
Procurement and circulation of obsidian in the province of La Pampa, Argentina

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Abstract:

The goal of this study is to report the progress regarding the procurement and circulation of obsidian by hunter-gatherer populations during the Late Holocene in the province of La Pampa, Argentina. Twenty five samples were analysed in two stages; in the first stage neutron activation analysis (INAA) was used, while X-ray fluorescence (XRF) was employed in the second stage. This paper adds nine archaeological samples from new sites and one from the Lihué Calel obsidian source, unknown so far. The results allow us to consider the sourcing of the obsidian, which was found in archaeological sites from four research areas located in the south and east of the province.

The results generated in this new stage are integrated with those previously obtained and discussed in relation to information provided by other researchers in the region. They indicate that the obsidian recovered was procured from Andean and extra Andean sources located in the Argentine provinces of Neuquén and Mendoza. New data expands the spatial perspective of our interpretations to four new research areas: Curacó basin, Lihué Calel hills, Valles Transversales (Transversal Valleys) and Bajos sin Salida (Endorheic low areas).

The origin of the obsidian at La Pampa sites adds to another cluster of archaeological evidence showing strong long distance interactions that existed between hunter-gatherer societies that inhabited the central region of Argentina in the late Holocene. Access to secondary deposits could have also contributed to source variability.

Keywords: Pampean hunter-gatherers; obsidian; provenance; procurement strategies; source variability



1. Introduction

Since the 1980s, the Western Pampa archaeological team has systematically conducted fieldwork and research in the south-central and eastern sectors of the province of La Pampa (Argentina). The focus is on the study of hunter-gatherer societies that inhabited this subregion from the early Holocene until the final moments of the late Holocene. Different disciplines and research themes have contributed to the understanding of the initial settlement of the region, including livelihoods, settlement patterns, population dynamics, social interaction, strategies of sourcing, and exchange and circulation of goods. Some of these issues can be addressed through different lines of evidence. The spatial distribution of lithic raw materials is one of the subjects used to study mobility, interaction and exchange between different social groups (Jones *et al.* 2003; Meltzer 1989). In the last 10 years, the advance in geochemical studies such as neutron activation analysis (INNA) and X-ray fluorescence (XRF) has allowed to generate new data and knowledge about the circulation areas of the lithic raw materials that these studies admit (Glascock 2002). Obsidian's particular characteristics make it the most suitable archaeological material to address them. Each obsidian source has a particular geochemistry that allows the identification of recovered products (cultural and natural) to be traced to their original source(s) (Glascock *et al.* 1998; Glascock & Neff 2003; Hughes 1998; Renfrew 1977; Shackley 2009).

Different approaches such as origin of mineral resources, extra-regional elements of material culture (ceramics, metal ornaments), isotopic analysis, archaeobotanical and bioarchaeological, among others, indicate intense interaction networks in this macro-region. The presence of obsidian is one of the proxies that allows contrasting these approaches and offers significant implications for understanding the human use and mobility at a macro regional scale. Based on the identification of sources from northern Patagonia and southern Cuyo, two alternative hypotheses are proposed: (1) the existence of extensive networks of social interaction between hunter-gatherer groups of the norpatagonic bioceanic corridor, since the beginning of late Holocene, (2) procurement was favoured by secondary sources such as Tehuelche Formation or by secondary river transport.

2. Materials and methods

2.1. Sample provenience

The sites from which the samples were obtained are: Tapera Moreira Archaeological Locality (n=13) located in the Lower Curacó River basin; Chenque I site (n=6) in Lihué Calel area; Laguna La Tigra (n=1) in the Valles Transversales area (Transversal Valley area), and finally La Chola (n=5) in the Bajos sin Salida area (Endorheic Lowlands area). Here we describe them and the sites from which the samples came (Figure 1).

2.1.1. Curacó basin area

This area, located in the south-central region of La Pampa, is linked to the basin of the Curacó River, the final stretch of the Atuel-Salado-Chadileuvú-Curacó River system (see Figure 1, A). The landscape is characterized as a wide prairie, where there are some elements that stand out, such as fluvial terraces and elongated plateaus oriented in NW-SE direction (Calmels 1996). The prevailing climatic conditions are semi-arid (Burgos & Vidal 1951; INTA 1980), and therefore water is the critical resource. As a consequence, water sources had an important role as attractors of people and animals (Berón 1994; 2004; Berón & Migale 1991).

Tapera Moreira is placed on the western bank of the Curacó River. This archaeological locality is formed by five sites, each of them with unique characteristics (Berón 2004). Site 1,

located on the 12 m terrace above the water level, is multi-component, with occupations ranging from the middle until the final late Holocene. The lower component, dated to 4550±60 BP (Beta 91937, bone), has been divided into two sub-components: Lower Levels and The Summit. The Summit subcomponent is located chronologically between 3500 and 3000 BP, the Middle component is developed between 2100 and 1800 BP, and the Upper component is dated between 1200 and 360 BP. The most outstanding feature of the upper component is the presence of pottery (Berón 2004). Site 2 is next to Site 1, but is superficial. Site 3 is 300 m to the West from site 1 and concentrates individual burials *ca.* 3000 years BP.

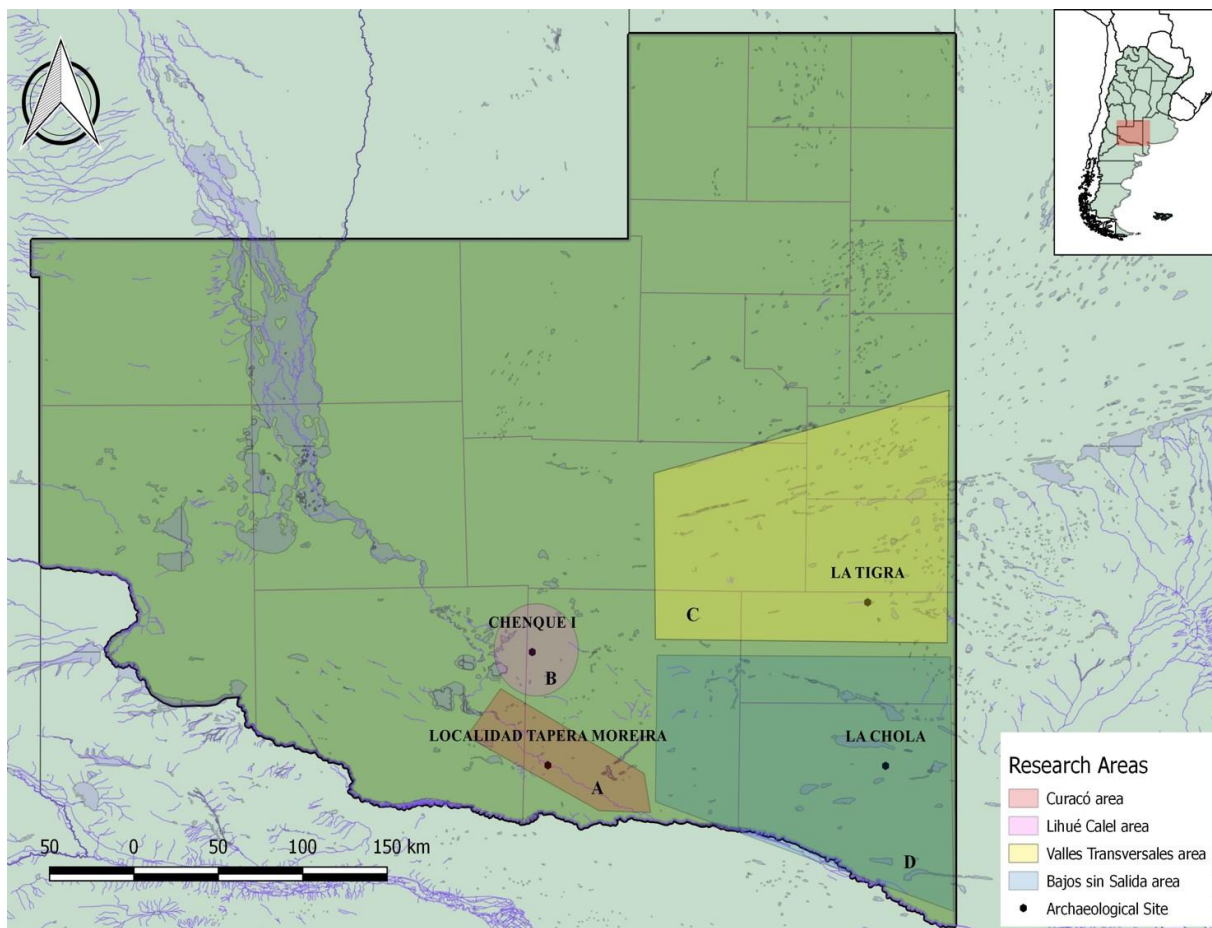


Figure 1. La Pampa province. Research areas and Archaeological sites. A- Curacó area; B- Lihué Calel area; C- Valles Transversales area; D- Bajos sin Salida area. QGIS 2.18.0.

2.1.2. Lihué Calel area

The Lihué Calel hills represent one of the most important features of the landscape in La Pampa province due to its marked relief and wide extension (see Figure 1, B). The geomorphology of the *sierras* enables the establishment of a microclimate more favourable and humid than in the adjacent areas, since the mountain relief helps to retain the water from scarce rainfalls and to moderate summer temperatures. As a result, it is an area with the ability to concentrate various biotic resources; becoming a geomorphological and biological island that contrasts with the marked terms of semi-desert of the immediate environment (Berón 2004; 2013).

Chenque I is a pre-Hispanic cemetery used between *ca.* 1050 and 290 years BP, stands out. Hundreds of individuals of both sexes and all age groups were buried there. An important collection of lithic artefacts is part of the context of this site, including some of obsidian, which were analysed in this paper (Velardez 2005; 2018).

2.1.3. Valles Transversales (Transversal Valleys Area)

The Transversal Valleys area is located in the eastern sector of the province and constitutes an ecotonal space between the subregions of western and eastern Pampa where the prevailing climatic conditions are dry subhumid (Berón *et al.* 2006; 2015; Burgos & Vidal 1951; INTA 1980). It is a landscape of undulating plains, cut by several transversal valleys between 5 and 15 km wide (Calmels 1996).

Laguna La Tigra is located in the western sector of the study area, *ca.* 30 km to the SSW of the town of Guatraché, at the head of the Maracó Grande Valley (see Figure 1, C). The analysed set comes from surface collections and was recovered in an area cleared of vegetation on the north Coast.

2.1.4. Bajos sin Salida (Endorheic Lowlands area)

This area is located in the southeast quadrant of La Pampa. Its environmental conditions are semi-arid, with annual precipitations that do not exceed 500 mm (INTA 1980). Regarding to the topography, the most outstanding trait is the presence of numerous salty low areas located below sea level.

La Chola site is located *ca.* 60 km NE of La Adela town, in the Caleu Caleu Department (see Figure 1, D). The materials were recollected in a sector surrounded by dunes. Although there are no absolute dates, the characteristics of the archaeological materials allow us to assign them to the final late Holocene.

2.2. Methodology

The samples were analysed successively using two different methods. In the first stage (before 2007) INAA was used; but from the second stage and onwards (2014 to 2017) XRF was employed.

Neutron activation analysis of obsidian at Missouri Research Reactor (MURR) consists of two irradiations with a total of three measurements. The first irradiation is applied for five seconds to samples weighing about 100 mg encapsulated in a polyethylene vial using a thermal neutron flux $8 \times 10^{13} \text{ n-cm}^{-2} \text{ s}^{-1}$. The short irradiation is followed by a twenty-five minute decay and twelve minute count, which allows measurement of seven short-lived elements (*i.e.*, Al, Ba, Cl, Dy, K, Mn, and Na). The second irradiation is applied to samples weighing about 250 mg encapsulated in high-purity quartz vials and subjected to one long irradiation of seventy hours using a thermal neutron flux of $5 \times 10^{13} \text{ n-cm}^{-2} \text{ s}^{-1}$. The long irradiation is followed by two measurements. The first count occurs about seven or eight days after the end of irradiation, using a sample changer to measure each sample for thirty minutes, in order to determine seven medium-lived elements (*i.e.*, Ba, La, Lu, Nd, Sm, U, and Yb). The second count occurs about four weeks after the end of irradiation, again using the sample changer for about three hours per sample, in order to measure fifteen long-lived elements (*i.e.*, Ce, Co, Cs, Eu, Fe, Hf, Rb, Sb, Sc, Sr, Ta, Tb, Th, Zn, and Zr). When the long irradiation is performed, the barium concentration from measurement of the medium-lived isotope (*i.e.*, ^{133}Ba) is normally superior and it is used in lieu of the value measured following the short-lived irradiation. The data from all three measurements are compiled into a spreadsheet (see also Glascock *et al.* 1998). Sixteen samples were processed through this method (Table 1).

Table 1. Results obtained from INNA, between 2004 and 2007. Update of the table published in Giesso *et al.* (2008).

Sites	Sample code	Chronology BP	Source name	Ba	La	Lu	Nd	Sm	U	Yb	Ce	Co	Cs	Eu	Fe	Hf	Rb
STM-SITE 1	LPTM01	510	Portada Covunco (<i>e.g.</i> , "La Bandera" in Giesso <i>et al.</i> 2008)	270	31.8	0.5	18.8	3.7	7.7	2.3	55.6	0.4	7.4	0.4	7569	5.0	154
	LPTM02	360±25	CP-LL1 (<i>e.g.</i> , "Unknown # 2" in Giesso <i>et al.</i> 2008)	710	13.1	0.4	11.5	3.4	3.6	2.4	28.9	0.1	5.0	0.5	4916	3.5	131
	LPTM03	>3700	CP-LL1 (<i>e.g.</i> , "Unknown # 2" in Giesso <i>et al.</i> 2008)	706	13.0	0.4	12.1	3.3	3.5	2.3	27.9	0.1	5.0	0.5	4802	3.5	131
	LPTM04	1220±67	Portada Covunco (<i>e.g.</i> , "La Bandera" in Giesso <i>et al.</i> 2008)	256	31.9	0.5	18.8	3.7	8.1	2.3	55.0	0.4	7.4	0.3	7272	4.9	155
	LPTM05	1220±67	Cerro Huenul	695	17.0	0.3	12.4	2.4	4.1	1.4	31.4	0.2	4.2	0.4	5051	2.4	103
	LPTM06	510	Varvarco (<i>e.g.</i> , "El Maule-3" in Giesso <i>et al.</i> 2008)	647	33.0	0.4	20.1	3.8	6.1	1.9	60.1	0.4	8.0	0.4	6377	4.0	185
	LPTM07	360±25	Maule 1-Laguna Negra (<i>e.g.</i> , "Unknown # 3" in Giesso <i>et al.</i> 2008)	698	33.5	0.4	23.4	4.4	5.5	2.1	63.4	0.3	4.4	0.7	7539	5.2	153
	LPTM08	< 360±25	Varvarco (<i>e.g.</i> , "El Maule-3" in Giesso <i>et al.</i> 2008)	658	32.9	0.4	19.5	3.8	6.5	1.9	59.6	0.4	8.0	0.4	6371	4.1	183
	LPTM09	1220±67	Varvarco (<i>e.g.</i> , "El Maule-3" in Giesso <i>et al.</i> 2008)	623	33.2	0.4	19.8	3.9	6.2	2.1	61.1	0.4	8.0	0.4	6436	4.7	186
	LPTM10	> 3700	Cerro Huenul	688	16.8	0.3	10.3	2.4	4.0	1.4	31.6	0.2	4.2	0.4	5121	2.5	102
PNLC-SCHI	LPEC01	1050-290	Unknown #1	476	38.2	0.7	32.5	7.5	8.1	4.6	79.9	0.7	10.4	0.5	11329	8.4	217
	LPEC02		Varvarco (<i>e.g.</i> , "El Maule-3" in Giesso <i>et al.</i> 2008)	645	33.7	0.3	21.3	3.9	6.4	2.1	62.9	0.5	8.4	0.5	7034	4.3	191
	LPEC03		Portada Covunco (<i>e.g.</i> , "La Bandera" in Giesso <i>et al.</i> 2008)	292	32.6	0.4	20.0	3.8	7.2	2.4	59.2	0.5	7.8	0.4	7986	5.3	161
	LPEC04		Unknown #4	705	51.8	0.5	46.3	8.9	3.3	3.6	105.6	61.3	2.3	1.6	57161	8.8	103
	LPEC05		Portada Covunco (<i>e.g.</i> , "La Bandera" in Giesso <i>et al.</i> 2008)	280	33.0	0.4	20.8	3.9	7.6	2.4	59.6	0.5	7.8	0.4	7929	5.4	161
	LPEC06		Maule 1-Laguna Negra (<i>e.g.</i> , "La Bandera" in Giesso <i>et al.</i> 2008)	290	32.3	0.4	18.5	3.8	7.2	2.4	58.5	0.4	7.7	0.4	7617	5.2	161

Sites	Sample code	Chronology BP	Source name	Sb	Sc	Sr	Ta	Tb	Th	Zn	Zr	Al	Cl	Dy	K	Mn	Na
STM-SITE 1	LPTM01	510	Portada Covunco (<i>e.g.</i> , "La Bandera" in Giesso <i>et al.</i> 2008)	0.2	1.3	65	2.7	0.4	24.1	35.3	193.1	68626	596	3.0	41291	428	32117
	LPTM02	360±25	CP-LL1 (<i>e.g.</i> , "Unknown # 2" in Giesso <i>et al.</i> 2008)	0.1	2.0	41	1.2	0.5	10.7	37.3	115.4	72286	411	3.7	40516	919	33140
	LPTM03	>3700	CP-LL1 (<i>e.g.</i> , "Unknown # 2" in Giesso <i>et al.</i> 2008)	0.1	2.0	29	1.2	0.5	10.6	45.2	122.4	71231	432	3.2	35578	929	34192
	LPTM04	1220±67	Portada Covunco (<i>e.g.</i> , "La Bandera" in Giesso <i>et al.</i> 2008)	0.2	1.3	41	2.7	0.4	24.3	34.3	178.0	73703	657	2.8	34136	416	31870
	LPTM05	1220±67	Cerro Huenul	0.1	1.6	117	1.2	0.3	8.9	31.0	94.1	70709	310	1.5	34434	674	31799
	LPTM06	510	Varvarco (<i>e.g.</i> , "El Maule-3" in Giesso <i>et al.</i> 2008)	0.4	2.0	63	1.0	0.4	24.0	27.3	149.1	69752	579	2.9	42744	448	28781
	LPTM07	360±25	Maule 1-Laguna Negra (<i>e.g.</i> , "Unknown # 3" in Giesso <i>et al.</i> 2008)	0.3	2.3	91	0.9	0.5	19.5	44.4	201.1	76132	582	2.9	35744	600	36296
	LPTM08	< 360±25	Varvarco (<i>e.g.</i> , "El Maule-3" in Giesso <i>et al.</i> 2008)	0.4	2.0	74	1.0	0.4	24.0	28.2	167.8	64123	664	2.8	39450	449	29591
	LPTM09	1220±67	Varvarco (<i>e.g.</i> , "El Maule-3" in Giesso <i>et al.</i> 2008)	0.4	2.0	85	1.0	0.4	24.2	27.0	198.4	65821	590	2.7	40063	446	29197
	LPTM10	> 3700	Cerro Huenul	0.1	1.6	107	1.2	0.3	9.0	26.5	96.8	69406	344	2.1	32993	687	32456
PNLC-SCHI	LPEC01	1050-290	Unknown #1	1.2	5.1	20	1.1	1.0	26.3	50.4	287.1	76164	864	6.9	45799	361	30924
	LPEC02		Varvarco (<i>e.g.</i> , "El Maule-3" in Giesso <i>et al.</i> 2008)	0.6	2.1	68	1.1	0.4	25.2	29.9	171.0	65537	590	2.9	36881	456	29849
	LPEC03		Portada Covunco (<i>e.g.</i> , "La Bandera" in Giesso <i>et al.</i> 2008)	0.3	1.4	55	2.8	0.5	25.7	29.8	196.8	71800	66	2.9	41608	439	32760
	LPEC04		Unknown #4	0.0	11.9	232	1.0	1.2	14.9	5.6	315.7	76900	53	6.8	23560	824	10711
	LPEC05		Portada Covunco (<i>e.g.</i> , "La Bandera" in Giesso <i>et al.</i> 2008)	0.3	1.4	33	2.8	0.4	25.9	29.6	206.9	69039	5837	2.8	39785	417	31328
	LPEC06		Maule 1-Laguna Negra (<i>e.g.</i> , "La Bandera" in Giesso <i>et al.</i> 2008)	0.3	1.3	147	2.8	0.4	25.9	28.6	193.1	75561	597	2.7	39874	421	31760

In the second stage, the samples were analysed using two different non-destructive XRF devices: portable Bruker III-V spectrometer and desktop QuantumX. Even though different instruments were used, the main elements (Rb, Sr and Zr) were identified by both of them. Bruker Tracer III-V spectrometer has a measurement time of one hundred eighty seconds, and it measures thirteen elements: K, Ti, Mn, Fe, Zn, Ga, Rb, Sr, Y, Zr, Nb, Pb, and Th, while in QuantumX the time is reduced to one hundred twenty seconds (or less), and the equipment analyses Mn, Fe, Zn, Rb, Sr, Y, Zr, Nb, and Th. Another advantage is that up to twenty samples can be loaded per measurement. The calibration for the Bruker III-V was verified by performing three replicate analyses on different international rock standards. The standards were prepared as pressed powders and measured using the same conditions as were used to measure all obsidian artefacts and source samples. The results for G-2, JR-1, and SRM-278 are presented in Table 2 and compared to the certificate values for each rock. Agreement is within 10% for a majority of the elements. In 2014 seven samples were analysed with a portable Bruker III-V spectrometer (Table 3) and three samples in 2017 with a desktop QuantumX (Table 4).

Table 2. Concentrations in ppm for international rock standards measured in this study compared to their certificate values. G-2 is from the US. Geological Survey; JR-1 is from the Geological Survey of Japan; SRM-278 is from the National Institute of Standards and Technology.

Element	G-2 granite		JR-1 rhyolite		SRM-278 obsidian	
	this study	certificate	this study	Certificate	this study	certificate
Mn	200 ± 50	260	790 ± 100	770	330 ± 60	397
Fe	17000 ± 200	18700	6010 ± 150	6220	13360 ± 150	14500
Zn	75 ± 2	85	22 ± 1	31	39 ± 2	44
Rb	172 ± 2	170	250 ± 2	257	131 ± 2	128
Sr	443 ± 2	478	28 ± 1	29	62 ± 1	64
Y	11 ± 1	11	42 ± 1	45	37 ± 1	39
Zr	321 ± 4	300	95 ± 2	100	291 ± 2	290
Nb	13 ± 1	13	15 ± 1	15	18 ± 1	18
Th	23 ± 1	25	28 ± 2	27	12 ± 1	13

3. Results

The studies made it possible to identify six known sources and four others with unknown locations. Four of the known sources are located in the province of Neuquén (Cerro Huenul and Varvarco in the North, Portada Covunco in the center, and CP-LL1 or Lolog Lake in the South). We also identified obsidian from the subsources Arroyo Paramillos (in the Laguna del Diamante, province of Mendoza) and Maule 1-Laguna Negra (Andean highlands of Argentina and Chile). The obsidian from each of these six known sources presents a distinctive chemical composition.

Artefacts and correspondence to the six known sources are shown in Figure 2. The results are based on two key elements: Rb and Sr, expressed in parts per million; 21 of the 25 items found in the ellipses of dispersion of 95% of six known sources, and the other four (LPEC01 and 04, LPTM10 and 11) are at a distance from all of them.

Table 3. Results obtained from XRF (Bruker III-V).

Sites	Sample Code	Chronology	Source Name	K	Ti	Mn	Fe	Zn	Ga	Rb	Sr	Y	Zr	Nb	Th	XRF
LA CHOLA	LPLC01	Late Holocene	Varvarco	35452.0	538.9	452.2	11328.8	69.8	19.2	193.3	50.1	17.7	167.4	27.4	24.7	Bruker
	LPLC02	Late Holocene	Portada Covunco	35162.9	622.5	359.5	8460.0	56.2	14.0	167.5	44.2	20.9	155.6	27.3	20.0	Bruker
	LPLC03	Late Holocene	Portada Covunco	33854.5	493.5	992.4	7534.7	59.8	15.1	169.8	43.7	20.4	141.6	15.7	10.5	Bruker
	LPLC04	Late Holocene	Portada Covunco	36621.0	537.4	400.4	8769.5	62.7	12.1	153.6	41.1	15.5	143.5	26.7	19.0	Bruker
	LPLC05	Late Holocene	Paramillos	35599.9	589.7	622.8	10256.0	42.8	17.0	112.9	214.9	11.0	111.3	7.5	11.3	Bruker
LA TIGRA	LPLT01	590 ± 20 AP	Paramillos	34789.4	578.1	478.8	9985.1	43.4	14.5	96.5	203.2	9.3	104.7	6.8	9.6	Bruker
STM-SITE 2	LPTMS2	Late Holocene	Maule 1 - Laguna Negra	35587.8	533.1	769.5	8820.8	74.7	19.1	149.5	131.0	19.4	120.7	7.1	11.5	Bruker

Table 4. Results obtained from XRF (Quantum X).

Sites	Sample Code	Chronology	Source Name	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Th	XRF
Lihué Calel	LICAL	-	Lihué Calel	782.3	9142.6	101.2	497.5	80.2	146.0	151.5	70.4	43.2	Quantx
STM-SITE 1	LPTM11	Late Holocene	Unknown #5	645.8	14826.8	65.0	257.7	78.3	57.7	548.4	21.5	28.9	Quantx
STM-SITE 3	LPTM13B	Late Holocene	Unknown #6	365.6	23790.6	60.3	190.1	290.3	16.3	236.3	11.6	21.9	Quantx

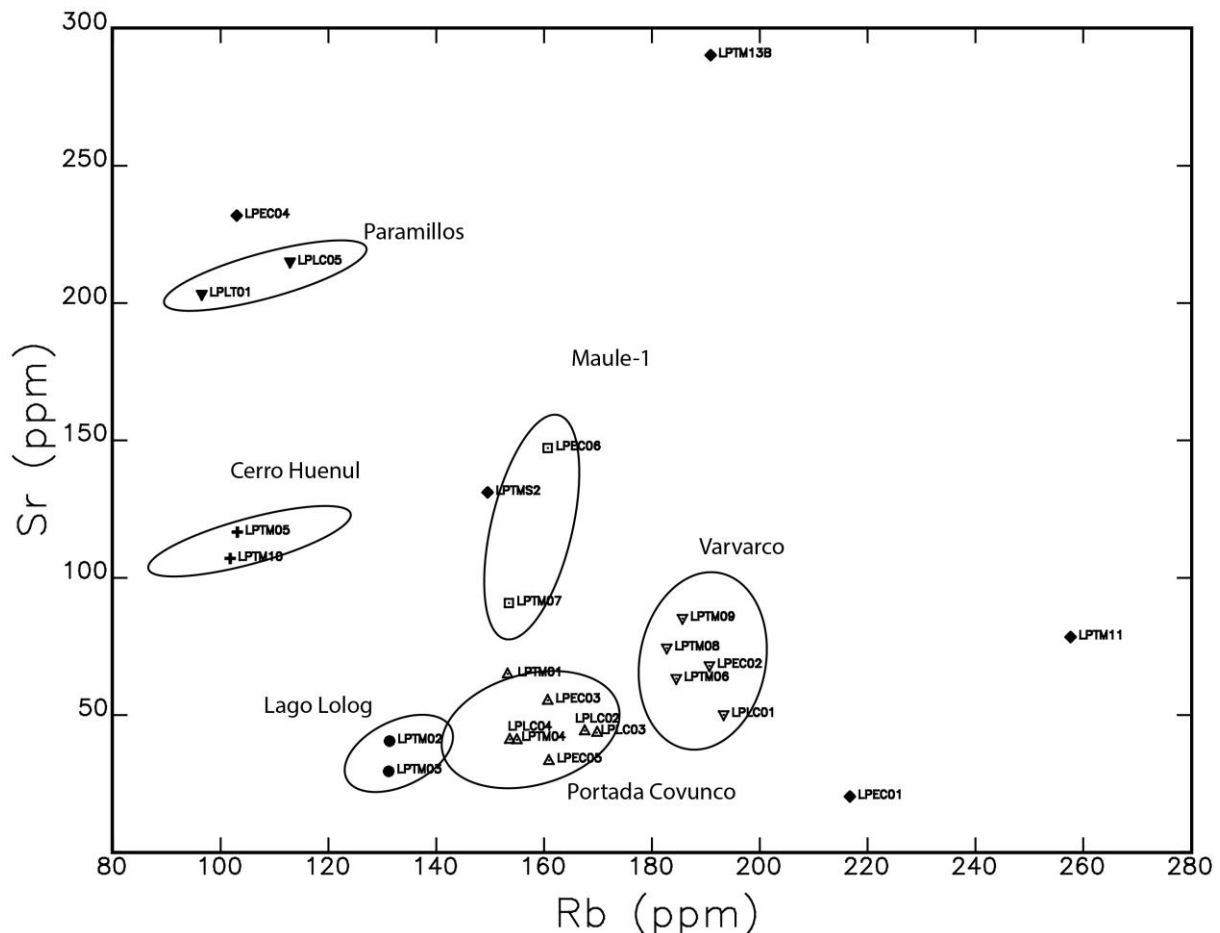


Figure 2. Artifacts and correspondence to the six known sources. Bivariate plot of Sr v. Rb (graphic by Michael D. Glascock).

3.1. Known sources

3.1.1. Arroyo Paramillos (Provincia de Mendoza).

Arroyo Paramillos is a subsurface of Laguna del Diamante, located in the Cordillera del Límite (the border range between Argentina and Chile), at $34^{\circ} 11' \text{ LS } 69^{\circ} 42' \text{ LW}$ (Cortegoso *et al.* 2012; Durán *et al.* 2004; de Francesco *et al.* 2018). The source presents small obsidian nodules of approximately 2 cm in diameter, recovered on the surface and scattered in large areas near the Diamante lagoon (Cortegoso *et al.* 2012). The primary source has not been located. Arroyo Paramillos obsidians show chemical similarities with the ones coming from the Las Cargas source, 125 km to the South (Cortegoso *et al.* 2012; de Francesco *et al.* 2006; Giesso *et al.* 2011). This source has a seasonal availability, since they are not accessible in winter. Arroyo Paramillos has abundance of good quality material (Cortegoso *et al.* 2012; Giesso *et al.* 2011, Figure 3). Two samples (8%) come from this source.

3.1.2. Laguna del Maule (Andean Highlands of Argentina and Chile, at 36° S).

It is located at 2250 m *a.s.l.* in the upper Maule River of south-central Chile (Seelenfreund *et al.* 1996). Here obsidian appears in the form of several volcanic flows covering a discontinuous field of approximately 600 km² (Cortegoso *et al.* 2012; Fernández *et al.* 2017; Giesso *et al.* 2011; Seelenfreund *et al.* 1996). The successive characterizations indicate that the raw material of the Maule encompasses one large area which includes the Laguna Negra and the headwaters of the Pehuenche River and points to the existence of at

least three subsources, traditionally called 1, 2, and 3. Laguna del Maule outcrops presents a seasonal accessibility during the summer months. It has an important availability and quantity of quality raw material (Cortegoso *et al.* 2012; Giesso *et al.* 2011; Salgán *et al.* 2012). Recently Barberena *et al.* (2019) located new primary and secondary locations where obsidians match the Laguna del Maule 1 and 2 subgroups. Maule 1 was located at Laguna Negra and along the upper Barrancas river, some 3-6 km from Laguna Negra, where it was brought by fluvial erosion. Barberena *et al.* (2019) estimate that this subsurface corresponds to the Group I Las Coloradas (Seelenfreund *et al.* 1996). Maule 2 was located at the locality of Barrancas, in the mid to low Barrancas river and upper Colorado river basin. These materials are of part of ash-fall volcanoclastic deposits, and not the product of fluvial transport as those of Laguna Negra. Barberena *et al.* (2019) use the terms Laguna del Maule 1-Laguna Negra and Laguna del Maule 2-Barrancas for these new locations (Figure 3). Three samples (12%) were characterized as Maule 1- Laguna Negra type.

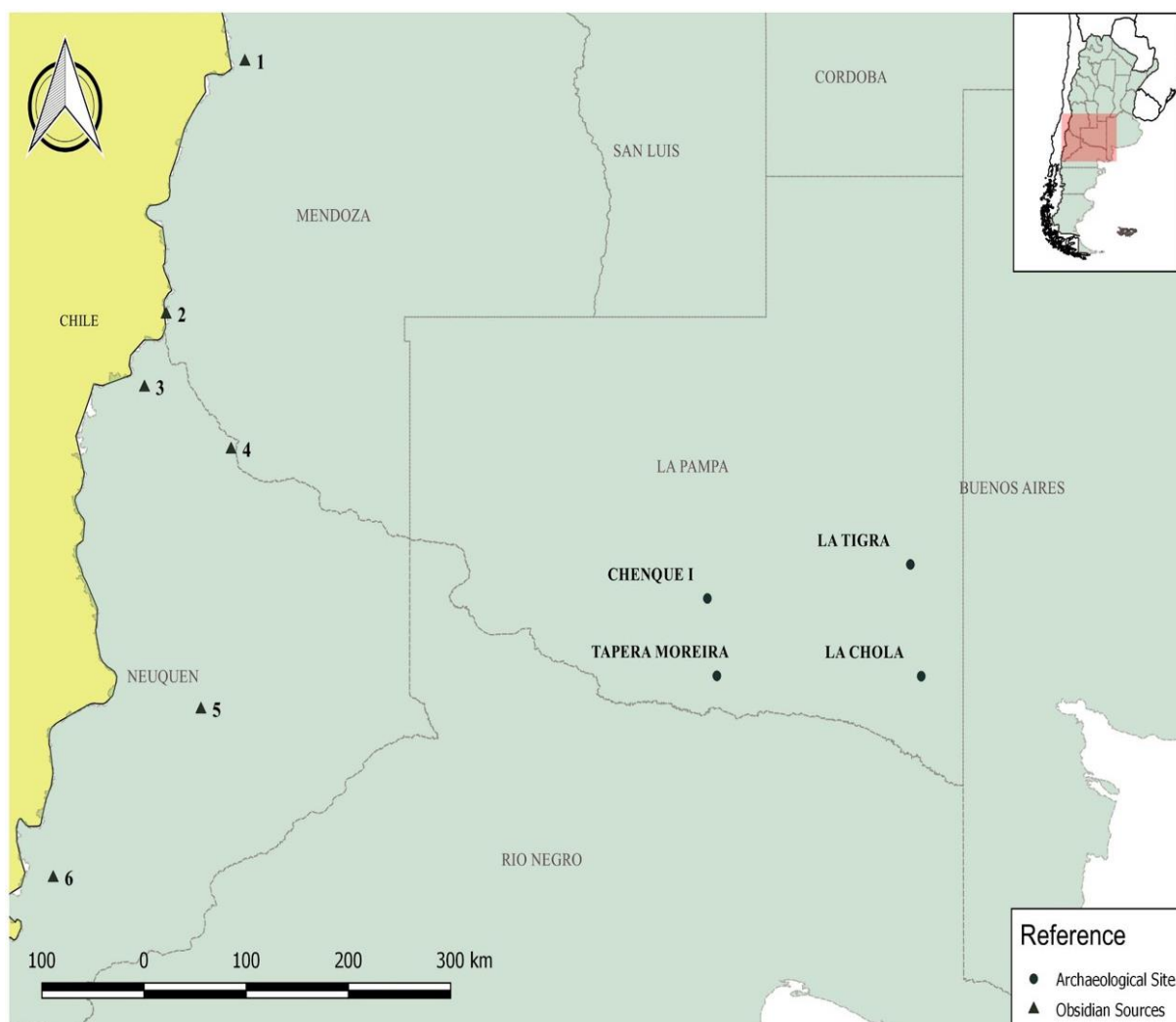


Figure 3. Obsidian sources and archaeological sites location mentioned in this paper. 1-Arroyo Paramillos, 2-Laguna del Maule, 3-Varvarco, 4-Cerro Huenul, 5-Portada Covunco, 6-CP-LL1 (Lake Lolog).

3.1.3. Cerro Huenul (Neuquén Province).

Cerro Huenul is located in the northern region of the province of Neuquén, on an extra-Andean plateau, on the south bank of the Colorado River ($36^{\circ} 56' 28,1''$ LS and $69^{\circ} 49' 18,9''$ LW). It is a secondary source, associated with the Tilhué Formation and is composed of

subangular to subrounded nodules whose sizes varies from less than 5 cm to more than 10 cm, grouped into specific geomorphic contexts such as dry ravines. This obsidian is a highly glassy rock with low crystalline inclusions which makes it very suitable for knapping. The quarry is available throughout the year and is of great accessibility (Barberena *et al.* 2011; Cortegoso *et al.* 2012; Durán *et al.* 2004; Fernández *et al.* 2017; Figure 3). Two samples come from here.

3.1.4. Portada Covunco (central Neuquén Province).

Portada Covunco is a secondary source located in the west-central region of Neuquén province, at *ca.* 1500 m *a.s.l.* (Bellelli *et al.* 2006). Stern *et al.* (2012) suggest that Cerro Bayo and Arroyo Grande Cochicó located at the west of Portada Covunco are the primary sources. These areas are not accessible during the winter. According to this proposal, the samples from Portada Covunco (previously referred as La Bandera in Giesso *et al.* 2008) may represent subtypes of obsidian from this area. These secondary sources are located on a prairie with fluvio-glacial sediments cut by the Covunco River.

The obsidian from all of these areas is visually very variable and includes rocks of dark black, translucent black and black with spots or reddish bands, with good knapping quality (Bellelli *et al.* 2006; López *et al.* 2009; Stern *et al.* 2012). López *et al.* (2009) identified two chemical signals involved in this source, which they called PC1 and PC2 that might be part of the chemical variation within the source. Seven of the twenty five obsidian samples (28%) come from this source (Figure 3).

3.1.5. CP-LL1, Lake Lolog (Southern Neuquén Province).

The Lake Lolog area has three locations with obsidian. The primary source is located on the Las Planicies Hill, and concentrations were also located on the north shore of the lake, in the sectors referred to as Puerto Arturo and Playa Norte. The primary source is covered by abundant obsidian nodules. These have variable sizes, going from a few centimetres to more than 30 cm in diameter (López *et al.* 2009). The nodules are very homogeneous and with excellent quality for knapping. Within the obsidianas of Lake Lolog two chemical signals have been identified (CP-LL1 and CP-LL2). The first is the most common one, while the second was only identified in two samples from Puerto Arturo (López *et al.* 2009). Two of the twenty five obsidian samples (8%) come from this source (*e.g.*, Unknown #2 in Giesso *et al.* 2008; Figure 3).

3.1.6. Varvarco (Northern Neuquén Province).

This source is located in the Varvarco Tapia lagoon and the upper basin of the Varvarco River (36° 30,078" LS and 70° 35.835" LW). There are large deposits of ignimbrites containing abundant obsidian nodules, whose diameters exceed 30 cm. The rocks from this source are of good knapping quality, are abundant and have archaeological evidence of exploitation (Fernández *et al.* 2019). Varvarco obsidian is available all year round. Five of the twenty five obsidian samples (20%) come from this source. In previous publications, Varvarco was known as Laguna del Maule-3 (Giesso *et al.* 2008) (Figure 3).

4. Discussion

Over the past decade, our knowledge about obsidian procurement in archaeological sites of the province of La Pampa has increased considerably, although the evidence is still scarce. During the process of multidisciplinary and macroregional research on the subject, there have been great advances. For example, sources and subsources have been identified, reassigned

and sometimes redefined, while others remain unknown. There were discoveries of new ones (Varvarco), and knowledge about the dispersal ranges of some sources has advanced (Barberena *et al.* 2011; Cortegoso *et al.* 2012; Giesso *et al.* 2011; Salgán *et al.* 2012; 2015; Stern *et al.* 2012). All of this allows us to rethink our own discussions and generate new ideas about the procurement and circulation of obsidian in the province of La Pampa. The sample analysed in this paper includes different timelines and different areas of study, so it allows us to evaluate obsidian use in the province of La Pampa from broad temporal and spatial scales.

In relation to the chronology of the results obtained, two oldest samples from site 1 of the Tapera Moreira locality correspond to the Cerro Huenul (LPTM10) and CP-LL1 (LPTM03) sources. Sample LPTM10 comes from level XV of the stratigraphic sequence of the site, while LPTM3 corresponds to level XIV. Both are translucent black microflakes without cortex (Figure 4). The stratigraphic sequence of the site presents an AMS date of 3685±40 years BP (AA 35955) at level XIII, just immediately above both samples, so it is estimated that its chronology may be considerably older than the assigned in Giesso *et al.* (2008), and would correspond to the end of the Middle Holocene. This chronological range coincides approximately with the one recorded by Stern & Aguerre (2013) at the site of Casa de Piedra 1, where they estimate the presence of obsidian from Nequén at *ca.* 4000 years BP, although in this case the source is Portada Covunco. For earlier periods, Stern & Aguerre (2013) indicate the presence of Laguna del Maule obsidian, in the radiocarbon dated level of 8620 years BP.

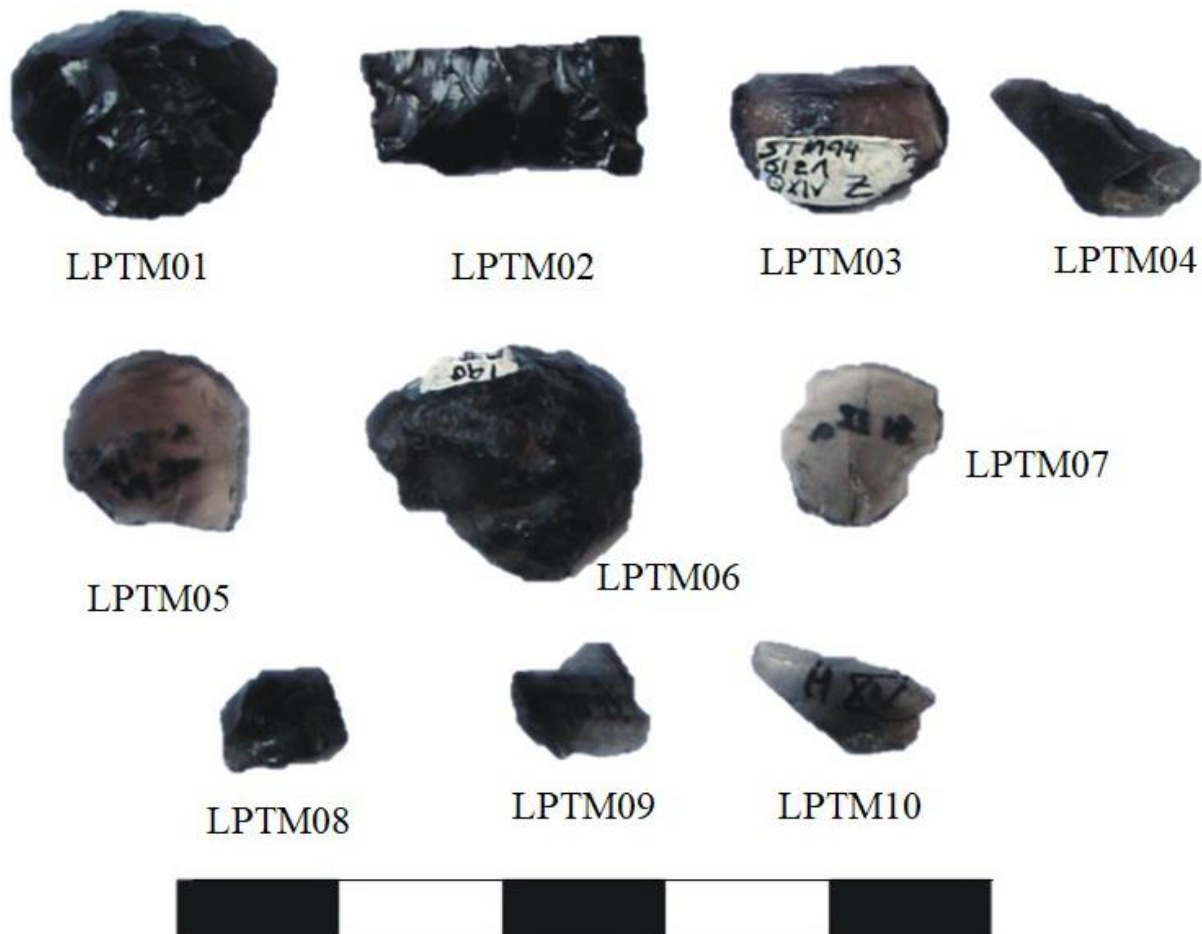


Figure 4. Obsidian artifacts from Tapera Moreira archaeological locality - Site 1. Scale bar = 5 cm (1 cm segments).

The Cerro Huenul source continued to be used at the Tapera Moreira locality, according to the results of the sample LPTM05 (level IV), which is at the basis of the Upper Component, with ceramics, whose initial date is 1220 ± 67 years BP. LPTM05 is also a translucent black microflake, without cortex. In this same component, two sources are present: Varvarco (LPTM09) and Portada Covunco (LPTM04, see Figure 4). Both samples were recovered in level V and correspond to two translucent black microflakes without cortex. Obsidian from Lake Lolog (CP-LL1) is not recorded at this time span.

The samples of the pre-Hispanic cemetery Chenque I represent a chronological range that matches the use of this site, from 1050 to 290 years BP. However, this site records a hiatus of almost 300 years during which burials were not carried out. The pre-hiatus period extends from 1050 to 700 years BP while the post-hiatus period goes from 435 to 290 years BP. The samples analysed cannot be discriminated within these periods since they come from sediments that surround the burial structures. The sources identified are Maule 1-Laguna Negra, Varvarco, Portada Covunco and two unknown sources (Unknown #1 and #4). Samples from Portada Covunco (LPEC03 and 05) correspond to bifacial thinning flakes and are translucent black. Sample LPEC01 (Unknown#1) is a bipolar product, of dark black colour. Varvarco (LPEC02) and Unknown#4 (LPEC04) samples are black microflakes (Figure 5). Sample LPEC06 from Maule 1-Laguna Negra is also a translucent black bifacial thinning flake.



Figure 5. Obsidian artifacts from Chenque I site. Scale bar = 5 cm (1 cm segments).

The 600 to 300 years BP period has a broader spatial scale towards the east, which spans from the basin of the Curacó River (site 1 of Tapera Moreira) in south-central La Pampa to the transversal valleys in the limit with the province of Buenos Aires (site La Tigra). In the

case of site 1 of Tapera Moreira, obsidians from Varvarco (LPTM06, 08), Portada Covunco (LPTM01) and Laguna del Maule 1 - Laguna Negra (LPTM07) were identified, but Cerro Huenul disappears. In addition, obsidian from CP-LL1 is present, (LPTM02) which was already recorded in the earliest levels of Tapera Moreira site 1. The sample LPTM01, assigned to Portada Covunco, is a frontal scraper and the sample LPTM02 of CP-LL1 is an unstemmed projectile point base. Both instruments have been carefully crafted and would have required larger nodules, especially the projectile point, which presents bifacial thinning. The LPTM06 sample, which comes from the Varvarco source, corresponds to an opaque black obsidian flake and presents cortex. The remaining samples (LPTM07 and LPTM08) are translucent black microflakes without cortex (see Figure 4). The easternmost sample of this temporary block comes from Laguna La Tigra, with a date of 590 ± 20 years BP. A primary obsidian flake (LPLT01) was recovered there, whose origin was identified as coming from Arroyo Paramillos (Figure 6).

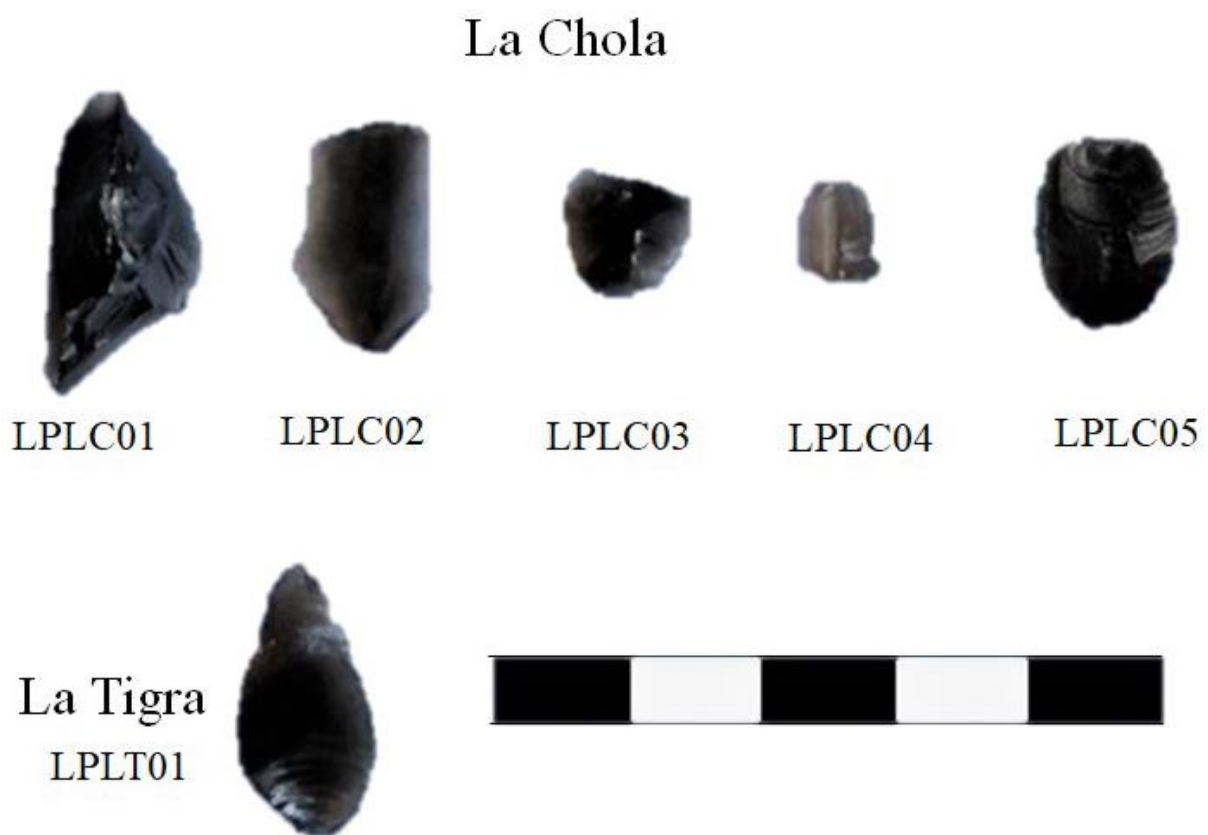


Figure 6. Obsidian artefacts from La Chola and La Tigra sites. Scale bar = 5 cm (1 cm segments).

There are also geochemical results coming from archaeological sites without absolute dates that may be chronologically assigned to the Late Holocene. There are three dark black microflakes from the Tapera Moreira locality. Two were found on the surface of Sites 1 and 2. The first sample (LPTM11 from Site 1) corresponds to a source that still remains unidentified (Unknown#5), while the second (LPTMS2 sample from site 2) comes from the Maule 1 - Laguna Negra source. In the Site 3 of the same locality, we recovered a black dark microflake without cortex from level III, associated with human remains (Figure 7). This sample (LPTM13B) also corresponds to a source still unidentified (Unknown #6). The other five samples were recovered in the surface of site La Chola (Bajos sin Salida area) and correspond to different sources. Samples LPLC02, LPLC03 and LPLC04 correspond to translucent black microflakes without cortex and come from the Portada Covunco source. The

LPLC01 sample is debitage from Varvarco, and the LPLC05 is a bipolar half nodule with cortex from Arroyo Paramillos (Figure 6).

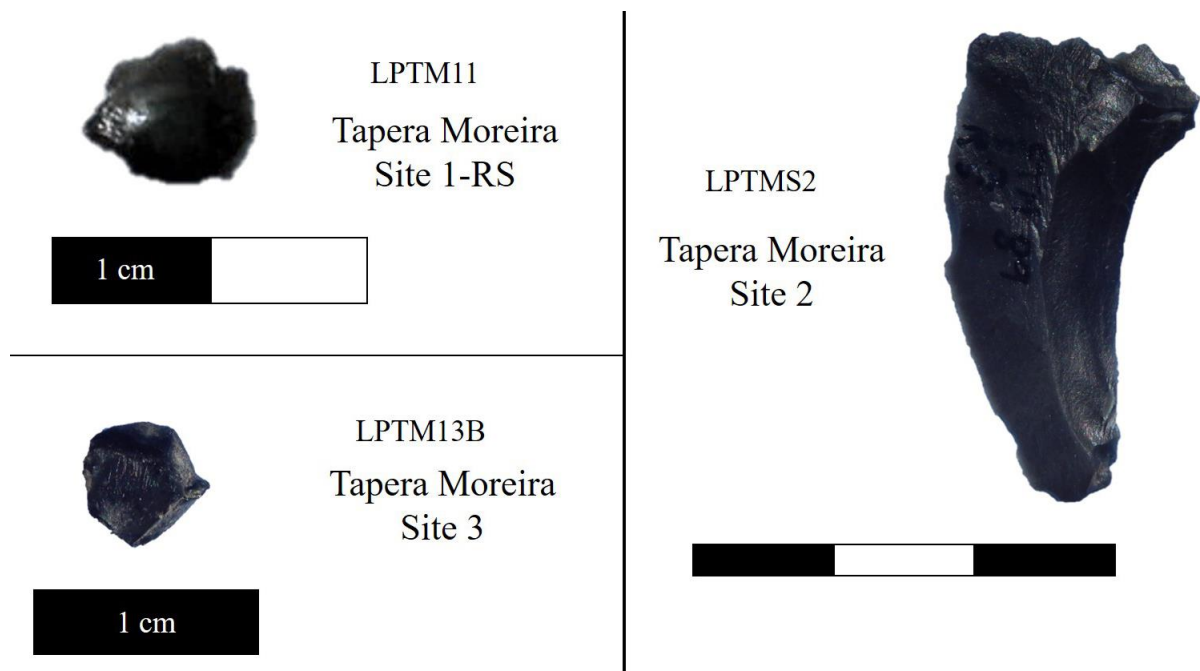


Figure 7. Obsidian artefacts from Tapera Moreira archaeological locality - Sites 1, 2 and 3. Scale bars are composed of 1 cm segments.

According to Salgán *et al.* (2015) the geochemical composition of the source Las Cargas is very similar to the subsurface Arroyo Paramillos (Durán *et al.* 2004; de Francesco *et al.* 2006). Based on XRF analysis, it is not possible to differentiate the obsidian from these sources. However, research by Salgán *et al.* (2015) indicates that using INAA it is possible to distinguish them. Another difference between both sources is that Las Cargas is characterized by the availability of blocks and generally larger nodules without cortex. For this reason, in this paper we consider that samples from La Tigra and La Chola, which are small half nodules with cortex, would correspond to the subsurface Arroyo Paramillos.

As in other areas mentioned above, the diversity of situations has revealed a much more complex picture than was initially available. These situations show that the procurement, use and disposal of obsidian is not linked only to the distance from archaeological sites to sources. On the contrary, aspects such as mobility, territoriality, topography and exchange, have played a strong role in spatial and temporal distribution patterns shown by the artefacts recovered in the different areas of the region (Cortegoso *et al.* 2012; Salgán & Pompei 2017).

In the south of Mendoza, the use of obsidian begins towards the early Holocene, with dispersion throughout the territory that intensifies during the late Holocene. The exploitation of obsidian sources would have occurred gradually (Durán *et al.* 2004; Giesso *et al.* 2011). Advances in the research show a differential use of mountain (Laguna del Maule, Laguna del Diamante-Paramillos and Las Cargas) and plain outcrops (Cerro Huenul and El Peceño). Mountain sources exhibit a greater spatial and temporal dispersion than the plain one, despite the difficulties of access posed by altitude, terrain and seasonality (Barberena *et al.* 2011; Cortegoso *et al.* 2012; Giesso *et al.* 2011; Salgán *et al.* 2015; Salgán & Pompei 2017). In the earliest moments, the exploited sources are the cordilleran ones, area of Laguna del Maule and Las Cargas (Barberena *et al.* 2011; Giesso *et al.* 2011; Salgán *et al.* 2015; Salgán & Pompei 2017). The source of Cerro Huenul, despite being close to the southern end of Mendoza, with very good availability, quality and easy access, has not been used intensively

in the region. Although it has been used from early times in Neuquén province, in the south of Mendoza it begins to be used after *ca.* 3000 years BP (Barberena *et al.* 2011). For these times obsidians coming from Laguna del Diamante-Paramillos were also used. For the last 1000 years BP, obsidian from the source El Peceño (Salgán & Pompei 2017) is recorded. The main distribution of obsidian in the south of Mendoza shows a preferential circulation following a west-east axis, over the north-south latitudinal vector. This phenomenon may have been related to the expansion of mobility ranges or to the establishment of large-scale exchange and interaction networks (Lagiglia 2002; Neme & Gil 2008; 2012; Salgán & Pompei 2017).

In the northwest of Patagonia, specifically in Neuquén, there is an exploitation and use of obsidian different from that of southern Mendoza. The obsidian from Cerro Huenul presents an early exploitation and is the most represented in the archaeological sites of the area. Obsidian coming from Maule 2-Barrancas follows in order of importance. The obsidian coming from CP-LL1 (Lake Lolog) circulated through different regions through great distances. In Neuquén its use is recorded in archaeological sites close to the sources since 3500 years BP, until historical times. It was transported hundreds of kilometres to the east and south (Bellelli *et al.* 2018; Favier Dubois *et al.* 2009; Stern *et al.* 2012). Obsidian from the Neuquén source Portada Covunco is underrepresented in northern Neuquén (Barberena *et al.* 2017). However, it increases and is distributed relatively systematically to the south, reaching to the province of Chubut (Barberena *et al.* 2017; Bellelli *et al.* 2018; Pérez *et al.* 2015; Stern *et al.* 2012).

For the mixed forest of northwest Patagonia, (particularly for the southwest of Río Negro and northwest of Chubut), the presence of obsidians from outcrops in the area of the Somuncura Plateau are recorded, though they are absent in our research area. The MS1 source of the Somuncurá Plateau has been recorded since the Early Holocene (8,230 years BP) in the Población Anticura (Bellelli *et al.* 2018). For the Late Holocene obsidians have been recorded from Sacanana 1 (S1), Portada Covunco and Laguna La Larga (Bellelli *et al.* 2018; Castro Esnal *et al.* 2011; Fernández & Vítóres 2015; Podestá *et al.* 2007). The representation of this rock is very low and the artefacts are very small, possibly linked to a need to ensure the availability of raw material of excellent quality in an environment in which it is not present (Bellelli *et al.* 2018).

It should be noted the absence of obsidian from sources located no more than 500 km away, towards Northwest or South, from the sites here analysed. El Peceño, a primary source located in the eastern plain of southern Mendoza (Cortegoso *et al.* 2012; Salgán & Pompei 2017), which has been linked to archaeological sites of late Holocene, is absent in La Pampa despite the fact that its geographical location, accessibility and quality give it advantageous characteristics in relation to other well-known obsidian Andean sources. Neither obsidians from the Somuncurá Plateau (MS1), Río Negro and Chubut provinces, nor from the sources located at the southern edge of the Somuncura Plateau: Telsen - Sierra Chata I and II in Sierra Negra and Cerro Guacho, located in the paleocauce of the Sacanana stream, have been recorded in La Pampa. These sources, located in the Patagonian plateau, have a wide dispersal, varying between 100 to 800 km (Bellelli *et al.* 2018; Gómez Otero & Stern 2005; Stern *et al.* 2000). However, we do not expect to find obsidians from El Peceño because its distribution rarely exceeds 70 km (Giesso *et al.* 2011). Exceptionally, it has been recorded 200 km far to the east (Heider 2015). Neither would we presume to find Somuncura plateau area obsidians because this latitudinal interactional vector has not been registered in the south of La Pampa.

To summarize, the results presented show the use of obsidian from different sources located in Andean highlands or Argentina and Chile and the Argentine provinces of Mendoza and Neuquén, to the northwest, west and southwest of the study areas. Towards the final moments of the late Holocene the use of a greater number of sources is recorded, which is

possibly associated with an accentuation of exchange networks existing since the Early Holocene. This is reflected also in a variety of archaeological evidence including human bone's isotopic values, ceramic types and body ornaments among other diagnostic elements (Berón 2004; Berón *et al.* 2017).

In agreement with Barberena *et al.* (2019), we consider that not all obsidian was obtained within the framework of such networks. In the upper section of the Colorado River small obsidian nodules from Cerro Huenul and Laguna del Maule 2 - Barrancas were identified (Fernández *et al.* 2017). Given the spatial proximity of some of the analysed archaeological sites (Tapera Moreira, Chenque I and La Chola) to the mid-Colorado River basin and its palaeobeds, we envision the possibility that the supply route was through sourcing from this secondary location. The small size of the recovered artefacts is consistent with the small dimensions shown by the obsidian nodules found in this sector of the river (Berón 2006, see Figure 8). However, in La Pampa province only the geochemical signal of El Maule 1 - Laguna Negra was recorded, whose distribution is circumscribed to the upper basin of the Barrancas river. We, therefore, believe that several alternatives for obsidian procurement should be taken into account. In the case of nodules which do not travel through the Colorado River we can consider that they were obtained through exchange networks with groups that had a direct access to the sources, or with intermediaries related to them. This is also the case of CP-LL1, whose obsidian has been recovered in different regions, and at distances exceeding 260 km to the south and 500 km to the Atlantic coast (Bellelli *et al.* 2018; Favier Dubois *et al.* 2009; López *et al.* 2009; 2010; Silveira *et al.* 2010). Its presence in Pampean sites could be due to other factors, including human agency. As we and another authors have already expressed in previous papers (Berón *et al.* 2012; Campbell *et al.* 2017; Hajduk *et al.* 2011; Mera *et al.* 2015; Musaubach & Berón 2012; Salazar & Berón 2013), during Late Holocene the social networks increased and expanded along the bioceanic northpatagonic corridor. In this sense Campbell *et al.* (2017), taking account of our proposals, states: “...*the presence of obsidian at Mocha Island's archaeological sites is an exceptional situation within the context of the lithic universe that has been recovered there. The mere occurrence of obsidian artifacts on Mocha Island lead us to interpret them as part of the more developed networks of communication that were becoming active around the end of the Early Ceramic period (1000 CE; 950 cal BP), connecting different areas of southern Chile with one another and the territory itself with areas on the other side of the Andean mountain range. Based on the temporal distribution of obsidian artifacts summarized above, these networks appear to have progressively grown in importance or fluidity from the Late Ceramic period...*” (Campbell *et al.* 2017: 623).

We also recognize the Manto Tehuelche (also known as Formación El Sauzal, Rodados Patagónicos, among other names) as a potential agent of provision of obsidian nodules. Manto Tehuelche is a conglomerate of more than 6 m height, formed by nodules of different lithologies, although fragments of effusive, acidic and basic, mesosiliceous volcanic rocks predominate (Berón 2004; Calmels *et al.* 1996; Gonzales 2014; Llambías 1975; Martínez *et al.* 2009). The Manto occupies the Colorado River beds and palaeobeds, although its distribution is not continuous, since it disappears in the valleys and lower endorheic areas. In the case of primary sources, the nodules have a size ranging between 5 and 10 cm, while in the "pebble fields" they do not exceed 5 cm (Berón 2004; 2006). In this case, their supply would be secondary and could comprise various known sources. Considering that the mantle extends from the Andes mountain range to the Atlantic Ocean, and from the north of the Colorado River to Tierra del Fuego (Fidalgo & Riggi 1970; Martínez *et al.* 2009), and that obsidian is an effusive volcanic rock, we could expect that among the gravels, obsidian shots may be found, although in a low proportion.



Figure 8. Obsidian sample from Lihué Calel hills and obsidian nodules from Curacó basin area. Scale bar = 5 cm (1 cm segments).

Finally, we highlight that the Lihué Calel obsidian source (Fantini 2014) has been geochemically characterized by a high content of Mn (*ca.* 800 ppm) and of Rb (approximately 500 ppm), significantly different from those of the remaining ten sources discussed in this paper (see Table 4). It has an irregular fracture and many inclusions (Figure 8).

5. Conclusions

Obsidians are one of the rocks that less frequently occur in the lithic assemblages of the province of La Pampa. This is because it is a raw material with a very low regional availability. Barberena *et al.* (2019) indicate the presence of nodules from Cerro Huenul and Laguna Maule 2-Barrancas sources in the upper Colorado River basin. It is considered that the presence of small-sized rocks in the vicinity of the Tapera Moreira archaeological site could extend the availability of these obsidians to the middle basin of this river and imply a closer and, therefore, less expensive access by the hunter-gatherer groups that inhabited the south Pampas. However, at the moment, the recovered nodules (Figure 8) have not been analysed chemically, so it is not possible to assign them to a particular source. On the other hand, the obsidians identified in Lihué Calel are of low quality and their chemical signal was not recorded in any of the archaeological samples analysed, though some good quality veins may be expected.

The samples analysed account for the exploitation of a variety of obsidians from six sources located at a great distance from the province of La Pampa. Four of them are located in different sectors of the province of Neuquén (Portada Covunco, Cerro Planicies - Lago Lolog, Varvarco and Cerro Huenul), while the remaining two are in the province of Mendoza (Laguna Maule 1 and Arroyo Paramillos). Except for the aforementioned cases, whose availability in a secondary way could imply a direct supply, it is considered that the acquisition had to take place within the framework of the exchange networks that were developed in the Norpatagonian bioceanic corridor from the end of the Middle Holocene. In addition to the wide distance between the sources and the place where the samples were recovered, it must be added that the characteristics of the analysed artefacts correspond to those expected for those generated in rocks obtained through indirect access (Salgán *et al.* 2012). In this sense, most of the artefacts correspond to small and internal waste associated with the last stages of the production system, or conserved instruments. In the case of the Cerro Huenul obsidian, since it has only been registered in the Casa de Piedra 1 and Tapera

Moreira site 1, both located in the vicinity of the Colorado River or its palaeobeds, it is considered that its supply could have been made directly from secondary outcrops.

The presence of obsidian in archaeological sites eastwards from the Andes, corresponding to different time ranges, enables discussion on how indigenous societies made use of this resource and its presence over time, and how it varied with different economic and social motivations. It is necessary further evaluation in conjunction with different research teams, about the role of these sources of obsidian within networks of mobility and social interaction at different spatial and temporal scales.

Acknowledgements

This research was funded by grants PICT 0437, PIP 0834 and UBACyT F-540. We want to thank the residents and families of Guatraché, Macachín, Puelches and the administration of Lihué Calel National Park. We want to thank Eliana Lucero for her collaboration in the preparation of maps and Camila Barcia for reading a previous English version of this paper. We also want to thank the organizers from 11th ISKM and Otis Crandell for inviting us to participate in this volume.

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