B.C.

All seven of the known utilized sources are located in the Andean highlands, generally in a NW–SE trending line. Quispisisa is the closest source to any given location within the SNR, as the condor flies, and is just over 100 km from the modern town of Nasca. Jampatilla, the next closest, is on average 18 km farther than Quispisisa. Likewise, Lisahuacho, Potreropampa, and Puzolana about 60–80 km farther than Quispisisa, and Alca over twice as far (ca. 125 km farther). Table 2 gives the straight-line distance between the seven known sources and key locations within the SNR.

Previous studies at both a regional central Andean (Burger and Asaro, 1977; Burger et al., 2000) and single-site (Vaughn and Glascock, 2005) scale have shown that Quispisisa obsidian is the dominant geochemical type at prehispanic sites in south-central Peru. This source includes high-quality glass available in several outcroppings near the town of Sacsamarca in central Ayacucho (Burger and Glascock, 2000). The Burger et al. (2000) study included a range of artifacts from a range of sites across a large cross-section of Peru, and thus, sample sizes for any particular time period and subregion were relatively small. The Vaughn and Glascock's (2005) study was more intensive, focused on a single-component site dating to the Early Nasca period ($n = 30$), but only included unmodified flakes and did not consider other time periods. Both studies provided intriguing results and suggest, by extension, that Quispisisa obsidian was the dominant source for all time periods in the SNR. However, such a hypothesis must be tested with new data. Our current sample builds on these previous studies and aims to test this notion by analyzing a large sample of obsidian artifacts, including a range of tool and waste flake types from a range of sites and time periods. As well, we independently date each artifact using hydration means.

Table 2
Known obsidian sources, and "as-the condor-flies" distances in km to locations in the SNR (all at 1600 m elevation except for Nazca and Cahuachi which are at 500 m).

	Quispisisa	Jampa-tilla	Lisa-huacho	Potrero-pampa	Puzolana	Anillo	Alca
Aja	85.7	105.7	154.3	157.5	164.3	195.5	221.4
TB	88.7	105.3	151.8	154.5	168.7	189.6	215.4
Taruga	100.0	114.9	159.2	161.4	180.2	191.6	217.2
Las Trancas	100.7	109.5	149.9	151.4	182.6	177.5	202.8
Town of Nazca	108.1	129.0	176.6	179.3	184.8	211.9	237.5
Cahuachi	119.4	144.5	194.0	197.0	192.1	231.1	256.6

We compare results from our analysis to a simple economic model predicting that people will obtain raw materials from the closest possible source. Departures from this model could indicate preference for raw materials from a particular source (e.g., obsidian from a more distant source is superior in quality than a closer one, or obsidian from a closer source is more difficult to exploit due to elevation), or some type of controlled access and distribution (e.g., an organized polity controls an obsidian source and discounts the cost of transportation by moving obsidian along with other goods).

If obsidian was moving in such a least-cost fashion, we would expect the dominant geochemical types at sites to be distributed approximately as shown in Fig. 2. This graphic plots the seven sources and shades the landscape according to which source is the closest, using a least-cost surface path (i.e., actual hiking distance). Dark lines show 40-km surface distances to the closest known obsidian source. As seen in the figure, Quispisisa is the closest source for a large swath of south-central Peru, from the area just south of Nasca to regions north of Ica.

Based on this model, Fig. 2, and the data presented in Table 2, our predictions are that Quispisisa obsidian should dominate local assemblages in all parts of the SNR. However, as one moves further south within the SNR, from the Aja to the Las Trancas Valleys, the difference between the closest (Quispisisa) and next closest (Jampatilla) decreases from 10 to 5 km. If obsidian was coming into the SNR directly from the sources, and if distance was the primary factor regulating access, we predict that non-Quispisisa obsidian should increase in frequency from north to south across the SNR.

Using an alternative model based on mobility practices (Beck et al., 2002; Eerkens et al., 2008b), we predict greater source diversity during periods of increased residential and logistical mobility. Under such conditions, people are more likely to encounter a range of obsidian sources and can embed toolstone procurement within their seasonal movements (Binford, 1979; see also Morrow and Jefferies, 1989). Individuals practicing a more restricted or sedentary settlement system tend to procure raw materials from the closest source, leading to decreased toolstone diversity. Furthermore, trade typically serves as the mechanism to acquire materials that are not available locally. Under this model, we predict greater source diversity in earlier archaic time periods when more mobile hunter–gatherers and pastoral populations are generally assumed to have made use of the region (Isla Cuadrado, 1990; Vaughn and Linares Grados, 2006).

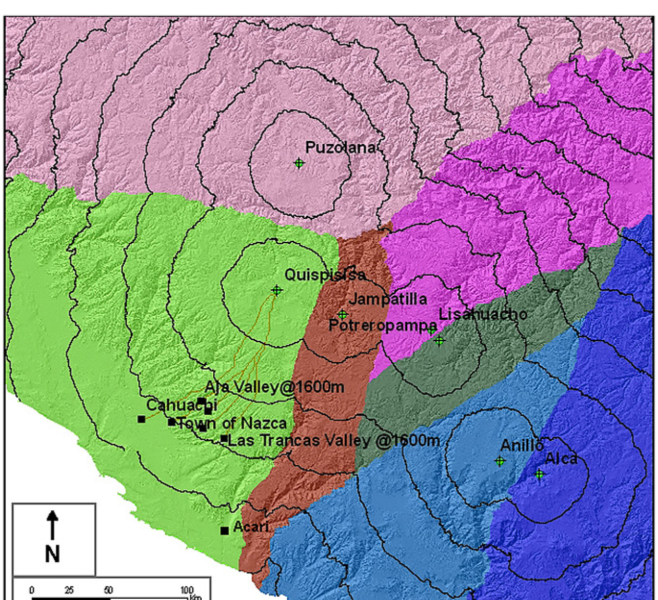

Fig. 2. Least-cost paths to different known obsidian sources across south-central Peru.

3. Sample

Obsidian samples were assembled from a range of previous archaeological projects in the SNR. Approximately 40% come from regional survey work conducted by the authors (by KJS between 1984 and 1996, and by KJV, JWE, and MLG between 2006 and 2007). The remaining 60% of the sample is derived from excavations by the authors at various habitation sites (e.g., Conlee, 2003; Vaughn, 2009; Vaughn and Linares Grados, 2006). One of the main goals in generating the sample was to gather obsidian from either radiocarbon-dated excavation contexts or single-component surface sites to help generate an obsidian hydration curve for the region (see Eerkens et al., 2008a). As a result, artifacts were taken from a wide range of temporal contexts and our overall sample is not a random draw of obsidian from SNR. By contrast, a truly random sample would likely be overwhelmed by the Nasca and later periods, when sites are more visible on the surface, large numbers of sites were occupied, exchange networks were well developed, and the overall influx of obsidian appears to have been greater. While such a strategy might better allow us to examine spatio-temporal patterns in the *overall* flow of obsidian into the SNR, it would provide less meaningful samples on changes in the sources of obsidian over time, especially in pre-Nasca times. Thus, we artificially increased samples from earlier time periods to ensure they were represented within our sample.

In total, our sample includes 426 obsidian artifacts, including 276 unmodified flakes, 9 modified or casual flake tools (containing micro-chipping along one or more edges as a byproduct of use, but no formal shaping or flaking), 13 cores, 1 unmodified nodule, and 127 formal tools (bifacially worked pieces). The latter class includes 75 complete or nearly complete projectile points and 52 fragments of bifaces, many of which likely served as projectile points as well but were too small to classify as points. This distribution represents the general range of types of obsidian artifacts encountered in the SNR.

Artifacts are most numerous from the Aja and Tierras Blancas valleys ($n = 107$ and 248, respectively) on the northern side of the SNR, and less so from the Taruga and Las Trancas valleys ($n = 21$ and 45, respectively). In addition, five artifacts were sampled from sites out on the Nasca pampa, west of the river valleys. The majority

($n = 28$) of our sites contributed less than 10 artifacts to the overall analysis, and many of these just one or two, while a small number of sites ($n = 6$) contributed 20 or more artifacts each. Table 3 tabulates our sample by tool type, site, and valley.

There are some biases in our sample which we note here and discuss further in Section 5. First, the pampa collection is obviously quite small ($n = 5$) and likely to be affected by sampling biases. Second, the Taruga Valley sample contains slightly fewer points and bifaces (14%) than the other valleys (27–31%), but more modified flakes (10% vs. 2% in other valleys), as a proportion of the total. This also likely relates to the slightly smaller sample size ($n = 21$) of artifacts. Thus results for the Pampa and Taruga Valleys should be viewed with greater caution than for the other valleys. Third, due to greater survey and excavation coverage, the Aja and Tierras Blancas Valleys are better represented in terms of total sample size. We have tried to note and consider their effects on the final results in the sections below, but we want to make clear, that in the final analysis where results are considered for the Nasca region as a whole, that these two valleys carry greater weight. Finally, very few cores are represented. This is likely due to the state in which obsidian was brought into the Nasca region, which appears to be mainly in the finished or near-finished form.

Table 3
Obsidian sample by artifact type and geographic location.

Valley	Site	Point/ Biface	Core/ Nodule	Modified Flake	Unmodif. Flake	Total
Aja	86-6	1			2	3
	86-12	1				1
	86-21	1				1
	89-54	3				3
	89-26	1			1	2
	89-46				4	4
	89-48	1				1
	90-1	1				1
	90-2	1				1
	90-72				1	1
	90-73	1	1		2	4
	Choquihuaycco	1		2	20	23
	Formative Uchuchuma	1			2	3
	Pirca LIP	1	4		18	23
	Uchuchuma	15	1		20	36
	Aja Total	29	6	2	70	107
Tierras Blancas	86-14	2			1	3
	86-15				4	4
	89-6				1	1
	89-38				1	1
	Marcaya	16				16
	Pataraya				8	8
	Tururuni	2				2
	Unnamed				1	1
	Upanca	57	5	4	146	212
	Tierras Blancas Total	77	5	4	162	248
Taruga	90-10	1				1
	Pajonal Alto	2	1	2	15	20
	Taruga Total	3	1	2	15	21
Las Trancas	90-38	1			1	2
	Higosñoc	7	2	1	26	36
	96-258	1				1
	96-259	1				1
	96-293	1				1
	Santa Luisa	3			1	4
	Las Trancas Total	14	2	1	28	45
Pampa	90-20	1				1
	90-77				1	1
	96-144	3				3
	Pampa Total	4	0	0	1	5
Total		127	14	9	276	426

4. Methods

Each obsidian artifact was analyzed using an Agilent 7500a quadrupole Inductively Coupled Plasma Mass Spectrometer (ICP-MS) system at the Interdisciplinary Center for Plasma Mass Spectrometry at UC Davis. The ICP-MS system is coupled to a Nd:YAG New Wave UP 213 laser. At the beginning of each day the ICP-MS was optimized for sensitivity during line scans that rastered across a polished NIST 612 glass standard. The production of both ionized oxides and doubly charged ions was also monitored and lowered to 0.5%. Helium was the transport gas from the laser ablation cell (~0.85 L/min) and was mixed with argon gas (1.02 L/min) before entering the ICP-MS.

Elemental data were collected in a time-resolve mode for 90 s, which included 30 s of background signal, 30 s for sample signal (dwell time), and washout time (30 s). Each spot was pre-ablated for 5 s to remove surface contaminants. Laser parameters were set to 80% power, 10 Hz, and 80 microns diameter spot size. Five spots were analyzed on each standard and obsidian sample. Twenty-eight different isotopes were measured. The NIST 612 glass served as a calibration standard and was analyzed five times at the beginning and end of each sample slide and after every 4–6 obsidian samples. To assess LA-ICP-MS performance, an obsidian source sample from Mt. Hicks in eastern California was used as an internal standard. This piece was analyzed daily and showed excellent precision from day to day. Moreover, the USGS andesite standard (AGV-2) was analyzed each day and showed good agreement with the accepted concentrations, ranging between 4 and 10% relative standard deviation (RSD) for most elements.

Raw data were reduced using the GEMOC Laser ICP-MS Total Trace Element Reduction (GLITTER) software package. The intensity of each element was normalized to that of Na (considered the internal standard) and the background signal was subtracted from the main ablation signal. Concentrations were calculated based on the known concentration of an internal standard, which is slightly different for each sample. We decided not to use Sc or Rb measures in our analyses because of the high RSD on internal standards, and inconsistencies found between Instrumental Neutron Activation Analysis (INAA) and LA-ICP-MS (Eerkens et al., 2008b).

A sample of artifacts ($n = 19$), including all those not belonging to the main geochemical type, were also analyzed by a combination of Instrumental Neutron Activation Analysis (INAA) and X-Ray Fluorescence at the Missouri University Research Reactor (MURR). This was to verify source ascription and to cross-check the LA-ICP-MS information collected at UC Davis. Fig. 3 shows the LA-ICP-MS geochemical information for artifacts included in this study, using the ratios of Zr/Nb and La/Sm along the X and Y axes, respectively. Several clusters are evident which were matched by subsequent INAA analyses to known obsidian sources.

In addition to source provenance, each artifact was also measured for an obsidian hydration band to provide an independent estimate of age. In general, hydration age estimates agree well with independent estimates of age based on associated radiocarbon dates or pottery styles (see Eerkens et al., 2008a). This information allows us to examine changes over time in the distribution of obsidian from different geochemical sources.

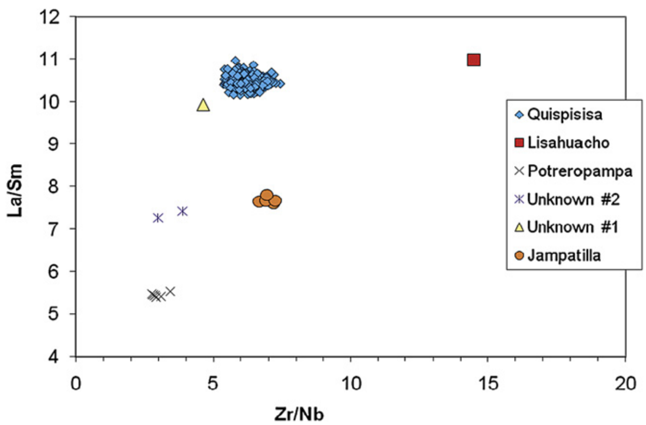

Fig. 3. Plot of La/Sm vs. Zr/Nb for artifacts analyzed by LA-ICP-MS, showing clusters of geochemical obsidian types.

5. Results and discussion

Consistent with previous studies, and expectations based on proximity, the vast majority of artifacts from the SNR were assigned to the Quispisisa source. Of the 426 pieces, just over 96% ($n = 409$) were from Quispisisa. The remaining 17 artifacts come from a range of sources, especially Jampatilla and Potreropampa ($n = 7$ and 6, respectively), and also include two distinct geochemical types not currently in geochemical databases at MURR or UC Davis. These latter types likely reflect to be located minor sources of obsidian in the south-central Andes that have not been described by archaeologists. Given their rarity, however, we believe these sources are located at distances that exceed those to Quispisisa and Jampatilla (ca. 100 km).

Table 4 shows that artifact type patterns with geochemical source diversity. In particular, source diversity is much greater among the formal tool (point/biface) assemblage. Though only 127 bifacial tools were sampled, no less than five geochemical types were found (with 92.9% Quispisisa). By contrast, the unmodified flake category contains over twice as many artifacts ($n = 276$), but only three geochemical sources (and 97.5% Quispisisa). Likewise, the two closest sources, Quispisisa and Jampatilla, are differentially represented among the unmodified flakes.

All of this suggests that obsidian working within the SNR was limited to materials imported from the closest source, with just a small amount of reduction material from the second-closest source. Judging by the presence of cortex on nearly 20% of the flakes and the large size of many obsidian tools, production was based on the importation of primary nodules from the Quispisisa source. Cortex is even present on a small number of projectile points and bifaces, indicating incomplete percussion and pressure flaking, or that inhabitants did not worry about the presence of some cortex on finished tools. At the same time, the frequency of bipolar flakes in the unmodified flake assemblage (ca. 10%), suggests fairly intensive reduction of obsidian materials. Thus, obsidian seems to have been valued as a raw material by SNR in habitants, who went to some lengths to extract the most flakeable material possible from the glass being transported into the region.

By contrast, obsidian from more distant sources seems to have been traded into the region in completed form, with little or no subsequent modification. Only one flake is from a more distant source, Potreropampa, despite the fact that we sampled a large number of small pressure flakes, which likely represent resharpening or final tool-finishing debris (Eerkens et al., 2008b). Interestingly, one unmodified nodule approximately 1 cm in diameter and recovered during excavations within the Middle Archaic stratigraphic levels at the site of Upanca (ca. 4000 BP), matched the geochemical signature of Lisahuacho. The nodule is too small to fashion into a serviceable tool. Why it was transported over 150 km is unknown.

Turning our attention to variation across space, there are also interesting differences in source distributions by river valley. Based on proximity, we had predicted that source diversity and the representation of non-Quispisisa would be higher in the southern two valleys (Taruga and Las Trancas). This expectation was only half realized. In support of our expectation, 7.6% of the 66 artifacts from the southern two valleys are from geochemical types other than Quispisisa, while only 3.4% of the 355 artifacts from the northern valleys are. However, this result is slightly misleading, because all five of the non-Quispisisa obsidians from the southern valleys are from a single Late Intermediate period site, Pajonal Alto, and all these pieces are from the Jampatilla source. Thus, source diversity is lower in the southern valleys, and greater in the Tierras Blancas valley, where at least four non-Quispisisa geochemical types are present. That Jampatilla obsidian is not more prominent in other time periods is somewhat surprising. This is particularly true in the Las Trancas Valley where Jampatilla is almost equidistant to Quispisisa (only 8.8 km, or 9%, further), yet no Jampatilla obsidian was recorded. Although measuring the flintknapping qualities of obsidian is difficult, our overall impression is that the quality of Jampatilla obsidian is significantly lower than that of Quispisisa (Burger, 1998). Thus, glass quality appears to have trumped spatial proximity for people in the southern valleys.

An interesting test of this hypothesis would be to sample obsidian from a N–S transect of sites to the southeast of the SNR, where Jampatilla is closer, at varying relative distances, than Quispisisa (as in Fig. 2). Indeed, data from two sites in the Acarí Valley to the southeast of the SNR provide initial support of this notion (Burger and Asaro, 1977). All forty-nine waste flakes examined from the preceramic shellmound of San Nicolas proved to be Quispisisa (exact dates and cultural historical periods for this site are not reported). Likewise, two-thirds of the 53 artifacts from the Initial Period site of Hacha (coeval with the Late Archaic in the SNR) were from Quispisisa. Thus, again, Quispisisa was favored over other sources, despite being located at a greater distance than Jampatilla. At the same time, there is evidence for greater geochemical diversity than in the SNR, at least at the site of Hacha, and we return to this issue below.

There are also slight differences in source distributions by elevation. As shown in Table 4, lower elevation sites (below 1000 m) have a higher frequency of non-Quispisisa obsidian at 8.7% of all artifacts, vs. higher elevation sites (only 2.5%). A chi-square

Table 4
Geochemical results tabulated by artifact type, river valley, and elevation.

	Quisp.	Jampa.	Potrero.	Lisa.	Unk. #1	Unk. #2	Total
Flake	269	6	1				276
Modified Flake	9						9
Nodule/Core	13			1			14
Point/Biface	118	1	5		1	2	127
Aja	107						107
Tierras Blancas	236	2	6	1	1	2	248
Taruga	16	5					21
Las Trancas	45						45
Pampa	5						5
Below 1000 m	95	5	2	0	1	1	104
Above 1000 m	314	2	4	1	0	1	322
Total	409	7	6	1	1	2	426

Notes: Quisp = Quispisisa; Jampa = Jampatilla; Potrero = Potreropampa; Lisa = Lisahuacho; Unk = Unknown geochemical signature.

test comparing elevation with Quispisisa vs. non-Quispisisa is significant ($p = 0.005$; phi coefficient = 0.14). This suggests that more exotic obsidian was differentially moving to sites in the lower stretches of these same valleys. It is possible that the non-Quispisisa obsidian entered the SNR by a different route, for example, along a north-south corridor along the coast. Alternatively, inhabitants of higher elevation areas may have had first choice of obsidian moving into the SNR, keeping the higher-quality Quispisisa material and passing along lower-quality glass from Jampatilla, Potreropampa, and other minor sources. Further research should seek to highlight this issue by examining the spatial distribution of different sources across a broader geographic area.

Finally, there are also interesting patterns in the distribution of obsidian geochemical varieties over time. As mentioned, each piece was measured for a hydration rim. Elsewhere we have established a hydration rate in the SNR for Quispisisa obsidian (Eerkens et al., 2008a). Research has shown that different geochemical varieties of obsidian hydrate at different rates (Hughes, 1988; Michels and Tsong, 1980; Stevenson et al., 2000), thus, we cannot apply the Quispisisa rate to non-Quispisisa obsidian. Instead, to date non-Quispisisa obsidian we rely on alternative temporal information specific to the contexts in which those artifacts were found (e.g., radiocarbon date or directly associated diagnostic pottery). Table 5 shows Quispisisa vs. non-Quispisisa obsidian by time period.

No age estimates pre-date 8000 B.C. This could indicate very low population densities in the SNR and/or a focus on non-obsidian lithic resources during the late Pleistocene and early Holocene. However, it may also be a byproduct of a lack of surface visibility of such sites (e.g., due to burial, masking by later occupation, or differential erosion), especially in valley-bottom locations where most survey took place.

Overall, there seem to be three temporal windows, or pulses, when non-Quispisisa obsidian was more heavily utilized (in a relative sense, of course, because Quispisisa dominates in all periods). The first window is during the Middle and Late Archaic periods, though we note that our early Archaic sample is quite small. The second is during the Early, but not Middle and Late, Nasca period (Early Intermediate), though again, our Middle Nasca sample is small. The final pulse is during the Tiza (Late Intermediate) period.

In terms of our expectations, we had anticipated the first pulse, during the Archaic period. Regionally, this correlates with a period when groups were more residentially mobile, either as hunter–gatherers or pastoralists. Our investigations at the site of Upanca (Vaughn and Linares Grados, 2006), which spans this transition, show that obsidian was readily available to early inhabitants of the site, as it outnumbers local chert, basalt, and andesite artifacts by a ratio of 4:1. By contrast, in the Paracas and Early Nasca periods, local raw materials outnumber obsidian by a ratio of 2:1. Thus, we believe that Middle and Late Archaic populations were frequently obtaining obsidian in the highlands during seasonal transhumance. These movements included migration near the Quispisisa source, but also included occasional visits to regions closer to the Jampatilla and Potreropampa sources, where obsidian was acquired and subsequently transported to the SNR.

Table 5
Quispisisa vs. non-Quispisisa obsidian by time period.

Culture	Calendar years	Quispisisa	Non-Quispisia	
Inca	A.D. 1476–1532	3	0	0%
Tiza	A.D. 1000–1476	34	5	13%
Loro/Wari	A.D. 750–1000	18	0	0%
Late Nasca	A.D. 550–750	18	0	0%
Middle Nasca	A.D. 450–550	7	0	0%
Early Nasca	A.D. 1–450	38	4	10%
Proto-Nasca	100–0 B.C.	16	0	0%
Paracas	800–100 B.C.	64	0	0%
Late Archaic	1550–800 B.C.	68	2	3%
Middle Archaic	5000–1550 B.C.	136	6	4%
Early Archaic	8000–5000 B.C.	7	0	0%

We had not anticipated the Early Nasca and Tiza period pulses. However, in retrospect we might have, given our understanding of socio-political developments in the region, at least for the latter. Tiza represents a time after the breakdown of the powerful Middle Horizon states of Wari and Tiwanaku, which may have controlled much of the obsidian trade in the Central Andes at that time. In Nasca, the collapse of the Wari state caused a great deal of disruption but after a period of 100–200 years society rebounded, and there is evidence for increased trade in the region (Conlee, 2003, 2006). During the Late Intermediate economic activities were restructured and diversified as new opportunities were created for communities and individuals in the absence of state control. These new opportunities appear to have included exploiting a broader range of obsidians, especially from the Jampatilla source (all five non-Quispisisa LIP artifacts are from this source).

By contrast, Early Nasca is the time period in which Nasca society emerged. While long-distance exchange is an important element of emerging political economies in the Andes (Goldstein, 2000; Vaughn, 2006), evidence for long-distance exchange of goods during Early Nasca appears to be relatively limited (Vaughn, 2009: p. 59). Items coming into the SNR include obsidian and a limited quantity of *Spondylus* shell from Ecuador. The obsidian has been hypothesized to be part of an exchange system involving llama caravans (Vaughn, 2009: p. 173). A small quantity of Nasca ceramics was exported to regions to the south including Acarí and Moquegua (Goldstein, 2000; Valdez Cardenas, 1998) and to the north in Pisco (Silverman, 1997). The exchange of these goods is probably indicative of elite interaction (Vaughn, 2009), though it is unknown what Nasca received in exchange for this small quantity of ceramics. If obsidian was part of this elite exchange we might have expected more obsidian from the southern sources (e.g., Anillo, Alca). Instead, the Early Nasca obsidian includes pieces from Potreropampa ($n = 2$) and two sources with unknown geographic provenance. Given current evidence, it appears that Middle and Late Nasca peoples were largely cut off from these conveyance channels and received all of their obsidian from Quispisisa.

We note also that, in contrast to most other regions of the Andes, there was not a major change in the pattern of obsidian exchange during the Middle Horizon in the SNR. This is curious as all other areas of the Andes have shown a significant change during this time period (e.g., Burger et al., 2000). There were major changes in most aspects of society during the Middle Horizon in Nasca (see Conlee, 2006; Schreiber and Lancho Rojas, 2003); thus, this lack of a disruption in the obsidian exchange system would appear to be anomalous. We caution, however, that the sample size of Middle Horizon artifacts in our study was relatively small ($n = 18$) and more data are needed to confirm this result. Moreover, our study focused on changes in the diversity of obsidian, not the overall flow of obsidian into the SNR, which we were not able to reliably measure due to our sampling strategy. Geochemical diversity and total volume of obsidian moved may not necessarily be linked.

6. Conclusions

Previous studies have suggested that Quispisisa is the dominant obsidian present in the SNR. Our research clearly supports this finding. Of the 426 artifacts we analyzed, only 17 (4.0%) were of geochemical types other than Quispisisa, the majority of these from Jampatilla and Potreropampa. However, non-Quispisisa obsidian is not randomly distributed across our sample. These geochemical types are more common among particular artifact types (projectile points and bifaces), locations on the landscape (the middle and lower valleys of the SNR), and time periods (Middle-Late Archaic, Early Nasca, and Tiza).

The presence of reduction material (i.e., flakes) at SNR sites, including material with primary cortex, demonstrates that local SNR inhabitants were producing artifacts (rather than receiving them only through trade). Based on the types of artifacts we have recovered during survey and excavation, these implements were primarily projectile points and expedient cutting tools (e.g., utilized flakes). It appears that Quispisisa obsidian was the source for virtually all this reduction activity. On the other hand, obsidian from other geochemical sources appears to have been moved into the SNR region in shaped forms (e.g., completed tools). Little subsequent modification and/or resharpening of these artifacts appear to have taken place within the SNR.

In sum, inhabitants of the SNR appear to have mostly followed the general economic model of minimizing costs when acquiring raw material to fulfill the demands of particular technologies requiring obsidian, especially the need to tip projectiles and to cut softer materials. Quispisisa is the most proximate source of obsidian and was overwhelmingly tapped to provision local knappers. Slight deviations from this model during the Archaic Period are in line with models where lithic procurement is embedded within residential and/or logistical mobility, which changes the relative costs of acquiring different raw materials. Additional minor deviations from the simple economic model during the Early and Late Intermediate periods are not easily explained by mobility. These departures likely relate to social conditions, especially changing exchange relations and political or economic ties between individuals from different regions.

An interesting test of the simple economic model would be to undertake similar analyses in valleys to the south and east where Quispisisa is not the closest source. For example, the Acarí Valley to the south of the SNR is closer to the Jampatilla source, and the Yauca Valley, farther south still, is closer to the Anillo source. Details on this latter obsidian source have not yet been published and are forthcoming by one of the authors (NT). If the economic model holds, we predict obsidian from Jampatilla and Anillo, respectively, will dominate in these valleys.

As well, it will be interesting to see if obsidian from the Anillo source matches the Acarí obsidian type identified by Burger and Asaro (1977) at the site of Hacha. Indeed, data published by Burger and Asaro (1977) from Hacha indicate the presence of at least three distinctive geochemical sources, including 11% Jampatilla and 19% Acarí type. Radiocarbon dates indicate the site was occupied about 1200–800 BC, coeval with the Late Archaic in the SNR (Robinson, 1994), precisely during one of the time periods when we document greater source diversity in the SNR. Thus, although sampling and analysis procedures were different, we are encouraged that there are similar patterns in our study and the Hacha data published by Burger and Asaro (1977). By contrast, a second site investigated by Burger and Asaro (1977), San Nicolas (also to the southeast of the SNR), did not have any source diversity. San Nicolas is preceramic, but is otherwise not well dated. Unless it dates to the early Archaic, the findings there of no source diversity are at odds with our findings in the SNR. However, we also note that all of the artifacts from San Nicolas are reported as waste flakes, an artifact category we found to have lower source diversity in the SNR.

Detailed comparison of glass quality and nodule size at the different sources would help archaeologists interpret departures from the simple economic model. For example, we may be able to evaluate the relative costs (or benefits) of acquisition effort vs. glass quality within particular flaked-stone tool technologies. Additional research into the reduction sequences and technologies employed in the SNR and surrounding regions, as well as standardized measurements of glass quality, are needed to begin such an endeavor.

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