QSOURCES, CIRCULATION, AND USE OF OBSIDIAN IN CENTRAL CHILE

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Abstract

A geochemical analysis of 392 obsidian samples from different archaeological sites in Central Chile (32 ° to 35 ° Lat. South) has identified the preferential use of three known sources in the Andean mountain range, Arroyo Paramillos and Laguna del Diamante located in the Maipo Volcano area, and Las Cargas located ca 120 km further south. The analysis of the circulation and use of this raw material from the beginning of the Archaic period until the arrival of the Inka to this territory reveals differences in how obsidian from these three main sources was used, both spatially and temporally. The hunter-gatherers occupying the andean mountain range preferred the obsidian source from the Maipo Volcano area, while the hunter gatherer and horticulturalist groups from the central valley used more frequently the obsidian from Las Cargas source. These differences are linked to the quality of the obsidian, its suitability for the intended use and the distance of the users from the source.

Key word: Obsidian Sources, Andean Mountains, raw material circulation, way of life, obsidian quality, Central Chile.

1. Introduction

Studies of obsidian provenance in the Southern Cone have been published regularly since the mid-1990s, with a particular focus on countries connected by the Andes Mountains (Bolivia, Argentina, and Chile) (see e.g. Escola 2004; Escola et al. 2016; Seelenfreund et al. 2005; 2010; 2010b; Yacobaccio et al. 2002; 2004), including the south (e.g. Barberena et al. 2011; 2019; Stern et al. 2008; 2009) and far south (Patagonia) of that region (e.g. Castro et al. 2017; Mendez et al. 2008/9; Stern et al. 2012; Stern 2018).

Central Chile has been no exception. Recent investigations into sources of the obsidian used in this territory have made major advaices. The pioneering work of Seelenfreund et al. (1996, 2005) identified and characterized major obsidian sources near Laguna del Maule and, for the past 15 years, a macroregional program has been characterizing obsidian sources in the Central Andes of Chile and Argentina (34°/37°S) (Cortegoso et al. 2014; 2016; 2020; De Francesco et al. 2006; 2018; Duran et al. 2004, 2012; Giesso et al. 2011). This work has led to the identification of obsidian sources in the Andes Mountains and, through the use of different methods (NAA, XRF, LA-ICP-MS), has enabled their characterization, differentiation, and distribution on both sides of the Andes.

This is especially relevant when we consider that in Central Chile, obsidian is a ubiquitous raw material. It is present in sites with very early occupations (Cornejo et al. 2005; Mendez and Jackson 2015) and in those dated throughout the Archaic, and it continued to be used by horitculturalist groups that occupied the territory from the beginning of our era up to the time of the Inka occupation (e.g. Pascual 2015).

In this context, we had the opportunity to carry out XRF analyses on 392 samples of obsidian from different sites in Central Chile covering a timeframe that spans from the Archaic to the Inka occupation (Table 1). This has provided us with an increasingly accurate picture of which obsidian sources were being used and how they were distributed within the western Andean watershed (Cortegoso et al. 2014; 2016; 2020; De Francesco et al. 2006; Duran et al. 2004, 2012; Giesso et al. 2011).

In this work we present the integrated results of our analysis of samples from sites on the Chilean side of the Andes, as the basis for a discussion in terms of the temporal and spatial distribution of the sites analyzed, and of local and regional historical dynamics. In particular, we are interested in temporal trends in how various sources were used in different subsistence and mobility contexts. These trends can help us to understand the territoriality, interactions, and connections between human groups in the zone, which in turn provides information about who was accessing a given source, when and how they were accessing it, and what the obsidian was used for.

2. The presence of obsidian in the historic-cultural sequence of Central Chilean sites

Central Chile (32° to 35° Lat. South) is a relatively narrow territory situated between the Pacific coast and the high peaks of the Andes, which rise over 6000 m above sea level (Figure 1). The climate has varied over time but is currently temperate (Villa-Martinez et al. 2003; 2004) and conditioned by the latitude, a marked maritime influence, and the high Andean peaks. Over the past 5000 years these factors have produced an ecology dominated by sclerophyllous forests, which cover the territory below 2000 m. These conditions are overlaid upon a landscape with four distinctive geographical features, arranged longitudinally, each with its own ecological zones: the Coastal Plain; the primarily intrusive Coastal Range; the Central Valley, which is composed mainly of sedimentary infill from the Quaternary; and the Andes Mountains, dominated by the igneous Abanico-Farellones formation. The sources of obsidian discussed herein are situated in the last of these (the Andes), near the continental divide that marks the border between Chile and Argentina in this part of the Andes.

Figure 1. Study area and distribution of the studied sites

Basin	Site	Total	ND	ChB	ChD	M2	LD	LC	AP
Maipo	1) Arevalo 2	6						6	
	2) Popeta	7			1			5	1
	3) Lonquen	1			1				
	4) VP-1	13		3	1			3	6
	5) Verde 2	1						1	
	6) V18	1						1	
	7) RML 021	1							1
	8) RML 034	6		1					5
	9) RML 037	1							1
	10) El Manzano 2	2							2
	11) El Manzano 3	19						2	17
	12) El Manzano 1	29	2		1		1	2	23
	13) Tío Coco	1						1	
	14) La Batea 1	3							3
	15) Doña Leonor	1							1
	16) Condominio 1	5							5
	17) Escobarino 1	4			1			2	1
	18) Los Panales	2		2					
	19) Las Cortaderas 2	9					1		8
	20) Las Cortaderas 3	4					1	1	2
	21) Las Morrenas 1	15			1		2	1	11
	22) Los Queltehues	60	1				10	2	48
	23) El Arenal	1							1
	24) Valle Blanco	1							1
	25) El Plomo	33	1						32
	26) Holoceno	37					1	2	34
	27) Cruz de Piedra	1						1	
	28) Buena Vista	1		1					
	29) Buenaventura	1						1	
	30) El Aro	1							1
	31) El Olvido	7							7
	32) Vega Linda	16	1				4	5	6
	33) Las Perdidas	23					9	1	13
Cachapual	34) Cuchipuy	50	3	1	7			37	2
	35) Chuchunco	1				1			
	36) Chamico	1						1	
	37) Pueblo Hundido	2		1				1	
	38) El Encanto	1						1	
	39) Caceron 2	1							1

	40) Caracoles Alero	3		1				2	
	41) Alero Cipreses	1						1	
Aconcagua	42) V. C. Silva Enriquez	4		2				2	
	43) Cerro La Cruz	1						1	
	44) Llanos de Rungue 6	2							2
	45) Casablanca 10	1						1	
		381	**8**	**12**	**13**	**1**	**29**	**84**	**235**

ND = unassigned; ChB = Chile-B; ChD = Chile-D; M2 = Maule 2; LD = Laguna del Diamente; LC= Las Cargas; AP = Arroyo Paramillos

Table 1. Samples of each source per site

This territory was first peopled some 13,000 years ago, at a time when the reigning Pleistocene conditions were favorable for large herbivores, which in turn made the area very attractive to human groups (Núñez et al. 1994; Mendez and Jackson 2015). As the Holocene was ushered in some 10,000 years ago, those hunter-gatherer groups began to hunt modern fauna, especially camelids (Cornejo and Saavedra 2003).

The Archaic period is divided into four phases based on differences in technologies, lithic instrument categories, mode of subsistence, and mobility patterns (Cornejo et al. 1998, Cornejo 2010). During this early period, subsistence would have been based on hunting, primarily of guanaco, but gathering wild plants gradually took on an increasingly important role (Belmar et al. 2005). Marine resources were also consumed in this territory, but did not represent a major part of the diet of these early humans (Falabella and Sanhueza 2019). In terms of mobility, the most significant development occurred around 3000 B.C., when the previous pattern of residential mobility shifted to one based on logistical mobility.

While there is evidence that objects were brought from the coast to the mountains from early on in the sequence—note the presence of seashells in Piuquenes Cavern, in the Andes, for instance (Stehberg et al. 2012)—the use and distribution of lithic materials were primarily based on locally available resources. Thus, on the coast, in the inland Chacabuco Range, and in the Andean Maipo River basin, human groups mainly used locally available raw materials, and the reported frequency of those materials (Aguilera 2012; Arenas 2013; Castelleti and Garcia 2007; Cornejo and Sanhueza 2011; Cornejo and Saavedra 2017; Planella and Falabella 1991; Ramirez et al. 1991) provides no convincing evidence that they circulated outside of those territories—except for obsidian. The technological emphasis in these groups' lithic industries, while they do display certain variations through the sequence, are predominantly curatorial, most notably so in sites where obsidian is the main lithic material used (Cornejo and Galarce 2010).

While this hunter-gatherer way of life remained in place in the mountainous parts of the region up to colonial times (Cornejo and Sanhueza 2003; 2011), around the beginning of our era, some groups began to grow crops and make pottery, ushering in what is now known as the Ceramic periods (Falabella et al. 2016). In the Central Valley and along the Pacific coast, horticulturalist groups developed a more sedentary way of life, establishing settlements on plains near rivers, in ravines, and near freshwater springs. Early Ceramic groups (ca. 200-1200 A.D.) took different approaches to this mode of subsistence; while the Bato groups grew a limited variety of crops with less emphasis on maize, for the Llolleo groups, corn was the staple food, complemented by other crops (Planella et al. 2014). In the Late Intermediate (ca. 1000-1450 A.D.), Aconcagua groups relied even more heavily on maize (Falabella et al. 2008). Around 1400 A.D. the Inka State imposed its rule upon these groups (Cornejo 2014) and installed a way of life unprecedented in the region that continued up to the time of the Spanish conquest.

During the Ceramic periods, the logic that governed the use of lithic raw materials was transformed, with groups showing a preference for resources available in river courses near residential sites. Basalts and andesites were worked expediently to craft choppers, scrapers, and hammers that were used and quickly discarded. Bifacial knapping of fine-grained raw materials was reserved almost exclusively for projectile points (Cornejo and Galarce 2004; Pascual 2015). Even so, there are hardly any sites in Central Chile where obsidian has not been found, although its frequency varies significantly, depending on the site's location (coast, valley, foothills or high Andes) and time period (Archaic / Ceramic periods).

In the *central valley* and the *coastal zone*, the Archaic period has not been well studied; although there have been a few reports of obsidian on the coast, most come from the Central Valley. Obsidian projectile points have been reported for sites in the Lampa hills (Jackson and Thomas 2005), at Las Cenizas (Gajardo Tobar 1958-89, Arancibia 2008), at Tagua Tagua 1 (second occupation) (Durán 1980) and Cuchipuy (Kaltwasser et al. 1980). The datings obtained for the latter two sites –5300 to 4730 B.C. and 6200 to 5640 cal B.C. respectively– situate them in the Archaic III, and the first two sites could also be assigned to that period, given the typological similarities in the projectile points found there. The presence of obsidian in the valley, however, dates back further, to the early occupation of Tagua Tagua 1, a site used for hunting and butchering of now-extinct fauna, for which a multipurpose scraper and at least one piece of knapping waste has been reported (Mendez and Jackson 2015).

On the coast, only two sites from this period have been systematically studied—Punta Curaumilla and LEP-C; the former presented no obsidian waste (Ramirez et al. 1991), and in our recent review of the material discovered at the latter (Falabella and Planella 1991), we identified just a single very small piece of obsidian waste.

At sites excavated in the Central Valley and dated to the Early Ceramic period, the frequency of obsidian among instruments with retouched edges is considerable (36% at Hospital, 14% at Lonquén), but the material accounts for less than 1.5% of overall lithic waste (0.7% at El Mercurio, 0.8% at Hospital, 1.4% at Lonquén). Obsidian is also absent in categories such as flakes, with one exception being the site of La Palma. There, obsidian accounts for 27% of the material discovered, represented mainly by microflakes with secondary retouching and knapping waste, along with a not insignificant proportion of the bifacially-worked instruments (points), and two "microcores" (smaller than 2 cm). The La Granja site, in the Cachapoal Valley, also presents a high frequency of obsidian—16% of all lithic materials—and displays the same pattern as La Palma, with a high proportion of obsidian retouching waste and bifacial obsidian instruments (56.9%). Undoubtedly, these two cases reflect a strategy for the provisioning and use of this raw material that is different from that observed at other sites dated to the same period (Cornejo and Galarce 2004, 2010).

Less information is available for the coast, but the reported relative importance of projectile points manufactured with obsidian compared to those made of other fine-grained raw materials is also seen at the LEP C, Arévalo 2 and Las Brisas 3 sites (Planella and Falabella 1987, Falabella and Planella 1991, Rivas and González 2008). There is little evidence of knapping waste (in our recent review, we identified only two pieces among the lithic material from site LEP-C). A comparative analysis of lithic material from Late Intermediate Aconcagua sites distributed along the coast-mountain axis found a situation similar to that described for the previous period, namely that obsidian is present in all sites, albeit in small proportions. Furthermore, this raw material is only present as blank knapping flakes (1-4%) and bifacial instruments, among which 26% of all points are made of obsidian (Cornejo and Galarce 2004).

A different situation is found in the *Andes Mountains*, where sites are located much closer to obsidian sources, particularly sites along the Maipo River, whose headwaters contain two of those sources: Laguna el Diamante and Arroyo Paramillos. This area was occupied primarily by hunter-gatherer groups throughout the entire sequence, although during the Ceramic periods they shared the space with a few isolated occupations of horticulturalist groups from the valley (Cornejo and Sanhueza 2003; 2011).

Analyses of obsidian distribution along the entire Andean stretch of the Maipo River have shown that sites in the southern or upper reaches of the river present high frequencies of obsidian, on the order of 40% or more of all lithic material, throughout their entire time sequence (Cornejo and Sanhueza 2011). In contrast, sites located in the northern or lower cordilleran course of the river present notably lower frequencies of obsidian (usually around 10%, and always less than 30%). What is interesting about this distribution is that the drop in the frequency of obsidian in these contexts is not proportional to distance from the source; rather, a dramatic shift occurs at 60 km from the source. This fact, and its relation to other archeological indicators such as the type of settlement (rock shelter versus open air camp) and the type of ceramics present at sites dated to ceramic periods, allow us to suggest that social factors (the presence of different socio-cultural groups) were responsible for this distribution (Cornejo and Sanhueza 2011). In any case, it is important to note that obsidian accounts for 7% of the material recovered from the El Manzano 1 site, on the northern area of the cordilleran course of the Maipo River, even during its earliest occupation (Archaic I) dated from 10,410 to 8560 cal B.C. (Cornejo *et al.* 2005).

3. Sources and their distinctiveness

The work of identifying, characterizing, and discriminating among obsidian sources has allowed the identification of three distinct sources in the Andes Mountains. Laguna del Diamante and Arroyo Paramillos, located nearby the lake itself, in the caldera of the ancient Maipo Volcano, at 3300 m asl, 19 km east of the headwaters of the Maipo River; and Las Cargas, in the Planchón Peteroa volcanic complex, at 2350 masl (Cortegoso et al. 2016; 2020; De Francesco et al. 2006, 2018; Giesso et al. 2011; Salgán et al. 2015). As all three sources are high up in the mountains, they are accessible only in summertime from either side of the Andes.

The Laguna del Diamante obsidian consists of less than 10 cm to up to 40 cm nodules dispersed high up on the steep slopes surrounding Laguna del Diamante, on its shoreline, and in the streams that flow down into it, such as Arroyo Las Numeradas. This obsidian can be described as low to medium quality for knapping, as it displays inclusions and devitrification (Cortegoso et al. 2016, 2020).

Arroyo Paramillos obsidian has been recorded as very small 2-3 cm nodules dispersed along the course of the Paramillos stream. As larger obsidian artifacts have been attributed to this source, larger-sized raw material should be available; however, the primary source of this raw material has not yet been found. The quality of this obsidian is higher than that of Laguna del Diamante, with few inclusions and even fracturing, and the most abundant variant is opaque and semi-translucent black (Cortegoso et al. 2020).

One hundred and forty-four kilometers further south, high up in the Mataquito River basin, is the Las Cargas obsidian source. The source itself is at least 1 km², and the obsidian appears as outcroppings, in boulders, or as nodules. The action of the Arroyo El Cura stream exposed the outcrop and transported the material at least 4 km downstream along the eastern watershed. The place was used as a quarry, with preforms, matrices, and waste from core manufacturing all found there. Chemical analysis revealed that the source is homogeneous, arising from a single volcanic eruption, and the obsidian is of good quality (Giesso et al. 2011, Salgán et al. 2015). Obsidian hydration dating performed on material from this source suggests that the source remained in continuous use from 10,350–1800 BP (Salgán et al. 2015; Garvey et al. 2016).

Apart from the sources described, the macrorregional program to characterize obsidian sources in the Central Andes of Chile and Argentina has also led to the identification of sources in the eastern area of the Laguna del Maule volcanic complex. Laguna del Maule 1 is located nearby of Laguna Fea and Laguna Negra, 2300-2500 masl. Laguna del Maule 2 is located ca 90 km downstream river Barrancas (ca 1000 masl) and is an ash-fall volcaniclastic deposit (Barberena et al. 2019; Fernandez et al. 2017). Only one sample has been assigned to the Laguna del Maule 2 source. In addition, two sources on the plains east of the Andes has been recorded (Cerro Peceño and Cerro Huenul) (Durán et al. 2004; Giesso et al. 2011); however, no obsidian from these sources has been reported in sites located in the western slope of the Andes. It is also worth noting that for nearly 900 km north of the Maipo River, no volcanism has been recorded that could have produced obsidian (SERNAGEOMIN 2018).

Obsidian sources analysis have been conducted at the Archaeometry Lab at MURR since the mid-1980s (Cobean et al. 1991, Glascock et al. 1994; Glascock 2020). That research was initially based exclusively on NAA. Recently, however, XRF has been used more often, due to its lower cost, non-destructiveness, and the portability of XRF instrumentation. XRF has proven to be satisfactory for most obsidian investigations, the main exceptions occurring when: (1) the sample dimensions are smaller or thinner than recommended; (2) the samples have surface contamination; (3) the possible sources are chemically similar to one another; and/or (4) the artifacts come from as yet unknown or unexpected sources. In the case of small or contaminated samples, the physics of XRF must be well understood in order to properly interpret the data and make the necessary corrections. When any of these difficulties lead to inconclusive results, or when new compositional profiles are identified, the more comprehensive analytical methods of NAA or LA-ICP-MS are employed.

The Arroyo Paramillos source and the Las Cargas source have a very similar chemical signature, which has made it difficult to differentiate them (see Cortegoso et al. 2014, 2016; De Francesco et al. 2018; Salgán et al. 2015). In fact, the lack of differentiation between these two sources in the first-ever analyses performed led to a mapping of usage of the sources that did not align with what would be expected based on the distance to them, as Giesso and associates have discussed

(2011). Starting in 2009, more samples from Arroyo Paramillos were analyzed using NAA at MURR, enabling this source to be differentiated from Las Cargas. This study determined that, among the elements that can be identified via XRF, Paramillos differs from Las Cargas only in the concentration of Sr, best expressed in the ratio Sr/Rb, with Paramillos having higher Sr concentrations (Cortegoso et al. 2020). The difference between the two sources had already been detected by De Francesco et al (2006) and was recently confirmed on the basis of Sr and Ba, using LA-ICP-MS (De Francesco et al. 2018).

Recent NAA studies also suggest that Arroyo Paramillo has two subgroups of obsidian, each with different concentrations of Sc and La that are not distinguishable by XRF, and one of which is located inside the volcanic caldera (Cortegoso et al. 2020).

The samples were analyzed by XRF at different times and with different instruments (for details, see Cortegoso et al. 2020). To enable comparison, the data were calibrated using the same samples from each source. Ultimately, the work focused on the elements Mn, Fe, Zn, Rb, Sr, Y, Zr, and Nb, and on element ratios (Sr/Rb, Rb/Zr) rather than element concentrations, which allowed greater confidence in assigning small artifacts to their respective sources.

4. Results

To date, we have analyzed 381 artifacts from 45 different sites located on the western side of the Andes in Chile's Central Valley and Pacific coast (150 km away). These sites are distributed from the Aconcagua Valley in the north to the Cachapoal Valley 190 km further south (Figure 1). The sites encompass a broad timeframe that extends from the Archaic to the Inka period, and includes different yet contemporary ways of life (hunter-gatherer and horticultural) and having different functions, including rock shelters, open air sites, residential sites, and social meeting places, with and without burial grounds (Table 1). It should be emphasized that, although the sample studied is sizeable, it is certainly not evenly distributed across space or time. It is concentrated geographically in the mountains (73.3%) and temporally in the Archaic period (60.5%) (Tables 1 and 2).

Source	Archaic II/III	Archaic IV	H-G Ceramic Perido*	Early Ceramic	Late Intermediate and Inka	Total
ND	5	3	1	1	0	10
%	4.3	2.7	1.0	2.6	0.0	2.6
ChB	1	1	2	6	2	12
%	0.9	0.9	2.1	15.4	9.5	3.1
ChD	6	3	0	2	3	14
%	5.2	2.7	0.0	5.1	14.3	3.7
M2	0	0	0	1	0	1
%	0.0	0.0	0.0	2.6	0.0	0.3
LD	0	10	19	0	0	29
%	0.0	9.1	19.8	0.0	0.0	7.6
LC	27	9	16	22	13	87
%	23.3	8.2	16.7	56.4	61.9	22.8

AP	77	84	58	7	3	229
%	66.4	76.4	60.4	17.9	14.3	59.9
Total	116	110	96	39	21	382

ND = Unassigned; ChB = Chile-B; ChD = Chile-D; M2 = Maule 2; LD = Laguna del Diamente; LC= Las Cargas; AP = Arroyo Paramillos. * H-G Hunter Gatherer

Table 2. Distribution of samples of the studied sources according to cultural affiliation

It is also important to note that there are only 10 sites for which more than 10 samples were analyzed, and for 19 of the sites, only one specimen was analyzed. These differences are related to the availability of obsidian at each site. The absolute frequencies of obsidian in most of the cases are a function of the quantity of knapping waste or artifacts present in the contexts of each site. This is why only one specimen was studied for some sites, while for others the sample size was much larger.[1]

According to our analysis, the majority of the obsidian found at these archeological sites came from three sources—Laguna del Diamante, Arroyo Paramillos, and Las Cargas; one sample is from the Laguna del Maule 2 source; 25 samples were assigned to other sources whose locations are still unknown (DES-B and DES-D); and 10 could not be assigned to any particular source, as they could not be grouped with any other sample. In this analysis we will focus on sources with known locations, excluding Maule-2, for while it is interesting to ponder how these groups accesssed that source, located further south and in the lowlands of the other side of the cordillera, it is difficult to draw conclusions about its use from a single sample.

The proportion of specimens assigned to each of the three main sources identified (n = 345) varies significantly, with the Arroyo Paramillos source very highly represented, at 66,4% of the sample, followed by Las Cargas with 25.2%, and finally Laguna del Diamante, accounting for just 8.4%. As the usual assumption is that the proportional representation of each source is related to the distance between it and the site, we would expect that proportion to diminish as distance between site and source increases (see e.g. Eerkens et al. 2008). Nevertheless, although Arroyo Paramillos and Laguna del Diamante (Figures 1) are virtually in the same place at the base of the Maipo Volcano, the representation of the former is 8.1 times that of the latter (Table 1). Furthermore, Las Cargas (Figure 1), despite being the most distant source of obsidian, is not necessarily the least frequently represented of the three, even for the sites furthest away from it.

In the majority of sites with more than 10 samples analyzed (see Table 1), one source commonly accounts for more than 70% of all obsidian found. Only the sites of Vega Linda and Las Perdidas, in the Andean stretch of the Maipo Valley, do not conform to this pattern; there, the Arroyo Paramillo source does predominate among the specimens found, but the Laguna del Diamante source also accounts for significant proportions at each site (25.0% and 39.1%, respectively). This can be explained by the fact that these sites are two of the closest to both sources (Figure 1), situated on the eastern edge of the Maipo Volcano. However, 31.2% of the samples studied from the Vega Linda site came from the Las Cargas source, a higher percentage than from the Laguna del Diamante source, despite the fact that the former is much further away from the site than the latter (Las Cargas is 119.1 km away, and Laguna del Diamante is 20.8 km).

Furthermore, the dispersion[2] of obsidian from these sources within the territory (Figures 2, 3, and 4; Table 3) is also not linked to distance from the respective source, whether average distance, maximum distance, or minimum distance. Figure 5 displays the dispersion area for obsidian from each of the three sources, which ranges from 19,995 km^2 for Las Cargas to 9,765 km^2 for Arroyo Paramillos, and 993 km^2 for Laguna del Diamante. Notably, the source that is most distant from the sites studied—Las Cargas—has the greatest dispersion (Figure 5; Table 3), as its obsidian is present in both the far north and far south of the area under study here, as well as in all four geographical features (Andes Mountains, the Central Valley, the Coastal Range, and the Coastal Plain). For their part, the Laguna del Diamante and Arroyo Paramillos sources show much less extensive distributions (Figure 5; Table 3), which are also quite different from each other.

	Dispersión (Km^2)	**Distancia media**	**Distancia Max.**	**Distancia Min.**
Laguna del Diamante	993	39,1 (σ = 18,9)	51,1	20,8
Las Cargas	19995	140,7 (σ = 48,6)	298,8	101,6
Arroyo Paramillos	9765	59,8 (σ = 29,9)	148,7	21,8

Table 3. Dispersion area of the sources and distance ranges in which they are distributed

Figure 2. Distribution of samples from Laguna del Diamante source

Figure 3. Distribution of samples from Las Cargas source

Figure 3. Distribution of samples from Arroyo Paramillos source

Obsidian from the Laguna del Diamante source is present only along the Andean reaches of the Maipo River, mainly in the southern sector; and while obsidian from the Arroyo Paramillos source is also concentrated along the Andean reaches of the Maipo River, it has a much broader distribution (Figure 5; Table 1) (cf. Cortegoso et al. 2016; 2020). This last difference could be an artifact of the great difference in the size of each sample, and if more pieces were to be sampled from other localities, more specimens from Laguna del Diamante may appear.

Figure 5. Distribution area of the studied sources

The Cuchipuy site presents a unique situation in regard to the frequency and diversity of obsidian from each source. While the Las Cargas source is clearly dominant among the finds, the site also includes seven of the 13 samples assigned to the DES-D source and one from the DES-B source, neither of which has been located to date. Furthermore, the site also yielded three of the 10 specimens in the overall sample that could not be assigned to any particular source. This characteristic of the Cuchipuy site could be related to the fact that it is the only site with a relatively large sample size that is not within the Maipo Andes, but in the Central Valley, and is also in the extreme south of the region studied here. This location seems to have enabled its inhabitants to access a battery of sources beyond those represented among the finds at the other sites.

The spatial distribution of the sources correlates with the ways of life and periods assigned to the region studied. The Las Cargas source is represented among all hunter-gatherer and horiticulturalist occupations in all periods (Table 2). Meanwhile, Arroyo Paramillos is more prevalent among hunter-gatherer sites, regardless of the period studied, and Laguna del Diamante is represented only among hunter-gatherers of the Archaic IV and the Early Ceramic period. The Shannon and Weaver diversity index (*H*), which in this case yields an ideal value of 1.61, assuming the sources are represented in all modes of subsistence and periods, and in equal proportion in each, indicates that while Las Cargas (*H*=1.52) yields 94.9 % of the ideal value, the Laguna del Diamante (*H*=0.65) source only yields 40.4% and Arroyo Paramillos (*H*=1.21) 75.7 % of this ideal value.

In terms of mobility patterns and access to resources, the sources of Laguna del Diamante and Arroyo Paramillos are especially interesting, as they are situated in the same area yet display significant differences. During the first part of the Archaic period (II and III), only Arroyo Paramillos was exploited; it was not until the Archaic IV that Laguna del Diamante began to be used as a source (Table 2). While late Archaic III datings have been recorded for the Andean upper Maipo basin (Holocene sites dated 3630 to 3350 cal B.C. and El Plomo, dated 3950 to 3670 cal B.C.), the use of the Laguna del Diamante source is linked to the actual occupation of the localities very near the sources, which only occurred after 3000 B.C., during the Archaic IV. In regard to mobility and access to resources, then, we have two different sources located close to one another yet with distinct usage histories. Arroyo Paramillos was first used by the inhabitants of distant settlements as part of their long-distance mobility circuits, then later by those in nearby settlements, while Laguna del Diamante was only used by the inhabitants of nearby settlements within local mobility circuits.

Moreover, the use of obsidian sources by hunter-gatherer groups in all periods is different than that observed among horticulturalist groups in the Early Ceramic and Late Intermediate periods. The latter more sedentary groups favored the Las Cargas source (75.9% and 81.3.0% in each period, respectively) and contained only a minor proportion of specimens from the Arroyo Paramillos source, and none at all from Laguna del Diamante. In contrast, hunter-gatherer groups tended to favor sources near the Maipo Volcano, making use of Arroyo Paramillos at first, then both that source and Laguna del Diamante later on.

It is apparent, therefore, that the preference for one source of obsidian over another does not seem to have been related entirely to distance from that source; other factors must have come into play to make Las Cargas—the most distant source, access to which was probably through indirect means—the most ubiquitous, both spatially and temporally.

In order to tease out some of these factors, we analyzed the form of fracturing (irregular or conchoid) and the presence of bubbles in 316 of the obsidian pieces in our sample (91.5%)[3]. Both are crucial variables that must be taken into account when working on a piece, as conchoidal fracturing and the absence of irregularities such as bubbles offer the optimal conditions for bifacial knapping.

Our analysis showed substantial differences between the artifacts from each source (Table 4). While the Laguna del Diamante specimens almost all displayed irregular fractures (88.5%), only a very small proportion of samples from Las Cargas (1.4%) showed this quality, with conchoidal fractures being much more common. Arroyo Paramillos, for its part, presents similar proportions of each kind of fracture. As for the presence of bubbles (Table 5), only 1.4% of Las Cargas specimens displayed them, while 50.9% of Arroyo Paramillos specimens and 23.9% of Laguna del Diamante specimens had them.

These marked differences in the quality of obsidian allow us to conclude that the source with the most suitable specimens for bifacial knapping, Las Cargas, is also the one with the widest obsidian distribution, both geographically and culturally, while the source providing obsidian that was least suitable for bifacial knapping, Laguna del Diamante, presents a more limited geographical and cultural distribution. The Arroyo Paramillos source, which yielded specimens of both higher and lower quality, displays an intermediate dispersion range.

Type of fracture	**Laguna del Diamante**	**%**	**Las Cargas**	**%**	**Arroyo Paramillos**	**%**	**Total**
Irregular	23	88,5			99	45,4	122
Conchoidal	3	11,5	72	100	119	54,6	194
Total	**26**		**72**		**218**		**316**

Table 4. Type of fractures in the obsidian samples

Bubbles	**Laguna del Diamante**	**%**	**Las Cargas**	**%**	**Paramillos**	**%**	**Total**
No-show	20	76,9	71	98,6	111	50,9	202
Present	6	23,9	1	1,4	107	49,1	114
Total	**26**		**72**		**218**		**316**

Table 5. Presence of bubbles in the obsidian samples

5. Discussion

The obsidian sources used by the groups inhabiting the western slope of the Central Chilean Andes are all located at high altitude, which means they were only accessible in summer. While it is not clear to us whether the raw material from these sources was procured directly or indirectly through exchange, it does seem clear that the spatial distribution of that raw material does not rely entirely upon the distance variable.

The quality and suitability of the obsidian used to manufacture artifacts are of major importance, and in this regard, it is the highest quality source, Las Cargas—which in fact is the only primary source of the three—that has the most extensive distribution over both time and space.

Still, Las Cargas is not always the most-represented source in all sites or all contexts. The different frequencies and distributions detected for each source are related to who was using the material, and why; it also had to do with territoriality, mobility, and social relations and networks among the different groups.

The hunter-gatherers who occupied the mountainous spaces of the Maipo basin were using Las Cargas obsidian throughout the sequence, but they also made a preferential use of the lower quality obsidian from more nearby or "local" sources. In fact, in the earliest times of human occupation of the zone, when only the Arroyo Paramillos source was in use, there are no significant archeological traces of the route used to access this source. Indirect evidence of the use of Arroyo Paramillos can only be found via the presence of obsidian from that source at sites further down the Maipo River.

Distance and quality therefore seem to have held equal weight for these groups, for while the Arroyo Paramillos obsidian was in effect being used to manufacture bifacial instruments, there was some investment made in accessing obsidian of an undoubtedly higher quality, such as that of Las Cargas. Accessing obsidian from these different sources would likely also have involved different strategies: direct in the case of Laguna del Diamante and probably indirect for Las Cargas.

Laguna del Diamante obsidian, of somewhat lower quality than that of Arroyo Paramillos, was first exploited in the Archaic IV and the early Ceramic periods, during a time when human groups began occupying the high Andes near those sources (Cornejo and Sanhueza 2011a & b). This is also expressed at sites around Laguna El Diamante on the eastern side of the Andes, which have a chronology of occupations starting at 2000 yrs AP (Duran et al. 2006). At those sites, Laguna del Diamante was used as a source at least as frequently as Arroyo Paramillos (Cortegoso et al. 2020).

The distribution of obsidian from this source is not only limited in its timeframe, however; it also covers a much smaller space, limited to the area around the source itself, with very little Laguna del Diamante obsidian present at sites in the lower course of the cordilleran Maipo River (cfr. Cortegoso et al. 2020). The distribution of obsidian from this source therefore replicates in a certain way what Cornejo and Sanhueza (2011) have proposed, i.e. that the northern and southern areas of the cordilleran Maipo River course were in fact different territories, and the groups inhabiting the southern sector would not only have been using obsidian preponderantly, but would have been virtually the only groups using the Laguna del Diamante source.

As obsidian from this source does not seem to have been among the items transported and ultimately exchanged beyond the Maipo Andes area, it can thus be proposed that the circulation of obsidian was conditioned by a demand for raw material that was suitable for manufacturing bifacial instruments in sites located in the valley. For these groups apparently the relatively good performance of the Laguna del Diamente obsidian for making sharp-edged flakes, that in fact performed much better than other locally available rocks, was not enough. This proposal is reinforced by the high proportion of bifacial instruments manufactured from obsidian from Las Cargas in the non-mountainous zones of the area studied (84.4%).

The Las Cargas source could have been accessed through the valley or through the mountains. The few specimens found in the mountainous zone of the Cachapoal basin, which is connected to the Maipo basin by the Blanco River, were assigned to Las Cargas, and in one case to Arroyo Paramillos, suggesting that this obsidian may have been transported through the mountains. The frequency of Las Cargas obsidian in Central Valley sites, and the Cuchipuy site in particular, further suggests that this raw material may have been transported through the Central Valley as well. Cuchipuy is located in the Central Valley on the northern shore of the former Laguna Tagua Tagua in the Tinguiririca River basin and boasts an extensive Archaic sequence. It is also much closer to the Las Cargas source, and therefore in this case distance and quality may be correlated, as the site with the highest number of Las Cargas obsidian samples is at the same time the closest site to that source (100 linear km).

Another particularity of Cuchipuy is the abundant presence, especially at Archaic levels, of obsidian specimens assigned to sources that have not been identified for this section of the Andes (24.0% of all samples from this site and 33.3% of all the samples of unidentified sources).[4] This indicates that the inhabitants of this site had direct or indirect access to other sources, most likely located further south. This access could have been facilitated by the site's location in the Central Valley, where there flow of obsidian apparently could have occurred. In this regard, the sources around Laguna del Maule are certainly a possibility that is worth exploring further, as the ones located on the western side of the Andes have not yet been extensively characterized using comparable methods (Seelenfreund 1996).

In the discussion about the dispersion of obsidian from these sources, it is thus necessary to take into account the geomorphology of the mountains and valleys, and the ease with which human groups may have circulated in and through those spaces. The Andean peaks in this area rise well above 4500 m asl, and transit is possibly only along the valleys and over mountain passes. Communication and circulation in the mountain space itself are certainly possible along tributaries and secondary ravines. These were likely among the access routes used by groups inhabiting sites in the Andes on the southern or upper sector of the Maipo River, enabling them to get to and from the Las Cargas obsidian site. But undoubtedly it was the most obvious circulation route—along the Maipo River itself—that seems to have been the main route along which obsidian from Arroyo Paramillo was transported from its source near the Maipo Volcano to the more notherly or lower reaches of the cordilleran Maipo River. Similarly, Cortegoso et al. (2020) have also noted the tendency of obsidian from sources around the Maipo Volcano to circulate down the western slope of the Andes.

In the case of Las Cargas, unfortunately, we have no surveys, identified sites, or analyzed material for the mountainous stretch of the Mataquito River. However, this source clearly predominates not only at the more southerly sites, but in all the sites located in the Central Valley. This suggests that once the obsidian reached the valley, it was distributed through the lowlands from south to north.

This seems especially evident among the more sedentary horitulcutralist groups. At that time, obsidian from the Las Cargas source predominated on both the coast and the Central Valley. The only exception consists of the Aconcagua sites situated on the lower Andean terraces in the lower cordilleran course of the Maipo River (El Manzano 2, Escobarinos 1); while very few samples from there have been analyzed, they do include obsidian from the Arroyo Paramillos source, which is consistent with the above.

Thus, sedentary groups whose lithic industry had a very expedient technological emphasis (Cornejo and Galarce 2004; 2010), in which bifacial knapping of suitable raw material was reserved almost exclusively for making projectile points, would have been much more selective when deciding between one source and another, no doubt favoring the one with better quality material. Their preference would have been enabled by a network of relationships oriented especially to groups further south, and not to their hunter-gatherer neighbors in the mountains of Maipo. Accessing the distant Las Cargas source would no doubt have involved an active system of long-distance exchange with other groups, enabling the raw material to arrive as small, easily-transported blanks.

In a predominantly local-scale world, in which the microregion was the primary spatial scale of everyday social interaction, and with little evidence of greater mobility (Falabella et al. 2015, Sanhueza et al. 2019), the provisioning of obsidian involves a much wider spatial scale, and is one of the few elements that reveals the presence of long-distance networks of interaction during these time periods. Such networks certainly cannot be observed in other materialities such as ceramic styles (cf. Scattolin and Lazzari 1997), which display a much more spatially limited expression, particularly during the Late Intermediate.

In these horticulturalist sites, as in Cuchipuy, we see not only Las Cargas obsidian but also the recurring presence of obsidian not assignable to recognized sources, again pointing us to more distant places, probably further south. The fact that obsidian from these as-yet unidentified sources is not distributed evenly among the different sites also suggests that access to them was resolved precisely at this local scale, in which each residential domestic unit would have activated its own networks to obtain this raw material, which is always scarce in these contexts (cf. Scattolin and Lazzari 1997; Lazzari 2010).

In that case, contrary to what would be expected based on other contexts where the trajectory of use for obsidian sources has been linked to mobility reduction, the more sedentary horticulturalist groups appear to have accessed sources that were not only more distant (p.e Roth 2000; Eerkens et al. 2008), but also more diverse (cfr. Eerkens 2008). Clearly, then, while criteria of quality were involved in decisions to use the material in these contexts, social relations also played their part, suggesting that obtaining obsidian was not only a practical matter, but also a social one, materializing the relationships and/or agencies that enable access to this non-local material. Lastly, we wish to note that no obsidian that can be assigned to sources identified on the plains on the other (eastern) side of the Andes has been detected in this area, as it has been in south-central Chile (Campbell et al. 2018; Peñaloza et al. 2019). The networks under consideration here seem to always relate to the western watershed of the Andes.

6. Conclusion

In this work we have presented and discussed the results of the analysis of 382 obsidian artifacts from different archeological sites in Central Chile, located from the Pacific coast to the Andes

Mountains, and belonging to different cultural periods ranging from the early Archaic to the Late Ceramic periods.

The results have enabled us to observe differences in how obsidian from the three main sources identified -Arroyo Paramillos, Laguna del Diamante, and Las Cargas- tended to be used, both spatially and temporally. Those differences are linked to the quality of the obsidian, its suitability for the intended use, and the distance of the users from the source, all of which would also have been intersected by the networks of relations that enabled access to this raw material.

Thus, we have a mountainous space in which groups of hunter-gatherers, regardless of their time period, preferred to make use of obsidian from the Maipo Volcano area (Arroyo Paramillos and Laguna del Diamante sources). Within this space, the selective use of obsidian from Laguna del Diamante—which appears only in nearby sites, and only later in the sequence—reaffirms not only that differences existed among the groups inhabiting the Andean territories north and south of the Maipo River, but also that the decisions and logics involved in the use of obsidian from two sources located very close together, but having different qualities for working, were quite distinct.

For Central Valley sites, Las Cargas was the main source of obsidian. Cuchipuy, the only site in that valley with Archaic occupations, displays a preponderance of obsidian from Las Cargas, which could be related to the site's proximity to this source. In the case of the horticulturalist groups, this could be the result of a preference for high quality obsidian suitable for bifacial knapping, judging by the artifacts that were made of this obsidian (mainly projectile points), and/or the existence of a network of social relations that were more relevant than actual distance from the source.

Thus, the determining vector in the circulation of this raw material seems to have been a combination of quality suitable for bifacial knapping and the existence of social networks, which prompted different groups to make distinct choices, based on which technologies they emphasized and the availability of the raw material.

Acknowledgements

The analyses reported here were partially supported by a grant to the Archaeometry Lab at MURR from the US National Science Foundation (grant # 1912276)

Notes

1) In fact, considering the proportion of samples from Arroyo Paramillos found beyond the Maipo Andes zone (5.6%), only two specimens of Laguna del Diamante obsidian would have been needed to attain a similar distribution to that of Arroyo Paramillos obsidian.

2) The area of dispersion was calculated using the QGIS program's minimum bounding geometry algorithm.

3) A small percentage of the pieces were not available at the time this analysis was performed.

4) The source DESC-B has also been found in cordilleran and precordilleran sites in northern Mendoza area (1500 - 1000 BP) (Cortegoso et al. 2019), but not in archaeological sites of southern Mendoza (Cortegoso et al., 2012).

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